San Francisco's Earthquake Risk

Report on Potential Earthquake Impacts in San Francisco

DRAFT WORKING DOCUMENT

DRAFT date: April 8, 2009

The Community Action Plan for Seismic Safety

A project of the Department of Building Inspection
Report prepared by the Applied Technology Council

Dear Draft Reviewers:

This is a working draft of the Community Action Plan for Seismic Safety report on consequences of four scenario earthquakes in San Francisco. It has all of the rough edges that such drafts generally have. We welcome comments on all aspects of this draft, and encourage you to send us your detailed comments on issues large and small.

There are several issues that already have been raised for your consideration:

1. Provide history of the CAPSS project. A history and explanation of the project and acknowledgement of earlier efforts will be included inside the front cover on the project overview page.
2. Some context is needed. The introductory section will be revised to describe how the loss estimates and consequences described will be used to inform retrofit policy decisions.
3. The technical underpinnings for the report must be clear. The appendix will contain numerous tables of analytical results for each of the scenario earthquakes. The report body will mention these and refer to the Appendix. Even more detail and will appear in a companion technical volume that documents methods used and results.
4. It has been recommended that the report use SPUR's terminology for post-earthquake buildings functionality rather than the scheme currently in use (for example, see page 22).
5. The report needs a conclusion. A short concluding chapter will be written that leads the reader to see how the loss information will be used to prepare a strategy to reduce earthquake risk and improve resilience.

We request all comments on this draft by **Friday, April 23rd.**

You can send us your comments in a variety of ways:

- Email your thoughts to Tom Tobin (lttobin@aol.com) and Laura Samant (laura.samant@gmail.com). Please cc both of us on any messages.
- Fax your written comments to 1-608-646-9869.
- Hand your written comments to Tom Tobin or Laura Samant at the CAPSS Advisory Committee meeting on Wednesday, April 14, 11am to 1pm at the Department of Building Inspection.
- Mail a copy of your written comments to Laura Samant at 2547 Diamond Street, San Francisco, CA, 94131.

For those of you who would like make your comments on an electronic version of the draft, you can request a Word version of the file from Laura Samant (laura.samant@gmail.com, 1-415-310-3618). You could also insert comments into a pdf version of the document.

We plan to list all names of meeting participants and reviewers on the credits page of the report. Please give us your name and brief affiliation as you would like them to appear in this report to make sure that we credit you properly. If you were listed in the *Here Today-Here Tomorrow* report credits, we will list your affiliation the same way, unless you request something different.

We greatly appreciate all of your help in improving this report.

Sincerely,

Tom and Laura

- Cover
- Project Overview page
- Title and Credits Pages
- Preface

Report Summary

No one knows when the next large earthquake will strike San Francisco, but it is certain that a big one will come. When it does, the City's people and economy, its housing and businesses, its culture and character, will suffer heavy consequences. Recovery could take many years and the new, post-earthquake San Francisco that emerges could be different in notable ways.

This report selects four possible earthquakes that could strike the City and estimates the amount of damage and resulting ripple effects that each could cause. It looks only at damage to privately owned buildings and the impacts that flow from this. Damage to utilities, transportation networks, and public facilities have not been studied but are likely to add substantial consequences to those described here. Focusing on one of these scenarios, a magnitude 7.2 earthquake on the San Andreas fault directly offshore from San Francisco, illustrates the types of consequences the City can expect following its next large earthquake.

The consequences of a large earthquake would be staggering, as summarized below and described in detail in this report. However, it is important to note that San Francisco has already taken great strides to reduce its earthquake risk. If the City continues these efforts in the decades to come, the damage expected in future earthquakes will decrease. As an example, the City's program requiring retrofit of unreinforced masonry buildings has resulted in a large decrease in the casualties expected to occur in future earthquakes. If the City pursues a program that results in retrofits of large, wood frame soft-story buildings as recommended in a previous report prepared by this project, the number of housing units that cannot be occupied or need to be demolished after an earthquake will go down significantly. This report focuses on identifying the consequences of large earthquakes on the City the way it is today. A follow-on report, guided by the information presented here, will examine and recommend steps the City can take to reduce those consequences.

Here is a likely scenario following a magnitude 7.2 earthquake on the section of the San Andreas Fault directly offshore from San Francisco:

Overall Damage

- Around 25,000 buildings in the City will not be safe to occupy after the earthquake. About seventy-five thousands more buildings will have light to moderate damage.
- Most of these will be wood frame soft-story buildings, but other structure types, notably concrete buildings built before the mid-1970's, will also suffer heavy damage.
- Around 3,500 buildings will need to be demolished and rebuilt. Many of these will be older and architecturally valuable buildings; some will be historic. The City will permanently lose the character and feel that these buildings contribute.

- Two hundred to three hundred people could be killed, and 7,000 more could have injuries requiring medical care. If the earthquake occurs during the day, older concrete buildings will be responsible for the largest share of casualties. If it occurs at night, soft-story residential buildings will cause the most casualties. Casualties could be much higher if a large, densely occupied building collapses.

- Earthquake shaking sparks fires. It is expected that more fires will occur than the San Francisco Fire Department can address simultaneously, meaning some will burn unchecked for hours. An estimated XXX additional buildings could be destroyed by fire. Damage from fire could be much higher or lower than these estimates, depending on weather, wind, and many other factors.

- Economic losses will be huge. The cost for owners to repair or replace their damaged buildings could be $30 billion. Most of this damage will be uninsured. Fewer than 10 percent of home owners in San Francisco carry earthquake insurance. An estimated 25 to 30 percent of commercial properties carry such insurance. An additional $10 billion could be lost in damage to building contents, loss of inventory, relocation costs, income losses, and wage loss directly linked to this damage. Post-earthquake fires could add $XX billion to these losses. Secondary economic losses, stemming from reduced business and household spending, would add additional losses.

Damage to Housing

- The City will experience heavy losses to its housing stock. About 11,000 single family homes and more than 70,000 units in multifamily residences will not be safe for occupancy. For the buildings with the worst damage, particularly multifamily apartment buildings, repairs can take years. Market conditions at the time of the earthquake strongly influence how long repairs take. In a strong economy, when financing is readily available, buildings will be fixed quickly. If the earthquake occurs during a downturn when credit markets are tight, repairs can be stalled for years. After recent California earthquakes, the average time required for heavily damaged residences to be reoccupied is nearly two years. Buildings requiring demolition and reconstruction took, on average, more than three years before they could be reoccupied.

- An estimated 1,500 buildings, with about 10,000 units, that need to be demolished will be multifamily residential buildings. When these buildings are reconstructed, any new rental units will be exempt from rent control. Owners may find that building condominiums provides a higher rate of return on their investment, meaning that rental units could be permanently lost. Renters will be hit hard.

- All neighborhoods will suffer, but some will see worse damage than others. In this scenario, the Sunset and Richmond will see heavy damage due to their proximity to the San Andreas Fault, although these areas would not be so hard hit if an earthquake on the Hayward Fault shook the City from its eastern side. The Marina, Inner Mission, Bayview, Downtown and Mission Bay will see heavy damage due to poor soils. Neighborhoods with many damaged multi-unit apartment buildings, such as the Mission, Tenderloin, Chinatown and Western Addition, will be the slowest to recover because of the amount of damage these buildings will experience and the difficulty in arranging for repairs.

- Predictable issues will slow recovery. Nearly 100,000 buildings will need some repair, although many owners will choose to cover and repaint damage rather than repair it. This process will take years and, as discussed above, will vary based on market conditions. Owners on fixed incomes with little savings will have the most difficulty financing repairs. In addition, construction workers will be in short supply. City agencies will have an increased workload to process permits for and review of all of this work. In many neighborhoods, locating space to stage construction materials and equipment in San Francisco's hilly neighborhoods with narrow lots and limited yard space will be a challenge.

Damage to Businesses

- Commercial spaces will also be hit hard. Over 900 buildings, mostly downtown, will be unusable immediately after the earthquake. Commercial buildings may get repaired more quickly than residential buildings when owners have an income source to finance repairs and are motivated to get rent paying tenants back in place but, again, it is highly dependent on market conditions at the time of the earthquake. In a time of high commercial vacancy rates, it could take years before all buildings are fully functional. Business interruption losses and government revenue losses will mount as the time to recover increases.

- Businesses and jobs will suffer. Businesses and workers that do not need to be in San Francisco may move. Key San Francisco industries, such as finance and technology, have been gradually shifting from San Francisco to other parts of the Bay Area in recent years. Heavy earthquake damage in the City could hasten this trend. The tourism industry will see severe impacts; visitors to the City can be expected to sharply decline in the years immediately following a large earthquake, which will impact the nearly 80,000 jobs that depend on these visitors. In the long-term, tourism and other businesses are likely to rebound and thrive, but not without some casualties. Many small and local businesses could close because they cannot weather an extended downturn in business or relocation from damaged facilities.

- The City will experience a temporary boom in the construction industry due to the massive repair and rebuilding effort required, but some of the benefit of this boom may be felt elsewhere. Many of these jobs are likely to be filled by workers from out of town, and much of the material needed for rebuilding, repair and refurnishing will be purchased elsewhere and transported to San Francisco.

The City's Resilience

- San Francisco has many characteristics that stand it in good stead to recover fully after the next earthquake – a diverse economy, a relatively wealthy and well-educated population, world-class educational institutions, and a region that has been aware of and preparing for disasters for many years. It also has some characteristics that will pose a challenge, such as the City's high cost of living. While the City as a whole will recover in time, some people will be left behind.

- The elderly, poor, persons with disabilities, and non-native English speakers will have the hardest time recovering. Many of the services that support these communities, such as non-profit organizations and churches, could suffer damage to their own facilities and have a reduced capacity to help. Neighborhood businesses that people rely on, such as pharmacies and grocers, may not be open. An unknown number of residents who lose their home or job, and businesses that lose their buildings or customers, will leave the City pending repairs. Many will never return.

- The City knows little about the seismic safety of private facilities that serve vulnerable people, including assisted living facilities, private schools, daycares and privately-owned medical clinics. Some of these buildings may be vulnerable structures; some may be unsafe.

- City revenues will go down. San Francisco receives income from a number of tax and fee sources that will decrease due to reduced value of damaged property and interruption of businesses. At the same time, City government expenses will increase as San Franciscans need expanded services and the City needs to repair and replace its own infrastructure and buildings. Support from the federal and state level will cover only a fraction of these costs.

- Important City policy goals will suffer set backs, such as the City's environmental goals to reduce waste disposal and its carbon footprint. In the scenario earthquake, almost 7 million tons of debris will require disposal, and replacing and repairing damaged buildings will be energy intensive.

The next major earthquake that strikes San Francisco will change the City and its people. San Francisco is a world-class city with many special attributes that draw businesses, innovative people who want to live here, and visitors from around the world. In the long-term, San Francisco will recover and thrive, but it will be a different San Francisco. It is likely that the new, post-earthquake San Francisco will have less socio-economic diversity. The destruction of many affordable housing options, exacerbated by a limited housing market in the years it will take to rebuild the City, will make it difficult for middle and low income people to remain in San Francisco. Earthquake damage will stress businesses and the jobs they provide, particularly the many small and independent businesses in the City. It will change the way the City looks, with some of the most interesting and beautiful buildings and neighborhoods changed forever. Despite the damage, San Francisco will retain many of the elements that make it an economically successful and socially desirable place – physical beauty, cultural amenities, and proximity to world-class universities, to name a few.

The scenarios described in this report present what is likely to happen if San Francisco makes no changes to its preparations for earthquakes. Much of this damage may be preventable. It is up to San Franciscans to decide how much to invest in steps to reduce the consequences of the next major earthquake.

- Table of Contents
- list of tables
- list of figures

Chapter One: Four Possible Earthquakes

No one knows when the next large earthquake will strike San Francisco, but it is certain that big ones will come. This report selects four possible earthquakes that could strike the City and estimates the amount of damage and resulting ripple effects that each could cause. The next large earthquake to strike the City will surely be different – in size, location, and many other characteristics – than the four scenarios examined in this report. The consequences of the next large earthquake, however, are likely to be similar in nature to the consequences estimated in the following chapters. To begin, this chapter describes the four earthquake scenarios studied in this report.

The chapters that follow present the estimated consequences of four possible earthquakes:

1. A magnitude 6.9[1] earthquake on the Hayward fault in the East Bay. Of the four earthquakes studied, this event has the highest likelihood in the next 30 years.

2. A magnitude 6.5 earthquake on the portion of the San Andreas fault closest to San Francisco.

3. A magnitude 7.2 earthquake on the portion of the San Andreas fault closest to San Francisco. This earthquake would produce a level of shaking in many areas of the City that is similar to the level of shaking that the building code requires new structures be designed to resist. For this reason, damage from this scenario is used as an example to explore consequences in detail in many places throughout the report.

4. A magnitude 7.9 earthquake on the San Andreas fault, which is a repeat of the 1906 earthquake. This is the largest known earthquake to have occurred in northern California on the San Andreas fault.

Any of the four earthquake scenarios examined in this study will result in very strong to violent shaking in San Francisco[2]. Figure Y shows the shaking that would be produced in each of these scenarios, and compares them to the actual shaking experienced during the 1989 Loma Prieta earthquake. All four of these scenarios would produce shaking throughout the City that is two to four times stronger than the shaking observed in the Marina – the City's hardest hit neighborhood – during Loma Prieta.

[Figure Y. graphic showing the shaking in the 4 scenarios, and Loma P shaking]

---

[1] All earthquake magnitudes in this report are moment magnitudes. Moment magnitude represents the total amount of energy released in an earthquake and is the preferred scale used by earth scientists. This is similar to Richter magnitude, which is related to the peak horizontal acceleration caused by an earthquake.

[2] The science of estimating the ground shaking that will occur given an earthquake of a specific size and location is continually evolving. The level of ground shaking that would occur in each location in the City during the four scenarios studied in this report was calculated in 2002. Since then, new methods of estimating ground shaking associated with scenario earthquakes and applying them to loss studies have been developed. However, the project's technical review process determined that the ground motions used in this study are the most appropriate choice to guide San Francisco policy and planning. For more discussion of this matter, please refer to [title of the technical appendix volume].

The chapters that follow describe what is likely to happen to San Francisco if these four scenario earthquakes occur. However, the next significant earthquakes to shake the City will be different than those studied here; perhaps they will have smaller magnitudes, or occur in different locations. Regardless, the same themes will emerge in the damage that follows. The City will lose housing, businesses, people, and historic character. The next chapter discusses the buildings in the City that these events would shake.

Chapter Two: San Francisco's Buildings

San Francisco has approximately 160,000 buildings, ranging from gleaming, new downtown high rises to small, single family homes. This chapter discusses the privately-owned buildings in the City: their numbers and value, how they are used, where they are located, and variations in how they are constructed. This report covers only privately-owned buildings, those under the jurisdiction of the City's Department of Building Inspection. The estimates do not include buildings located on Treasure Island, in the Presidio, or in Golden Gate Park.

Dividing up the City

Earthquakes will affect different parts of the City in different ways due to each location's proximity to faults, underlying soil, and types of buildings. For this reason, some of the findings in this study are presented by neighborhood. For the purposes of this project, the City is divided into sixteen neighborhoods used by the Department of Public Works, shown in Figure XX[3]. There is still considerable diversity within any of the relatively large neighborhoods used in this study. Further, the titles used by this study may represent a larger area than when those same titles are used colloquially by City residents. For example, the CAPSS "Downtown" neighborhood encompasses the Financial District, Chinatown, SOMA, the Tenderloin, and Nob Hill. Some of the different communities that make up each of the 14 large neighborhoods addressed in this study are presented in Table X.

Figure XX. Map of CAPSS neighborhood divisions.

[insert figure]

Table X. Communities that make up CAPSS neighborhood divisions.

CAPSS neighborhood titles	Neighborhoods included in each division
Bayview	Bayview, Candlestick Point, Hunter's Point, Silver Terrace
Downtown	Chinatown, Financial District, Nob Hill, SOMA, Tenderloin
Excelsior	Bayshore, Crocker Amazon, Excelsior, Portola, Visitacion Valley
Ingleside	Ingleside, Ingleside Heights, Ingleside Terrace, Oceanview
Marina	Marina
Merced	Lakeshore, Stonestown
Mission	Bernal Heights, Castro, Glen Park, Mission, Noe Valley
Mission Bay	Dogpatch, Mission Bay, Potrero Hill, South Beach
North Beach	Fisherman's Wharf, North Beach, Russian Hill, Telegraph Hill
Pacific Heights	Cow Hollow, Pacific Heights
Richmond	Inner Richmond, Outer Richmond, Seacliff
Sunset	Golden Gate Heights, Inner Sunset, Outer Sunset, Parkside
Twin Peaks	Diamond Heights, Forest Knolls, Miraloma Park, St. Francis Wood, Sunnyside,

[3] The Presidio, Golden Gate Park and Treasure Island (not shown) were not analyzed by the project because no building inventory data were provided to the project for these locations. Many buildings in those areas are government-owned. This study focuses only on privately-owned buildings.

	Twin Peaks, West Portal, Westwood Park
Western Addition	Alamo Square, Cole Valley, Fillmore, Haight Ashbury, Hayes Valley, Japan Town, Laurel Heights, Western Addition

Source: This study

The City's Buildings

San Francisco is made up of approximately 160,000 buildings. These buildings range from small homes built over a century ago to newly-constructed high-rises. The way each of these buildings responds to earthquake shaking depends on many things, including the materials they are constructed from, their size and shape, their engineering design, their quality of construction, and how well they have been maintained.

San Francisco's buildings house the many activities that take place in the City. Table Q presents estimates of the number and value of buildings used for various purposes.

Table Q. Estimated number and value of buildings used for various purposes in the City

Building Use	Estimated number of buildings[1]	Estimated replacement value of buildings[2] (billions)
Single Family Residences	112,000	$53
Two unit Residences	19,000	$22
Three or more unit Residences	23,000	$45
Other Residences[3]	800	$13
Commercial Buildings	5,000	$48
Industrial Buildings	2,100	$7.7
Other[4]	700	$2.6
Total[5]	**160,000**	**$190**

1. These numbers are estimates for 2009.
2. These figures represent an estimate of the cost to replace or reconstruct a building in 2009. They do not include the value of the land the building sits on or a building's contents, and these values are significantly different than real estate prices or assessed valuation. Building value is based on square footage from City Assessor's Data, not the estimated number of buildings. Information about how these numbers were derived appears in Appendix X.
3. Other Residences includes hotels, motels, nursing homes, and temporary lodging.
4. Other includes religious, educational and government buildings listed in Assessor's data.
5. Numbers in table have been rounded, which can make totals differ from sum of columns or rows.

Source: This study, City Assessor's Data, Census data, San Francisco Planning Department, and San Francisco Department of Building Inspection.

The density of buildings and the way they are used varies throughout the City. Many neighborhoods – the Sunset, Twin Peaks, Ingleside, and the Excelsior, to name a few – are primarily residential. Other neighborhoods have much of their building space used for commercial or other non-residential purposes, such as Downtown and Mission Bay. Similarly, the value of the building stock varies by neighborhood. More than a quarter of the City's building value is concentrated in the Downtown neighborhood. This reflects the sheer quantity of building square footage in this dense and high rise area. The consequences and costs of earthquake damage depend on which neighborhoods are shaken most strongly, and the types and quantity of buildings that reside there. Table W shows the estimated number and value of buildings by neighborhood.

Table W. Estimated number and value of buildings by neighborhood.

Neighborhood	**Estimated number of buildings[1]**	**Estimated replacement value of buildings[2] (billions)**
Bayview	7,600	$5.8
Downtown	5,500	$52
Excelsior	23,000	$11
Ingleside	8,200	$3.5
Marina	2,200	$3.4
Merced	2,600	$1.8
Mission	25,000	$22
Mission Bay	3,600	$9.9
North Beach	5,500	$13
Pacific Heights	6,000	$10
Richmond	15,000	$15
Sunset	33,000	$19
Twin Peaks	13,000	$7.4
Western Addition	12,000	$19
Total[3]	**160,000**	**$190**

1. These numbers are estimates for 2009.
2. These figures represent an estimate of the cost to replace or reconstruct a building in 2009. They do not include the value of the land the building sits on or a building's contents, and these values are significantly different than real estate prices or assessed valuation. Building value is based on square footage from City Assessor's Data, not the estimated number of buildings. Information about how these numbers were derived appears in Appendix X.
3. Numbers in table have been rounded, which can make totals differ from sum of columns or rows.

Source: This study, City Assessor's Data, Census data, San Francisco Planning Department, and San Francisco Department of Building Inspection.

Table X shows estimates of the number of buildings of various structural types that exist in San Francisco. The structural types, which reflect a building's materials and the system it uses to carry loads, are used by engineers to differentiate how buildings perform in earthquakes. These numbers are estimates only, based on engineering judgment, City databases, and available surveys by engineers[4]. The way that a building's use relates to its structural characteristics can be complex. Buildings used for some purposes tend to be of a predictable structural type; for example, single-family homes in San Francisco are overwhelmingly constructed out of wood. Buildings used for other purposes can be constructed in a wide range of structural types. For example, this study assumes that buildings used for retail could be

[4] There have been sidewalk surveys conducted by engineers for unreinforced masonry buildings and wood frame buildings with three or more stories and five or more residential units (these are a subset of the wood frame buildings listed in Table X). The number of concrete buildings built before the mid-1970's have been estimated by a project called the Concrete Coalition [reference] using street surveys and historical records. CAPSS conducted limited surveys of a small number of wood frame buildings in all City neighborhoods to estimate the percent of buildings with soft-stories and other conditions.

one of twelve different structural types, with additional variation in their seismic resistance based on the building's age, height and quality of construction.

Table X. Estimated number and value of buildings of various structural types in the City.

Structural Type	Estimated number of buildings[1]	Estimated replacement value of buildings[2] (billions $)
Single family wood frame with ground floor garage/opening	60,000	29
Two unit residential wood frame with ground floor garage/opening	10,000	12
Three or more unit wood frame residential with ground floor garage/opening	13,000	26
Single family wood frame without ground floor garage/opening	52,000	24
Two unit residential wood frame without ground floor garage/opening	9,000	10
Three or more unit residential wood frame without ground floor garage/opening	6,000	12
Concrete built before mid-1970's[3]	3,000	19
Tilt up concrete	200	0.8
Modern concrete[4]	600	4
Steel moment and braced frame	1,500	21
Unreinforced masonry, retrofitted[5]	1,500	5
Unreinforced masonry, unretrofitted[6]	400	**1**
Other[7]	4,200	$27
Total[8]	**160,000**	**$190**

1. The numbers of buildings are estimates for 2009 based on available studies and engineering judgment.
2. These figures represent an estimate of the cost to replace or reconstruct a building in 2009. They do not include the value of the land the building sits on or a building's contents, and these values are significantly different than real estate prices or assessed valuation. Building value is based on square footage from City Assessor's Data, not the estimated number of buildings. Information about how these numbers were derived appears in Appendix X.
3. Older concrete buildings include concrete shear wall buildings built before 1976, concrete frames with masonry infill walls, and concrete tilt-up buildings.
4. Modern concrete buildings include concrete moment frame and shear wall buildings built after 1976.
5. This includes buildings retrofitted under the City's program.
6. This includes buildings in the City's program that have not yet received their certificate of completion, and buildings not included in the City's retrofit program. Some of the latter category may, in fact, be retrofitted.
7. Other includes steel frame with cast in place concrete walls or masonry infill walls, reinforced masonry buildings, and non-residential wood frame buildings.
8. Numbers in table have been rounded, which can make totals differ from sum of columns or rows.

Source: This study, Concrete Coalition, and San Francisco Department of Building Inspection

Vulnerable Structure Types

Some building types in the City are known to have particular weaknesses in earthquakes, which are briefly described below. In future earthquakes, it is likely that damage will be concentrated in buildings of these types. A few of the most vulnerable building types are described below.

Soft-story buildings

The first floor in many buildings in San Francisco is significantly weaker or more flexible than the stories above it. The weakness at the ground level usually comes from large openings in perimeter walls, due to garage doors or store windows, and/or few interior partition walls. During strong earthquake shaking, the ground level walls cannot support the stiff and heavy mass of the stories above them as they move back and forth. The ground level walls can shift sideways until the building collapses, crushing the ground floor.

This type of weakness, called a soft story, can be found in buildings of all types. It is common in single-family homes, where the dwelling space sits over a garage, and multifamily buildings, which may have parking or commercial space at the ground level. It also occurs in commercial buildings constructed from concrete or steel, often with retail space at the ground level and offices above. A previous CAPSS report, *Here Today-Here Tomorrow: Earthquake Safety for Soft-Story Buildings*, took a detailed look at large, wood frame soft-story buildings. Many smaller wood frame soft-story buildings and soft-story buildings constructed from other materials also exist throughout the City.

[Photos: a single family home over garage; a multifamily home with a row of garages, a non-wf example?]

Concrete buildings built before the mid-1970's

Older reinforced concrete buildings can experience dramatic and deadly collapses during earthquakes. They are responsible for many of the casualties in earthquakes around the world. However, many older concrete buildings might suffer a great amount of damage, but remain standing. Inside the columns, beams, walls and floor slabs of reinforced concrete buildings lie appropriately placed steel reinforcing bars. Ideally, these bars allow reinforced concrete buildings to not only carry loads from gravity, but also to withstand the side-to-side shaking caused by earthquakes. Well-designed, modern concrete buildings are called "ductile concrete." Older reinforced concrete buildings may not have enough steel inside them or may not have steel in adequate configurations to survive the level of shaking that occurs in California earthquakes. Older concrete buildings are called "non ductile concrete."

Many older concrete frame buildings have unreinforced masonry walls filling the space between columns and floors to form walls for the exterior, elevator shafts, and stairwells. The masonry can help these buildings to remain standing after earthquakes, but the walls can crack up and fall into or out of the building, creating significant dangers to those on sidewalks, and causing damage that would be expensive and time-consuming to repair. Some of these buildings also have a soft-story at the ground level, and could collapse. It is costly and difficult to reinforce these buildings and repair them when they are damaged.

There are older reinforced concrete buildings in San Francisco being used as apartment buildings, private schools, office buildings and warehouses. Thousands of people use these buildings daily. What is not known is which specific buildings are most dangerous, and identifying the dangerous ones is challenging. Typically, it requires engineers with specific skills to conduct invasive and costly tests and analyze performance. The loss estimates described in this report do not capture the vulnerability of individual buildings. If one of these buildings collapses when densely occupied, it could significantly increase the casualties that occur.

[Photo: concrete building collapse?]

Unreinforced masonry bearing wall buildings

Unreinforced masonry bearing wall buildings have long been recognized as one of the most dangerous types of buildings in earthquakes. These buildings are constructed with brick walls that bear the weight of the building. They typically have six or fewer stories and were built before the mid-1930's, when building codes were changed to prevent this type of construction. They perform very poorly in earthquakes. Building parapets and sections of walls can fall outward, and some buildings can collapse in even moderate shaking. This building type has been responsible for many deaths in past earthquakes.

San Francisco has been working to improve the safety of its unreinforced masonry bearing wall buildings for decades, first through an ordinance requiring parapets to be anchored, and later through an ordinance requiring most of these buildings to be retrofitted. As of the writing of this report, 1,526 of the 1,699 buildings on the City's list of unreinforced masonry buildings had been retrofitted or demolished, and a remaining 173 were in process or were brought to the attention of the City Attorney's Office for enforcement[5]. It is important to note that retrofitted unreinforced masonry buildings remain highly vulnerable to earthquakes. When exposed to strong shaking, it is likely that retrofitted buildings would cause significantly fewer casualties than those that have not been retrofitted, but many could be damaged beyond repair, displacing their occupants and requiring demolition. A few hundred masonry buildings were exempted from the City's retrofit ordinance, including residential only buildings with four or fewer units and those not under the jurisdiction of DEPARTMENT OF BUILDING INSPECTION. It is likely that many of these remain unretrofitted.

[Photo: typical URM with bolts plus?]

Other vulnerable structural types and elements

A number of other building types and characteristics have been well-documented as vulnerable in earthquakes. These include the following:

- *Welded steel moment frame buildings.* The welds connecting columns and beams in steel moment frame buildings built before 1994 can crack in earthquake shaking. Before this vulnerability was discovered, this construction type was thought to have excellent seismic performance and, therefore, was popular for large office buildings.

[5] Laurence Kornfield, 2009.

- *Concrete tilt-up buildings.* This subset of older concrete buildings has precast concrete panels that are raised in place to form the building walls. If the walls are not adequately connected to each other and the roof, they can separate when shaken by an earthquake, causing the roof to lose support and collapse on the occupants and contents of the building. This structure type is often used for industrial purposes, but may also be used for some grocery stores or other commercial purposes. There are about 200 of these in San Francisco.

- *Older steel buildings with masonry infill walls.* San Francisco has many steel frame buildings from the early part of last century with masonry walls filling the space between columns and floors to form walls for the exterior, elevator shafts, and stairwells. The steel is often encased in concrete for fireproofing purposes, making the building appear to be a concrete frame to a casual observer. The masonry walls in these buildings can crack up and fall into or out of the building, creating significant dangers to those on sidewalks and causing damage that would be expensive and time-consuming to repair. These buildings are used as residences and offices, and many have beautiful period details.

- *Hillside buildings.* San Francisco's characteristic hills have led to many buildings that have more stories on one side than the other. For example, it is common to see buildings with one or two stories of street frontage, but three or four stories when examined from the back. Structurally, buildings with irregular heights can be more vulnerable to earthquake shaking, particularly if the lower levels have a soft-story condition.

- *Cladding, parapets and chimneys.* Buildings of all structural types have elements that can fall off during earthquakes, particularly if their connections have deteriorated due to age or corrosion, hurting people or affecting the functionality of the building. This includes cladding (outside finishes of glass, brick, stone, or other materials), and decorative elements. Masonry chimneys are brittle and often lack reinforcing steel. During earthquakes they can snap at the roof or pull away from a building. Falling bricks can crash through roofs or onto ground below.

Future earthquakes will shake all 160,000 buildings in the City. The next chapter presents estimates of how much damage these buildings will sustain.

Chapter Three: Earthquake Damage to Buildings

This chapter presents direct estimates of damage to the City's buildings in four possible earthquakes, with a focus on a magnitude 7.2 scenario on the San Andreas fault. In that scenario earthquake, nearly 15 percent of the City's buildings – almost 25,000 buildings – will not be fit for occupancy after the earthquake. 3,500 buildings will be damaged beyond repair. It will cost $30 billion to repair and replace damaged buildings. The type of structure that will experience the most damage, both in terms of the number of buildings damaged and the cost of damage, is soft-story wood frame residences. This is also the most common type of structure in the City. Other types of structures, such as concrete buildings built before the mid-1970's, will also fare poorly. This chapter presents losses due to shaking and liquefaction, but additional losses due to fire are discussed in a later chapter.

Purpose and Proper Use of These Estimates

The purpose of the damage estimates in this report is to guide the City in developing policies and plans to make San Francisco safer during and more resilient after future earthquakes. The losses and impacts described in the following pages are reasonable estimates of what could occur in future earthquakes, not accurate predictions of exactly what would happen. Estimating earthquake damage is an inherently uncertain process; if one of the exact events studied in this report should occur, damage could be double or half what is reported here. Some of the many sources of uncertainty include selecting which scenario earthquakes to study, modeling the way seismic forces travel through the ground, modeling the impact of differing degrees of shaking on structures of various materials and configurations, and estimating exactly which structural types of buildings are in various locations throughout the City. It is impossible to know exactly what will happen in the next large earthquake to strike San Francisco. However, the estimates presented in this report rely on nationally accepted techniques to provide sensible estimates to guide City decisions.

This report only examines buildings regulated by the Department of Building Inspection: those that are privately owned. There are many structures, buildings and facilities in San Francisco that were not analyzed. For example, public buildings (public schools; city, state, and federal buildings; and port facilities) and infrastructure (water, sewer, power, gas, transportation, bridges, piers, and tunnels), were not included. Data were not collected for these structures and damage was not estimated. Only private-sector building damage and repercussions on the people and economy of San Francisco traceable to this damage are addressed in this study. Therefore, the total damage following any of the scenario earthquakes will be higher than those presented in the report.

Direct Damage to Buildings

The amount of damage that buildings in the City would experience in future earthquakes depends on many things, including the size of the earthquake that occurs, the soil that each building sits on, the proximity of the building to the earthquake fault, and the structural characteristics and configuration of each building. This study uses the Hazards US (HAZUS) methodology[6], developed by the Federal

[6] The study used HAZUS99 SR2, FEMA/NIBS, 2002.

Emergency Management Agency (FEMA), to estimate the amount and types of damage that could occur in four possible scenario earthquakes. The analysis using HAZUS has been extensively customized to represent the unique buildings and conditions in San Francisco. The details of the technical analysis are described in a companion volume, [Title of technical volume].

Table X shows the estimated cost of direct damage that could occur in four possible scenarios due to shaking and ground failure due to liquefaction, expressed in dollar terms by building use. These figures represent the costs to repair or replace buildings damaged in the scenarios. The figures combine the costs of minor repairs with the costs incurred by buildings that need to be demolished and replaced from the ground up. The following issues stand out as important findings:

- Residential buildings have the largest losses. Depending on the scenario, sixty to seventy percent of the total citywide estimated cost to repair and replace damaged buildings is due to damages to residences. This finding is not surprising since most of the City's buildings – about 95 percent of all buildings and about 70 percent of all building value – are residential.

- Single-family homes have the largest total losses in the three San Andreas scenarios. Many single family homes are located in the City's western neighborhoods, closest to the San Andreas fault.

- The Hayward Fault scenario would shake the City's eastern neighborhoods more strongly than the western ones. This causes higher relative losses to multifamily homes and commercial buildings and lower losses to single-family homes, compared to the San Andreas scenarios. This difference is due to different building patterns in the City's eastern and western neighborhoods.

- Multifamily residences are hit hard. In all scenarios, they are responsible for a disproportionate share of the losses compared to their value. This is because many multifamily dwellings are located in vulnerable structure types, notably soft-story wood frame buildings and concrete buildings built before the mid-1970's.

- Industrial buildings also experience heavy damage in all scenarios, compared to their value, particularly in the Hayward Fault scenario. Again, this is due to vulnerable structure types – older concrete, concrete tilt-up, and masonry buildings – being common in buildings used for industrial purposes.

Table X. Estimated cost to repair and replace damaged buildings in four scenario earthquakes, by building use.

	Cost of Building Damage in Four Scenario Earthquakes (billions $)[1]			
Building Use	**Hayward Magnitude 6.9**	**San Andreas Magnitude 6.5**	**San Andreas Magnitude 7.2**	**San Andreas Magnitude 7.9**
Single Family	2.3	6.0	8.8	13

Residences				
Two unit residences	1.4	2.4	3.6	5.4
Three or more unit residences	4.2	5.2	7.8	12
Other Residences[2]	0.8	0.7	1.3	2.6
Commercial Buildings	4.5	4.2	6.6	11
Industrial Buildings	0.9	1.0	1.4	2.2
Other[3]	0.1	0.2	0.3	0.7
Total[4]	**$14**	**$20**	**$30**	**$48**

1. Estimates are in 2009 dollars.
2. Other Residences includes hotels, motels, nursing homes, and temporary lodging.
3. Other includes religious, educational and government buildings listed in Assessor's data.
4. Numbers in table have been rounded, which can make totals differ from sum of columns or rows.

Source: This study

Another way to look at damage is to look at the number of buildings or amount of space that will suffer various degrees of damage in an earthquake. This report expresses damage to buildings in terms of their expected functionality after an earthquake, with the following categorizations[7]:

- *Usable, light damage.* Buildings would experience only minor damage and residents could continue to use them. This report does not assess the likelihood of utilities – water, sewer, power, etc. – being functional, which would influence whether occupants choose to remain in these buildings.

- *Useable, moderate damage.* Occupants of these buildings could continue to use them safely after a major earthquake and during its aftershocks, but there would be damage that may cause inconvenience. The use of these damaged buildings will depend in part on the City's post earthquake inspection and posting policies and on the willingness of building owners to let tenants occupy moderately damaged buildings.

- *Repairable, cannot be occupied.* Buildings in this state would experience heavy damage and could not be occupied until repaired. Few buildings in this state would be demolished, thus, repaired rental units would remain under rent control restrictions, and neighborhood character, as defined by style of construction, building scale, and mix of uses, would be maintained.

- *Not Repairable.* These buildings would experience heavy damage and would need to be demolished after the earthquake. The city could permanently lose significant amounts of rent-

[7] These functionality states were adapted from San Francisco Planning and Urban Research (SPUR) (February 2009), and roughly correlate with the states of Safe and Operational, Safe and Usable During Repair, Safe and Usable After Repair, and Safe but Not Repairable.

controlled housing, as well as buildings that contribute to the architectural character of the city. Some of these buildings would collapse or experience partial collapse.

Table X shows the amount of damage that buildings used for various purposes are estimated to experience in the Magnitude 7.2 San Andreas scenario due to shaking and liquefaction. Key points that emerge from looking at expected damage this way are:

- About 25,000 buildings in the City would not be safe to occupy. This includes more than a quarter of the City's residential buildings.

- About 1,500 multifamily residential buildings would need to be demolished. When these buildings are reconstructed, the new units will not be covered by rent control. Many owners may choose to rebuild their buildings with condominiums rather than as rental properties.

- Eighteen percent of commercial space – about 900 buildings – would not be safe for occupancy after the scenario. Over 200 of these buildings would be demolished and rebuilt.

- Twenty-five percent of industrial buildings – more than 500 buildings – would not be usable after the scenario earthquake. About 160 of these would need to be demolished and rebuilt.

Table X. Estimated damage states of buildings in a Magnitude 7.2 earthquake on the San Andreas fault, by building use.

Building occupancy	**Number of buildings in various states of damage[1]**			
	Usable, light damage	**Usable, moderate damage**	**Repairable, cannot be occupied**	**Not repairable**
Single Family Residences	45,000	56,000	9,500	1,700
Two unit residences	8,200	7,400	3,200	300
Three or more unit residences	7,200	7,500	7,100	1,200
Other Residences[2]	300	400	90	30
Commercial Buildings	1,600	2,500	700	220
Industrial Buildings	750	820	370	160
Other[3]	330	280	70	20
Total[4]	**63,000**	**75,000**	**21,000**	**3,500**

1. Building functionality categorizations are derived from HAZUS damage states, presented in Appendix XX.
2. Other Residences includes hotels, motels, nursing homes, and temporary lodging.
3. Other includes religious, educational and government buildings listed in Assessor's data.
4. Numbers in table have been rounded, which can make totals differ from sum of columns or rows.

Source: This study

Damage varies by neighborhood. The neighborhoods close to the fault, those on poor soils, and those with a prevalence of vulnerable building types experience proportionately more damage than other neighborhoods. It is important to remember that a different scenario earthquake, such as an event on the Hayward Fault that occurs on the other side of the City, would change the relative damage patterns among neighborhoods. Table Y shows how damage to buildings would be distributed among different neighborhoods in the City. Looking at damage by neighborhood illuminates the following issues:

- Citywide, an average of about 15 percent of buildings would not be occupiable.

- The Marina, while small, has a higher percent of buildings that would not be safe for occupancy than any other neighborhood. This is due to the poor soils and expected increased shaking and pockets of liquefaction in the neighborhood, as well as a high number of multifamily residences. Due to the way the neighborhood has been defined, nearly all of it has poor soils, whereas other neighborhoods in the study – Downtown, Mission Bay, the Mission, the Bayview – are larger and encompass many areas with firm soil as well as those with poor soils. Mission Bay and Western Addition have the next highest percentages of buildings that could not be occupied, both over 20 percent.

- Citywide, about two percent of buildings could not be repaired and would need to be demolished.

- Mission Bay has the highest percentage of buildings that could not be repaired, just over six percent. It is followed by Bayview, with over four percent of buildings unrepairable. Vulnerable industrial and commercial buildings in these neighborhoods account for most of the unrepairable building stock.

Table Y. Estimated damage states of buildings in a Magnitude 7.2 earthquake on the San Andreas fault, by neighborhood.

Neighborhood	Number of buildings in various states of damage[1]			
	Usable, light damage	Usable, moderate damage	Repairable, cannot be occupied	Not repairable
Bayview	3,100	3,300	840	320
Downtown	2,000	2,600	650	200
Excelsior	9,900	11,000	2,000	340
Ingleside	3,000	4,500	700	120
Marina	700	770	590	80
Merced	840	1,400	270	60
Mission	10,000	10,000	3,600	560
Mission Bay	1,100	1,600	550	210
North Beach	2,500	2,000	800	140
Pacific Heights	2,600	2,400	880	120
Richmond	5,400	6,600	2,500	330
Sunset	12,000	16,000	4,300	620
Twin Peaks	5,400	6,700	1,200	160
Western Addition	4,900	4,900	2,200	300

Total[2]	**63,000**	**75,000**	**21,000**	**3,500**

1. Building functionality categorizations are derived from HAZUS damage states, presented in Appendix XX.
2. Numbers in table have been rounded, which can make totals differ from sum of columns or rows.

Source: This study

Damage by Structural Type

As discussed previously, some structure types are more vulnerable to earthquake shaking than others. Not surprisingly, these vulnerable structure types are responsible for a disproportionate share of damage to the City's buildings. Table X presents expected costs of building damage in four scenario earthquakes by structural type. The following conclusions emerge when looking at damage this way:

- Residential wood frame soft-story buildings are responsible for the largest economic losses in all scenarios. This building type, known to be vulnerable in earthquakes, is very common in San Francisco. It has the highest value of any structure type in the City and, because many of these buildings are small one or two unit residences, it represents by far the largest number of buildings in the City.

- Older concrete buildings also account for significant economic losses in every scenario, particularly when losses are viewed as a percentage of the value of each building type.

- Wood frame residences without a soft-story have relatively high economic losses, but this is due to how common these structures are rather than their vulnerability. In fact, when losses are viewed as a percentage of the value of each structure type, these buildings have the lowest percentage loss of any structure type.

Table X. Expected costs of building damage in four scenario earthquakes, by structure type.

Structure Type	**Cost of building damage in four scenario earthquakes (billions $)**				**Estimated replacement value[1] (billions)**
	Hayward Magnitude 6.9	**San Andreas Magnitude 6.5**	**San Andreas Magnitude 7.2**	**San Andreas Magnitude 7.9**	
Residential wood frame with ground floor garage/opening	6.6	10	15	23	67
Residential wood frame without ground floor garage/opening	1.0	2.8	4.1	6.6	47
Concrete built before mid-1970's[2]	2.0	2.1	3.4	6.7	20
Modern concrete[3]	0.3	0.3	0.4	0.6	4
Steel moment and braced frame	1.9	1.7	2.6	3.8	21
Unreinforced masonry[4]	0.5	0.5	0.7	1.3	6

Other[5]	2.0	2.0	3.2	6.1	27
Total[6]	**$14**	**$20**	**$30**	**$48**	**$190**

1. These figures represent an estimate of the cost to replace or reconstruct a building in 2009. They do not include the value of the land the building sits on or a building's contents, and these values are significantly different than real estate prices or assessed valuation. Building value is based on square footage from City Assessor's Data, not the estimated number of buildings. Information about how these numbers were derived appears in Appendix X.
2. This includes concrete shear wall buildings built before 1976, concrete frames with masonry infill walls and concrete tilt-ups.
3. Modern concrete buildings include concrete moment frame and shear wall buildings built after 1976.
4. This includes both retrofitted and unretrofitted buildings, and buildings not included in the City's retrofit program.
5. Other includes steel frame with cast in place concrete walls or masonry infill walls, reinforced masonry buildings, and non-residential wood frame buildings.
6. Numbers in table have been rounded, which can make totals differ from sum of columns or rows.

Sources: This study, City Assessor's Data

The Impact of Liquefaction

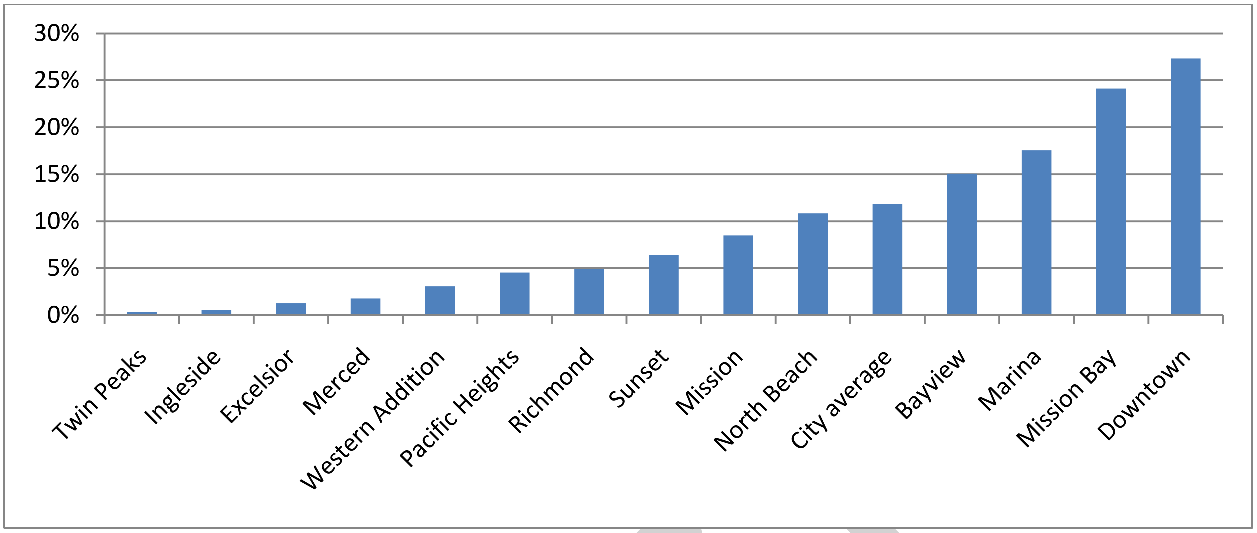
The quality of soils has a profound impact on the level of shaking and type of damage that occurs in each part of the City. Liquefaction is a phenomenon that can lead to ground failure and costly damage to buildings. Liquefaction occurs when wet and sandy soils are shaken. It results in a loss of soil strength, and can cause the ground and buildings to move sidewise or settle unevenly.

A number of neighborhoods in San Francisco could experience liquefaction, as shown in Figure X. Citywide, the amount of direct dollar losses to buildings due to liquefaction in a Magnitude 7.2 event on the San Andreas is slightly over 10 percent of total expected losses, although in selected areas, such as Mission Bay and Downtown, the contribution of liquefaction can be twice this. Figure Z shows the percent of each neighborhood's losses attributable to liquefaction. Losses due to liquefaction are included in the losses to buildings presented earlier in this chapter.

Figure X. Liquefaction susceptibility map.

[insert map]

Figure Z. Percent of direct dollar losses to buildings attributable to liquefaction in magnitude 7.2 San Andreas scenario



Damage to Buildings with Special Uses

The City has many privately-owned buildings that serve special purposes. These include the following:

- Facilities occupied by vulnerable people (e.g., private schools, daycare centers, assisted living facilities)
- Businesses and organizations that provide key services to people (e.g., pharmacies, medical offices, medical suppliers, dialysis centers, non-profit community service organizations, grocery stores)
- Culturally important buildings (e.g., historic and architecturally important buildings, buildings in historic neighborhoods, museums, universities)

In general, the City and the Department of Building Inspection know very little about the seismic safety of these buildings. Many of them may be vulnerable; some of them may be unsafe. No inventories have been conducted to assess the seismic safety of buildings used for these purposes.

Buildings used for these special purposes are probably much like other buildings in the City. In many cases, this means they are old and built to outdated building codes. The average date of construction of buildings in the City is 1937[8]. Only 16 percent of the total building square footage in the City was constructed after the mid-1970's, when significant improvements in seismic safety were made in the building code. It is important to note that a building's age alone does not make it unsafe. Many older buildings were built more solidly and used better quality materials than relatively newer buildings from the 1950's and 1960's.

Buildings built to older codes, including those that would be considered unsafe by today's standards, comply with City laws. Only buildings that have recently changed use or conducted extensive

[8] This is the building area weighted average, calculated by this study using Assessor's data.

renovations, or were covered by the City's unreinforced masonry building ordinance have been required to conduct seismic safety upgrades.

Most people assume that school buildings are safe. For public school buildings this is generally true: the state has had stricter building regulations for public schools than other building types since the 1930's and has required retrofit of public schools built before 1933. However, there are no retrofit requirements for private schools. Newly constructed private schools, especially those built after the mid 1990s when enhanced private school building regulations were enacted, should perform well. However, many of San Francisco's private school buildings were constructed when building standards were much less stringent. Nearly one third of school children—more than 23,000—attend private schools in San Francisco, the highest rate in the entire state[9]. The City knows very little about the seismic safety of its private school buildings.

Non-profit organizations serve a critical role to the City's poorest and most vulnerable residents. Generally, these organizations operate with tight budgets and may be located in older and poorly maintained buildings, meaning their buildings could face a higher risk of damage than many other buildings in a large earthquake. As discussed in Chapter X, the elderly, poor, disabled, and non-native English speakers – many of whom rely on non-profit agencies for support – are most affected by the dislocation caused by disasters and would be in great need of support services after a large earthquake.

The City has about 250 designated historic buildings and 11 historic districts[10]. These numbers of officially designated buildings and areas could increase as efforts to survey older parts of the City progress, however, it is certain that there are many more buildings with historic characteristics in San Francisco. Historic buildings contribute to the unique character and culture of the City and provide a connection with the past. The presence of these buildings keeps past events and eras in mind and helps residents understand and appreciate the unique values and attitudes of San Franciscans. Historic buildings would have vulnerabilities similar to other buildings of their era and construction type. It is difficult to make any uniform statements about the seismic vulnerability of historic buildings because they range considerably in construction material, size and configuration. Some older buildings are very vulnerable to earthquake shaking; others are quite robust. What is unique about historic buildings is the impact of damage: every historic building that is destroyed in a future earthquake is a loss of the City's cultural heritage.

The impact of future earthquakes on privately-owned buildings that serve special functions in the City can only be understood by learning more about the buildings they are housed in. Until a survey of these buildings is conducted, the City will not know the damage that could occur to these buildings and its consequences to the people of San Francisco.

----

[9] California Department of Edication, 2009.
[10] San Francisco Planning Department, 2010, designated Article 10 Landmarks and Article 10 Historic Districts.

Building damage due to earthquake shaking is only one piece of the total impacts earthquakes can have on a community. The next chapter looks at another critical piece: damage due to fire sparked by the earthquake. Post-earthquake fire is a particularly relevant topic for San Francisco, given the City's experience of a devastating conflagration after the 1906 earthquake.

Chapter Four: Additional Damage Caused by Fire

Fires that ignite in the hours and days following damaging earthquakes pose a serious threat to people and property throughout San Francisco. Large fires following an earthquake in an urban region are relatively rare, but have occasionally been of catastrophic proportions. Earthquakes caused the two largest peacetime urban fires in history: in 1906 in San Francisco and in 1923 in Tokyo. The experience in 1906, in which more than 28,000 buildings were lost, about 90 percent[11] of them due to fire, is well-known. The 1906 earthquake and conflagration occurred when the City had less than half the number of people and buildings existing today, and when there was very little development in the western Richmond, Sunset and Lake Merced neighborhoods closest to the San Andreas fault. There were 52 fires following the 1906 earthquake[12].

The fires following the 1994 Northridge and 1995 Kobe earthquakes demonstrate that large fires following earthquakes remain a threat today. There have also been several recent, large fires not caused by earthquakes that illustrate the challenges of extinguishing fires in built-up areas, including the 1991 East Bay hills fire. After the 1906 fire, San Francisco was rebuilt in much the same way as before, with densely packed, flammable buildings. It remains a city ready to burn.

Ignitions occur following earthquakes due to a variety of causes. These include electricity (shorts, frayed wires, tipped appliances); gas leaks ignited by sparks or open flames; exothermic reactions from spilled chemicals; open flames from stoves, candles, fireplaces and grills; and arson. After the southern California Northridge earthquake in 1994, about 56 percent of the ignitions were sparked by electrical systems, about 26-percent by gas, and 18 percent were related to a variety of other sources[13] .

The San Francisco Fire Department today is a well-prepared, professional organization that trains for earthquake-caused fires. However, it will not be able to respond immediately to every fire after a large earthquake, and response time is a key factor. The time taken to detect and report fires and for fighters to respond greatly affects fire severity and spread. After an earthquake, fire departments are called to respond to multiple simultaneous ignitions and life threatening conditions while, at the same time, their response is impeded due to damaged communications, water supply, and transportation systems. Additionally, fire departments need to respond to other emergencies caused by the earthquake, such as structural collapses and hazardous material releases, and their personnel are needed to provide emergency medical aid. In the City's next large earthquake, it is likely that some fires will spread beyond the original building to adjacent buildings. Out-of-town firefighters would probably not reach the City to help for many hours; firefighters in nearby cities will be absorbed with their own community's problems. Some fires could burn out of control and threaten entire neighborhoods.

Following 1906, San Francisco clearly recognized the dimensions of this problem and constructed the Auxiliary Water Supply System, a system exclusively used for fighting fires with features designed to

[11] [confirm number and cite]
[12] Scawthorn [DATE]
[13] [cite]

increase the likelihood it will function after an earthquake. The combination of the Auxiliary Water Supply System, cisterns located throughout the City, fireboats that can pump Bay water into the auxiliary system, and other special capabilities, enables San Francisco to be better prepared for post-earthquake fires than most other cities.

Estimates of the number of fires ignited by future earthquakes are based on historic California earthquake data that relate the number of ignitions to the area of buildings exposed to various levels of ground shaking intensity. The severity of resulting fires depends on how quickly adequate suppression arrives, building density and construction type, humidity and wind.

Table X summarizes estimated ignitions requiring fire department response within hours following the four scenario earthquakes. Losses were calculated for each scenario for no wind, low winds, average winds, and high winds conditions, with Table X indicating the probability-weighted average of these conditions. Under certain high-wind conditions, the losses due to fire may be much higher than presented here.

Table X. Estimated number of ignitions, large fires and lost buildings due to fire in four scenario earthquakes.

Scenario	Number of Ignitions	Number of Large Fires[1]	Number of buildings lost[2]
Hayward Magnitude 6.9			
San Andreas Magnitude 6.5			
San Andreas Magnitude 7.2			
San Andreas Magnitude 7.9			

1. Large fires refers to fires larger than one fire engine can suppress.
2. [Buildings lost in addition to those damaged by shaking? Does "lost" mean unrepairable?]

Source: This study

The additional damage to San Francisco from fire would be significant. Table XX provides estimates of the costs to repair or replace buildings damaged by fire that is in addition to the damage caused by shaking and liquefaction. The additional increment of loss, from XX percent ($XX billion) following a magnitude 6.9 earthquake on the Hayward fault to ZZ percent ($ZZ billion) following a magnitude 7.9 on the San Andreas fault, documents the economic importance of strategies to reduce fire risks.

Table XX. Summary of damage caused by fire following the scenario earthquakes.

Scenario	Shaking Damage (billions $)	Additional Damage due to Fire[1] (billions $)	Shaking Plus Fire Damage (billions $)
San Andreas Magnitude 6.5			
Hayward Magnitude 6.9			

San Andreas Magnitude 7.2			
San Andreas Magnitude 7.9			

1. Additional damage is the damage that occurs on top of the shaking damage and does not double count shaking damage.
Source: This study

Post-earthquake fires will add to the City's damage, making recovery more difficult and longer. They increase the number and severity of damaged buildings, lengthen the time required to repair and replace damaged buildings, displace residents and weaken neighborhoods, even those with many buildings left standing. Buildings that survive the shaking can succumb to fire. Conflagration threatens historic neighborhoods, architecturally important buildings, and the character of communities.

Fire damage often is insured by private home- and building-owner insurance policies. Payments, if made quickly, can expedite recovery construction. However, disputes have occurred after previous earthquakes about whether burned buildings were also damaged by earthquake shaking. Earthquake damage is not covered by general home- and building-owner insurance policies. These disputes can lead to lengthy delays in owners receiving payments to repair or rebuild their properties.

The damage to buildings from shaking and fire can lead to deaths and injuries. The next chapter looks at how many casualties would be expected in the scenario earthquakes, and what might cause them.

Chapter Five: Casualties

Damaged buildings kill people. Table X estimates the number of injuries and deaths that could occur in the four scenario earthquakes studied by CAPSS. Depending on the size and time of an earthquake, deaths could range from less than 100 to nearly 1,000. These estimates are based on statistical probabilities based on casualties in past earthquakes; the collapse of a single densely packed high-rise building would dramatically increase deaths. These estimates do not include potential casualties due to a conflagration.

Table X. Estimated injuries and deaths in four scenario earthquakes.

	Casualties			
Earthquake scenario	**Severity 1: Injuries needing first aid[1]**	**Severity 2: Injuries needing hospitalization[2]**	**Severity 3: Life threatening injuries[3]**	**Severity 4: Death[4]**
Hayward Magnitude 6.9	1,500 to 2,300	330 to 510	40 to 60	70 to 120
San Andreas Magnitude 6.5	1,800 to 3,600	390 to 740	40 to 60	80 to 120
San Andreas Magnitude 7.2	3,200 to 5,600	760 to 1,300	90 to 150	170 to 300
San Andreas Magnitude 7.9	6,500 to 10,600	1,800 to 3,000	220 to 450	420 to 880

1. Severity 1: Injuries requiring basic medical aid that could be administered by paraprofessionals. These types of injuries would require bandages or observation. Some examples are a sprain, a severe cut requiring stitches, a minor burn (first degree or second degree on a small part of the body), or a bump on the head without loss of consciousness. Injuries of lesser severity that could be self-treated are not estimated by HAZUS.
2. Severity 2: Injuries requiring a greater degree of medical care and use of medical technology such as x-rays or surgery, but not expected to progress to a life threatening status. Some examples are third degree burns or second degree burns over large parts of the body, a bump on the head that causes loss of consciousness, fractured bone, dehydration or exposure.
3. Severity 3: Injuries that pose an immediate life threatening condition if not treated adequately and expeditiously. Some examples are uncontrolled bleeding, punctured organ, other internal injuries, spinal column injuries, or crush syndrome.
4. Severity 4: Instantaneously killed or mortally injured.

Source: This study, FEMA/NIBS

The deaths and injuries in the next San Francisco earthquake are likely to be on a much smaller scale than those seen in recent international earthquakes, especially those in developing countries. There are many reasons for this. One notable reason is that San Francisco has been effectively enforcing building standards for generations. Fifty years ago, those standards were not as good at producing earthquake-resistant buildings as they are today, but they were far better than no standards. Today, many countries continue to have most of their buildings constructed without any design or construction standards, often due to lax enforcement of their building codes. Another reason for San Francisco's low casualty estimates is that most buildings in the City are constructed from wood. Wood buildings, even when they collapse, are far less lethal than brick, concrete and other heavy structure types.

Casualty estimates vary by time of day because people are located in different places at different times of day. At night, most people are at home in small wood frame buildings. During the day, many people are at work or school in buildings with markedly different structural characteristics than their homes. During commute times, people are traveling from one place to another. The numbers of deaths and injuries that occur in an earthquake can vary significantly depending on circumstances. For example, the World Series game during the 1989 Loma Prieta earthquake, and the consequent decline in traffic, may have prevented more people from being killed by the collapse of the Oakland Cypress viaduct.

The estimated deaths and injuries in Table X are only those caused by privately-owned buildings. This study did not estimate possible casualties from other causes, such as damage to infrastructure. In the Loma Prieta earthquake, 41 of the 63 deaths that occurred in the Bay Area were due to the collapses of the Oakland Cyprus Viaduct and the Bay Bridge[14].

A few structure types bear a disproportionate blame for the estimated deaths in the scenarios studied. One of the most lethal structural types is concrete buildings built before the mid-1970's. Figure X shows the number of deaths[15] caused by each structure type at three times of day in the Magnitude 7.2 San Andreas scenario. This figure shows that concrete buildings built before the mid-1970's (labeled "older concrete buildings" in figure) are expected to be most lethal if an earthquake occurs during the day, but residential wood frame soft-story buildings will cause the most deaths if an earthquake occurs at night. This difference is due to the different ways these types of structures are used and when they are most densely occupied.

Figure X. Deaths caused by each structure type for the M7.2 San Andreas scenario.

[14] Earthquake Spectra, May, 1990.
[15] HAZUS severity 4 casualties.

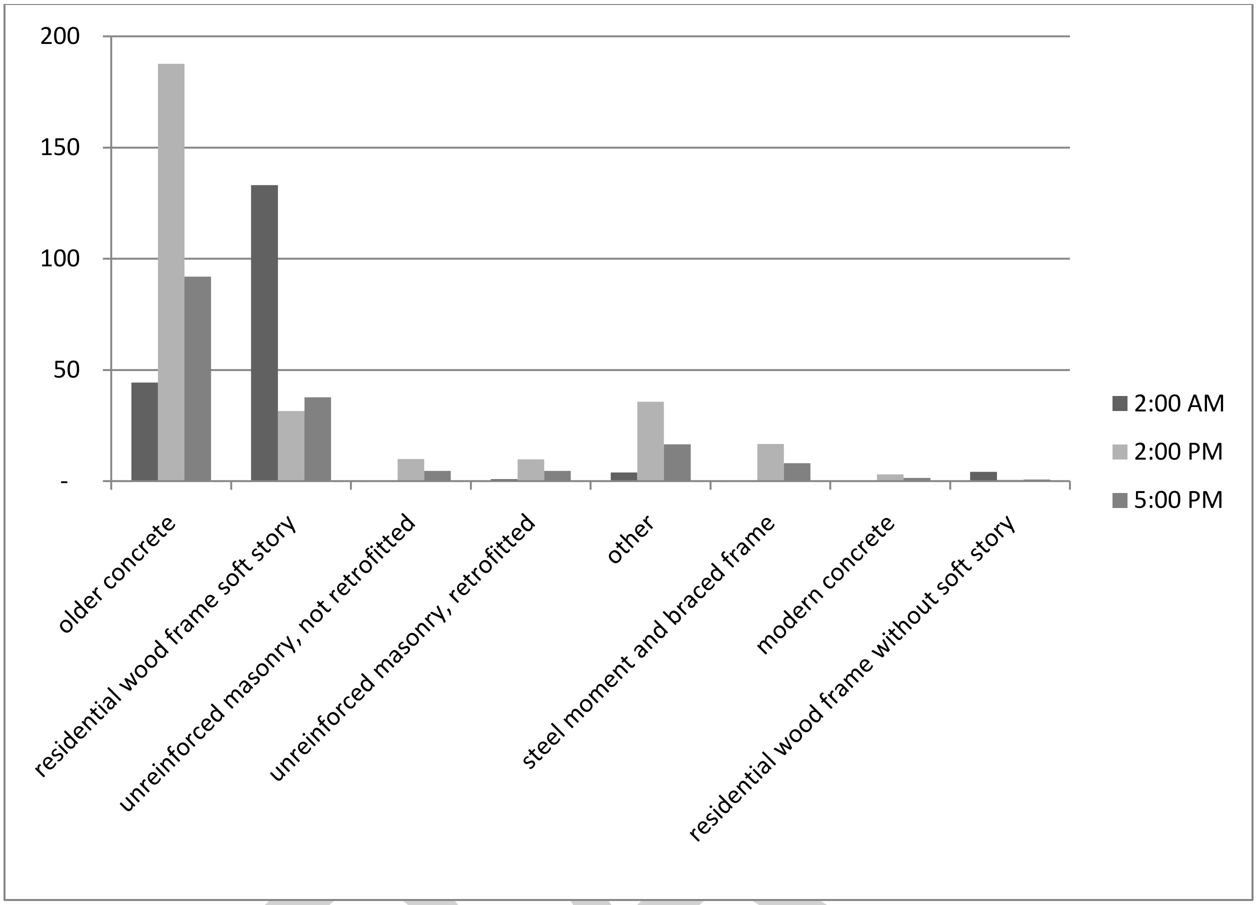
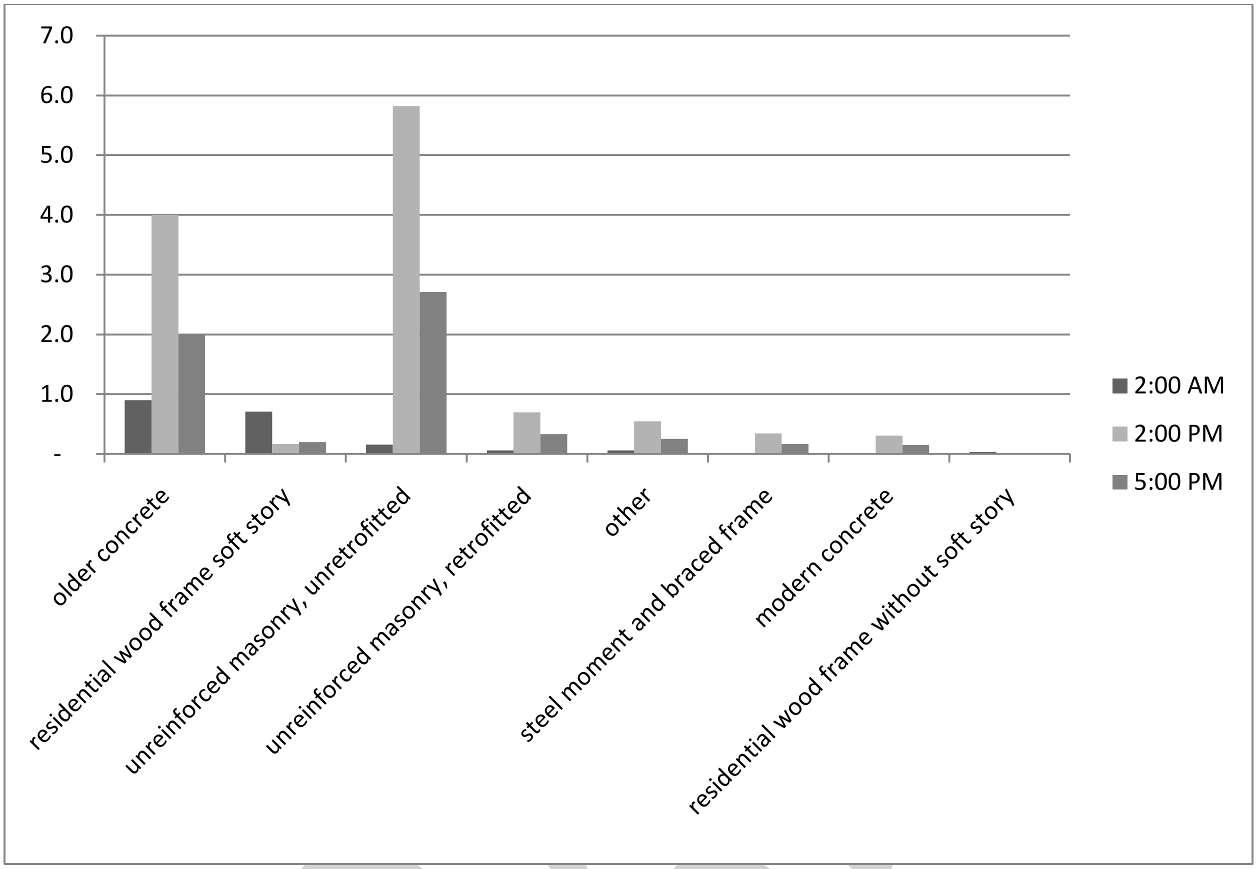


Figure Y looks at estimated deaths in another way. Instead of expressing which structure type is responsible for the most deaths overall, it shows how many deaths are expected per million square feet of space. When presented this way, it is clear that two building types are considerably more lethal per square foot than others in the City: concrete buildings built before the mid-1970's and the last few unreinforced masonry buildings that remain unretrofitted. This chart also makes clear that, per square foot of floor space, wood frame soft-story buildings are less lethal than most other structure types.

Figure Y. Deaths per million square feet caused by each structure type for the M7.2 San Andreas scenario.



Every death and injury the next earthquake causes will be a tragedy. However, there are other types of losses that will have profound impacts on the entire City for years, perhaps decades, after the earthquake. The next chapter examines one of the most important of these: damage to housing.

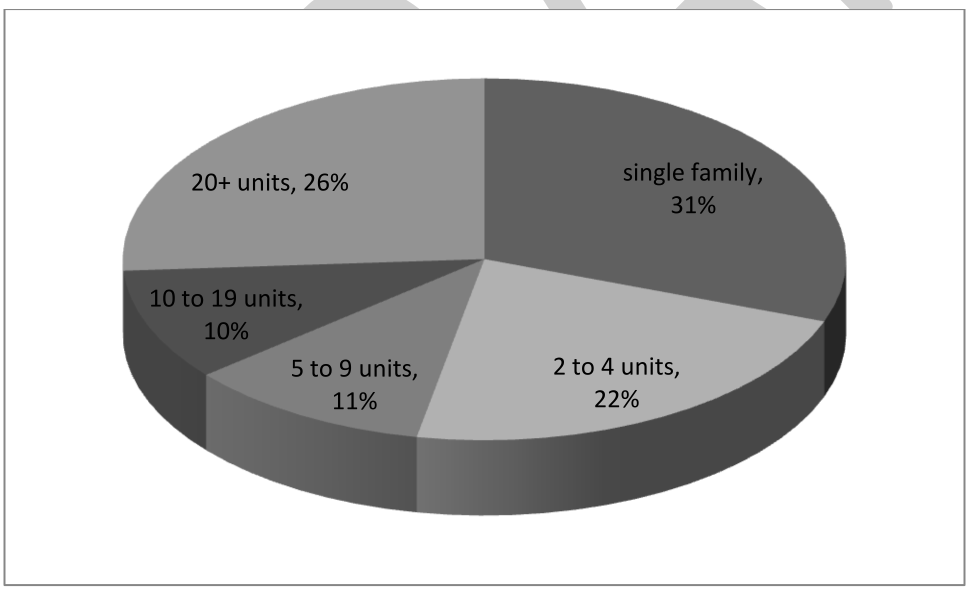
Chapter Six: Impacts on Housing

After an earthquake, many people will not be able to stay in their homes. For some, this displacement will last only a few days. For others, it could last years. This study estimates that after a magnitude 7.2 San Andreas earthquake, more than 80,000 dwelling units will not be safe to occupy. These buildings will require extensive repairs and would take years before they are usable again. It is the long and slow rebuilding and recovery process that follows the emergency that truly shapes what the post-earthquake San Francisco will be like. The recovery of housing is a critical part of that picture. This chapter looks into damage to the City's housing and issues that will affect how long it takes people to get back in their homes.

The City's Housing

About 95 percent of the City's buildings are residential. These range from single-family homes to high-rise condominium and apartment towers. There are many different ways to look at the City's residential building stock. Figure XX shows how the City's dwelling units are distributed among buildings of various sizes. The number of units in a building affects building and planning code regulations, condominium conversion, financing, and many other issues. Table Y shows the number of residential buildings and units used for this study.

Figure XX. Percent of Dwelling Units in buildings of various sizes



Source: San Francisco Planning Department (2009)

Table Y. Number of residential buildings, dwelling units and building value used in CAPSS analysis

Size of building	Number of buildings[1]	Number of dwelling units[2]	Value[3] (billions $)
Single family homes	112,000	112,000	53

Two unit residences	19,000	38,000	22
Three or more unit residences[4]	23,000	180,000	45

1. These numbers are estimates for 2009.
2. Note that dwelling unit counts used by this study do not exactly match other sources. The counts presented in this table represent a best effort using all available data sources to match building counts with unit counts.
3. These figures represent an estimate of the cost to replace or reconstruct a building in 2009. They do not include the value of the land the building sits on or a building's contents, and these values are significantly different than real estate prices or assessed valuation. Building value is based on square footage from City Assessor's Data, not the estimated number of buildings. Information about how these numbers were derived appears in Appendix X.
4. Note that wood frame residences with three or more stories and five or more units, discussed in a previous CAPSS report *Here Today Here Tomorrow: Earthquake Safety for Soft-Story Buildings*, are a subset of these buildings. That report discusses that there are an estimated 4,400 of those buildings built before May 1973, with 45,000 units, valued at about $14 billion. Many have a soft-story condition.

Source: This study, City Assessor's Data, Census data, San Francisco Planning Department, and San Francisco Department of Building Inspection.

Table Z shows how the City's housing is distributed throughout its neighborhoods. This table shows that certain neighborhoods have many more housing units than others. Some neighborhoods largely consist of single-family homes (e.g., Ingleside, Excelsior and Twin Peaks), while others have mostly multifamily dwellings (Downtown, Marina, and Pacific Heights).

Table Z. Distribution of dwelling units by neighborhood

Neighborhood	Number of dwelling units[1]	Units in single family homes (%)	Units in multifamily dwellings[2] (%)
Bayview	11,000	61	38
Downtown	51,000	2	98
Excelsior	25,000	82	17
Ingleside	7,700	90	9
Marina	8,400	11	89
Merced	7,100	41	59
Mission	53,000	28	72
Mission Bay	15,000	13	84
North Beach	29,000	5	94
Pacific Heights	19,000	15	85
Richmond	29,000	30	70
Sunset	38,000	66	34
Twin Peaks	15,000	72	28
Western Addition	44,000	12	88
Total/Average[3]	**350,000**	**31**	**69**

1. Note that dwelling unit counts may vary from what is presented in other tables due to different source materials.
2. For this table, multifamily dwellings are buildings with two or more units.
3. Numbers in table have been rounded, which can make totals differ from sum of columns or rows..

Source: This study, Claritas.

The vast majority of residential buildings in the City are constructed from wood; nearly all one and two unit residences are wood frame. This study estimates that 85 percent of dwelling units in buildings with three or more dwelling units are also wood frame. The remaining 15 percent of multifamily units are spread among many structural types, old and new.

Many dwelling units are located in structure types that are known to be vulnerable to earthquakes. This study estimates that about 55 percent of single family homes have a garage or other opening at the ground level, giving them a potential soft-story weakness. Nearly 60 percent of units in buildings with three or more units are estimated to be in wood frame buildings with an open ground floor and potential soft-story condition. An additional 8 percent of units are estimated to be in other structure types with known vulnerabilities, including concrete buildings built before the mid-1970's, retrofitted unreinforced masonry bearing wall buildings, and older steel frame buildings with masonry infill walls.

Damage to Housing

Residential buildings are expected to suffer significant damage in the four scenario earthquakes studied in this report. Focusing only on one of these scenarios, the Magnitude 7.2 event on the San Andreas, illustrates the scope of damage that could occur to the City's housing. Table ZZ presents estimates of the amount of damage estimated to residential buildings for the Magnitude 7.2 scenario on the San Andreas. Key things to note are:

- About 23,000 residential buildings and 80,000 residential units will not be usable after the scenario earthquake.
- Most of the residential buildings that cannot be occupied will be single-family homes, but most of the dwelling units that cannot be used will be in multifamily buildings.
- More than 3,000 residential buildings with 11,000 dwelling units will need to be demolished. Some of these will be rent-controlled apartments that will no longer be under rent control when rebuilt.

Table ZZ. Estimated damage to City's housing after M7.2 San Andreas scenario.

Type of Housing	Repairable, cannot be occupied[1]		Not Repairable[1]		Cost to repair/ replace damaged buildings (billions $)[2]
	Number of buildings	Number of dwelling units	Number of buildings	Number of dwelling units	
Single Family	9,500	9,500	1,700	1,700	8.8
Two unit residences	3,200	6,400	290	580	3.6
Three or more unit residences	7,100	55,000	1,200	9,100	7.8
Total[3]	**20,000**	**71,000**	**3,100**	**11,000**	**$20**

1. Building functionality categorizations are derived from HAZUS damage states, presented in Appendix XX.
2. These estimates include costs to repair damaged buildings that can be occupied, as well as those presented in the other columns of this table that cannot. Costs are in 2009 dollars.
3. Numbers in table have been rounded, which can make totals differ from sum of columns or rows.

Source: This study.

Again, certain structural types are responsible for a disproportionate share of the damage to housing. Wood frame soft-story buildings are responsible for about three-quarters of the cost to repair or replace damaged residences, but they are a larger part of the problem when the post-earthquake functionality of buildings is considered. Wood frame soft-story buildings account for over 95 percent of the single family homes and two unit residences that cannot be occupied, and an even higher percentage of those that are unrepairable. When looking at dwellings with three or more units, the picture is more nuanced because these buildings have a greater variety of structure types. Wood frame soft-story buildings account for nearly three-quarters of the residential units that cannot be occupied in buildings with three or more units. However, they account for only 40 percent of those that cannot be repaired. This is because wood frame buildings that have not collapsed can often be repaired, even when heavily damaged. Other vulnerable structure types that are used for multifamily dwellings, such as concrete buildings built before the mid-1970's, retrofitted unreinforced masonry buildings, and early steel buildings with masonry infill walls, are more likely to be demolished if heavily damaged.

Recovery of Housing

The amount of damage the City's housing stock sustains in future earthquakes will primarily dictate how well and how quickly the City rebounds and recovers. If most residents can be back in their homes quickly after an earthquake, it would greatly speed all aspects of the City's recovery. Residents would be able to contribute to helping their neighbors and neighborhoods recover, and would remain close to the jobs, schools, businesses and services that they rely on. On the other hand, if many residences cannot be occupied for months or years after an earthquake, neighborhoods would have vacant buildings for extended periods, people may permanently relocate to new areas, perhaps outside the City, and the neighborhood businesses and services that depend on local customers would suffer.

Repairing and rebuilding homes damaged by an earthquake usually takes years, not months. The time for housing to get back in service is influenced by many factors and can vary a lot. Table X shows the length of time housing took to recover after two recent California earthquakes, Loma Prieta in 1989 and Northridge in 1994. Housing repair and reconstruction after San Francisco's next major earthquake will happen differently than occurred in either of these two events, but these data provide an interesting snapshot of the range of housing recovery times in small, localized events with moderate damage. When looking at the San Francisco specific data from Loma Prieta, it is important to note that all of the four scenarios studied by the CAPSS project would produce much stronger shaking and much more damage than the 1989 earthquake did. Nearly 100,000 buildings would need repair or replacement following the magnitude 7.2 earthquake.

Table X. Average time required to repair and rebuild housing in 1989 Loma Prieta and 1994 Northridge earthquakes.

Building damage level[1]	Loma Prieta average time to reoccupy[2] (months)	Northridge average time to reoccupy[3] (months)	San Francisco average time to reoccupy after Loma Prieta[4] (months)
Needed repair	11	25	7

Needed rebuilding	34	36	46

1. Only includes analysis of buildings with enough damage to be unsafe to occupy.
2. Analyzed data from San Francisco, Hollister, and Watsonville.
3. Analyzed data from Los Angeles, unincorporated Los Angeles County, and Santa Monica.
4. San Francisco Loma Prieta results are based on a small dataset, and detailed timing information was not available for all damaged buildings.

Source: Comerio, Mary C. and Howard E. Blecher, Estimating Downtime from Data on Residential Buildings After the Northridge and Loma Prieta Earthquakes, prepublication draft, Earthquake Spectra.

Many steps are required before a damaged building can be reoccupied. Building owners need to make decisions, hire design professionals to analyze damage and design repairs, hire construction professionals, get permits, arrange financing, and conduct cleanup and construction activities. The many factors that can influence the pace of repair and rebuilding include the following:

- *Amount of building damage.* The amount of damage influences the length of time required for buildings to recover, both from the perspective of an individual building and citywide. Intuitively, a building with more damage takes longer to repair than a building with less. If there is a lot of damage in the City, all construction work takes longer because many of the steps required reach a sort of saturation point. There may not be enough skilled design and construction professionals to do required work without delay. Construction materials and equipment may be in limited supply. Building owners in other Bay Area communities will also have damaged properties and will be making repairs to their buildings simultaneously. All of the scenarios studied in this report would damage many more residences than were damaged in Loma Prieta; the magnitude 7.2 scenario would damage 25 times as many[16].

- *Economy at time of earthquake.* If the next earthquake occurs when the City's economy is strong, rebuilding would happen more quickly than if it strikes during a weak economy. There are many reasons for this. Landlords would be motivated to repair buildings quickly to get rent paying tenants back in place. Financing for the work would be more readily available. Building owners may also have healthier finances. During economic downturns, owners are less able and motivated to act quickly. Housing was rebuilt more slowly after the Northridge earthquake than Loma Prieta because there were high residential vacancy rates at the time[17].

- *Availability of financing.* Securing construction funds can be difficult as owners need to demonstrate the ability to repay loans and have sufficient equity to serve as collateral. Few would be helped by earthquake insurance, which means that owners will need to rely primarily on loans and savings to finance repairs. After past disasters, lenders have sometimes been reluctant to finance repairs in heavily damaged neighborhoods due to concerns about reduced property values. As discussed below, building ownership can also affect financing. Owners with high debt to equity ratios may not qualify for repair loans. Some owners will be forced to default on loans and the damaged buildings would go into a foreclosure process.

[16] Estimation based on tagging data reported in Comerio [cite her unpublished paper].
[17] Comerio, 1998.

- *Building ownership.* Residential buildings with multiple owners face particular recovery challenges. These include condominiums, co-ops, and the recently popular ownership model, tenancy-in-common (TIC). Unlike co-op ownership, in which members own shares of the corporation that owns the building, TIC residents actually co-own a parcel of real estate. This form of ownership has been popular in San Francisco in recent years because it offers would-be buyers a way to bypass the City's condominium conversion regulations, and typically features a discounted sales price due to the added complication and cost of financing a TIC. Buildings with multiple owners may find it more difficult to arrange financing for repairs and reconstruction than buildings with one owner. Different owners may have varying levels of financial resources. The unconventional financing structure of TICs may present additional complexities in the repair process for those buildings. These buildings, however, are generally occupied by their owners, which leads to a high motivation to repair and reoccupy the property quickly after an earthquake.

- *Building use.* Multifamily housing is repaired and replaced significantly slower than single-family housing, particularly rental housing. A year after Loma Prieta, 90 percent of the multifamily units destroyed or rendered unserviceable in the Bay Area were still out of service. Four years after the earthquake, 50 percent of these units had not been repaired or replaced[18]. For an owner of an apartment building, the incentive to rebuild is connected to his or her ability to enhance cash flow and to service debt. Owners have little incentive to rebuild if construction costs cannot be recovered through rents. For units serving lower-income households, access to construction financing is even more difficult.

- *Insurance.* Payments from insurance companies can help finance repair and rebuilding, but they can also lead to delays. Fewer than 10 percent of San Francisco homeowners carry earthquake insurance[19], but many more carry policies that cover fire damage. After disasters, it is common for insurance payouts to take many months. Often there are disputes about the amount of payment to be made. For example, for properties damaged by post-earthquake fire, insurance companies may want to investigate whether the structure was damaged by earthquake shaking prior to the fire and reduce payments if this is found to be the case. Those homeowners who do carry earthquake insurance may find that not all of their costs to repair or replace their building are covered due to high deductibles and limited coverage of these policies.

- *Availability of manpower.* The Bay Area has a limited number of licensed contractors, skilled construction workers and design professionals who must serve the entire Bay Area. Limited manpower can caused delays and make construction more expensive, which could lead to

[18] Camerio, et al., 1994.
[19] Risk Management Solutions, 2010.

additional delays for some owners. Undoubtedly, construction professionals from outside the region will come to help rebuild.

- *Regulatory uncertainties.* Recovery occurs quickly if regulations guiding repair and rebuilding are clear. Regulations cover repair standards, when owners can demolish their buildings, what they are allowed to rebuild, rules particular to historic buildings and buildings with hazardous materials, and many other considerations. The City uses its building and planning codes to express many of its values—environmental, social, and preservationist, to name a few—that can make the approval and permitting process slower than in other jurisdictions. The sheer quantity of buildings needing repair will pose a challenge to the City in the permitting process.

- *Construction logistics.* San Francisco is a dense City. Most residences have no front yards, small back yards, and little if any access along the sides that could be used to stage construction materials. Streets and sidewalks will probably need to serve this function, but they often are narrow, steep and busy. Construction supplies and equipment may be in short supply, causing delays.

It is inevitable that the repair and reconstruction of housing after a damaging earthquake will take time. However, many of the problems described above can be mitigated by community planning and preparation.

Impacts on Affordable Housing

Affordable housing is particularly slow to recover after natural disasters, as observed after Loma Prieta[20] and, more recently, Hurricane Katrina[21]. San Francisco's affordable housing stock consists primarily of rent-controlled apartments, single room occupancy hotels (SRO's), and publicly assisted housing. While all apartments in buildings constructed prior to June 1979 are covered by rent control, it is important to note that many of these units are currently renting at rates that would not be considered affordable to residents with the median City income, as shown in Table X. Each time a unit is rented to a new tenant, apartment rents can be reset to market rates. This project estimates that 40 to 60 percent of rent-controlled apartments have rents that are at or close to market rates. The City has an estimated 160,000 rental units covered by rent control[22], 19,000 units in SRO's[23], and about 21,000 units of publicly assisted housing[24].

Table X. Average rent and affordability in San Francisco

Median household income, 2009	$70,818
Monthly income available for rent and utilities[1]	$1,770

[20] Comerio et al, 1994
[21] Rose, et al., [date]
[22] [cite and confirm number]
[23] San Francisco Planning Department, 2009. (Put SF Housing Inventory into biblio)
[24] Mayor's Office of Housing, 2010. Assumes 6,500 units of public housing, 6,000 households subsidized through HUD section 8, and 8,900 units assisted with financing or rent through US Department of Housing and Urban Development.

Monthly utility payment[2]	$170
Affordable rent payment	$1,600
Average rent in San Francisco, June 2009	$2,323

1. Assumes 30 percent of gross household income spent on rent and utilities.
2. Based on San Francisco Housing Authority Utility Allowance chart.

Source: San Francisco Housing Authority (2009), RealFacts (2009).

Building demolitions in multifamily apartments could result in permanent loss of rent controlled apartments. When multifamily properties are demolished after an earthquake, the market would likely favor those properties being reconstructed as condominiums, rather than apartments. Under current conditions, buildings owners generally find that condominiums generate greater financial returns than do apartments, even in high-priced rental markets such as San Francisco. When demolished apartments are reconstructed, the new construction is not subject to the City's Condominium Conversion Lottery, and the lost rental units may therefore be replaced as ownership units. Similarly, new apartments replacing demolished units are not subject to the City's Rent Stabilization Ordinance, commonly known as rent control. Newly constructed buildings will have a different look and character than the buildings they replace.

Units renting at below market rate are often occupied by long-term residents, a significant percentage of whom are seniors. As a result, these residents will be seriously affected as they may have no alternative, affordable places to move. Typically these units are older, may have deferred maintenance, and could be more susceptible to damage from an earthquake than typical multifamily residences. For example, more than 90 percent of units in SRO's are located in buildings built before 1920[25], and although the structural characteristics of these buildings are not known, anecdotal evidence suggests that many are highly vulnerable to damage in earthquakes, such as concrete and steel frame buildings with masonry infill walls or soft-stories.

In the scenario earthquakes studies, it is not known what percent of housing units lost will be apartments that are currently rented at below-market rents. What is known is that the heavy damage to the City's housing stock is likely to cause the cost of housing of all types to rise as owners invest capitol to carry out repairs and turnover in units occurs as tenants leave due to loss of jobs and disruption. Owners will seek to pass through some costs of repairs to tenants. Vacant apartments may be in short supply, leading to price increases. Low and middle income residents displaced from their homes may no longer be able to afford to live in San Francisco.

After a large earthquake, the City's housing will be hard hit. Housing is a key part of having a functional City, but it is not the only part. People also need the City to have a functioning economy. The next chapter looks at the impact of future earthquakes on the City's businesses.

[25] Analysis of date of construction of SRO's conducted by this study based on data from the San Francisco Department of Building Inspection.

Chapter Seven: Impacts of Earthquake Damage to Businesses, Jobs and the Economy

San Francisco's economy depends on a complex and interdependent mix of many elements. Business places need to be open. Housing needs to be available to the City's workers and customers. Utility systems and transportation networks need to function. These issues are affected by building damage and the time needed to conduct repairs, as well as how prepared businesses are to cope following earthquakes. This chapter describes how the buildings that house businesses could be affected by future earthquakes, and the impacts that could flow from this damage. One business' loss could be another's gain, and losses experienced in San Francisco may be gains in other jurisdictions as customers or businesses relocate and the mix of residents and workers change.

Direct Economic Losses in Addition to Building Damage

The direct physical damage to buildings, presented in previous chapters, is only one component of the economic losses due to earthquakes. Many different types of economic losses flow from the building damage and loss of functionality described in previous chapters. The additional types of direct losses estimated by this project include[26]:

- *Contents damage.* This includes furniture, equipment that is not integral with the structure, computers and other supplies. It does not include inventory (counted separately, below) or integral components such as lighting, ceilings, mechanical and electrical equipment, and other fixtures, which are included in building damage.

- *Inventory loss*. The value of inventory varies considerably by type of business. Typically, inventory damage occurs when items fall off shelves or are damaged by water from broken pipes.

- *Relocation loss*. This includes the costs of relocating and the rental of temporary space. Relocation costs are estimated only for some uses; others, such as theatres and parking facilities, are assumed to close until repaired.

- *Output loss*. This includes income associated with business profits, gross receipts or revenues.

- *Rental income loss*. This includes rents for residential, commercial and industrial properties.

- *Income and wage loss*. This includes losses to wages and salaries. In some cases, wage losses can be mitigated by overtime work once a business resumes.

Table X presents estimates of the total economic loss resulting from the four scenarios studied. Note that these losses do not include indirect losses in sectors not sustaining direct damage, which are

[26] Adapted from FEMA/NIBS [date].

discussed later. Further, these losses are only those attributable to damage to privately-owned buildings, and this project did not put resources into modeling the vulnerability and economic losses associated with the City's infrastructure (roads, bridges, transit systems, water system, sewer system, electrical system, telephone system, gas system, etc.). In the four scenarios studied, the additional direct economic losses estimated equal about 30 to 40 percent of the costs to repair and replace damaged buildings.

Table X. Total direct economic losses estimated for four scenario earthquakes

Scenario	Direct losses in four scenario earthquakes[1] (billions)		
	Damage to buildings	Other capital stock and income losses	Total losses
Hayward Magnitude 6.9	$14	$6	$20
San Andreas Magnitude 6.5	$20	$6	$26
San Andreas Magnitude 7.2	$30	$10	$40
San Andreas Magnitude 7.9	$48	$15	$63

1. Estimates are in 2009 dollars.

Source: This study.

Ripple Effects of Business Losses

When businesses shut down, even temporarily, the loss of revenue ripples through the local economy, creating a negative multiplier effect. These closed or suspended businesses do not support other businesses; workers do not spend their incomes on consumer goods. This analysis uses estimates of lost revenues from business interruption, in conjunction with the IMPLAN[27] input-output model, to estimate the economic impacts of business interruption following an M7.2 earthquake along the San Andreas fault in San Francisco. For the magnitude 7.2 scenario earthquake, the direct output loss, or loss to business revenues, is estimated to be $2.9 billion. Two additional types of economic losses are estimated, described below:

- *Indirect Impacts.* This refers to the impacts of business closure or slowdown on other businesses. For example, a legal office that needs to close due to earthquake damage no longer purchases office supplies. Thus, the firm that sells those office supplies suffers economic losses due to damage to its customer, even if the office supply company suffered no damage itself. This category includes non-labor inter-industry payments.

- *Induced Impacts.* This refers to the impacts of household expenditures. When households earn income, they spend part of that income on goods and services. In the example described above, the induced impacts include the reduced expenditures of employees at the legal firm, as well as the reduced expenditures of people who work in the office supply company that depends on

[27] The economic model used in this analysis, IMPLAN ("IMpact analysis for PLANning"), is a PC-based computer software package that automates the process of developing input-output models for regions within the United States. The IMPLAN model is well respected as the industry standard for projecting economic impacts resulting from future "events." Details of this analysis are presented in [Title of Technical Volume],

business from the legal firm. Only the disposable incomes from San Francisco workers are analyzed.

According to the IMPLAN analysis, the business interruption losses due to a magnitude 7.2 San Andreas earthquake would generate a loss of approximately $650 million in indirect activity, or business to business lost expenditures within the City of San Francisco. The greatest decreases in output would occur in the real estate, banking, and insurance sectors, as these sectors provide services to the broadest array and largest number of businesses.

In addition to the indirect impacts, the business interruption losses would also generate induced citywide losses of approximately $840 million, or lost household expenditures. Induced impacts represent the impacts of household expenditures of workers in the directly affected and indirectly affected firms. The greatest induced output losses would occur in the payments to housing, wholesale trade, and eating and drinking establishment sectors.

Dividing the City's total lost output by its direct output yields an economic multiplier that measures the economic activity of every dollar lost. Thus, every dollar of economic loss that would occur from business interruptions following an M7.2 San Andreas fault earthquake would generate a loss of approximately $1.52 in total citywide economic impacts.

According to IMPLAN, the output of the entire San Francisco economy in 2009 was $150 billion. Thus, the total losses from business interruptions following an M7.2 San Andreas fault earthquake would represent approximately 2.8 percent of total citywide economic activity. As a measure of comparison, since 1960, recessions in the United States have averaged a 1.7 percent decline in economic output from peak to trough. This suggests that the economic effects of the earthquake would be on par or greater than a recession. It is also important to note that these impacts would be over and above the damage to buildings and other losses described previously.

This analysis does not account for business interruption losses associated with fire or damage to utilities and transportation systems. These impacts can be significant. Additionally, behavioral responses to the earthquake could also affect the local economy, but that is not factored into this analysis. For example, people's fear about earthquakes could compel them to leave the region or forestall investments in the area.

Notwithstanding these conclusions, certain industries would conceivably recover more rapidly following the earthquake than others. The construction industry and its suppliers, for example, would likely see a boost in activity, particularly as federal assistance, state aid, and insurance payments are injected into the economy. This kind of response could mitigate some of the negative economic impacts of the earthquake. The economic benefits that come from reconstruction have not been quantified or considered in this analysis.

Damage to Commercial and Industrial Buildings

San Francisco's commercial and industrial buildings take many different forms. Some are modern high-rises. Others are early high-rises that went through the 1906 earthquake. Many are smaller buildings used for a variety of industrial, retail and office functions. They have considerably more variety in their structural make-up than the City's residential buildings. Many buildings incorporate both residential and commercial functions. A common example of this is the wood frame apartment building with ground floor retail space, often with a soft-story condition, that is highlighted in a previous CAPSS report, *Here Today - Here Tomorrow: Earthquake Safety for Soft-Story Buildings*.

As presented previously in this report, commercial buildings are likely to suffer significant damage in the four scenarios studied. The estimates of direct damage to commercial and industrial buildings are:

- $4 to $11 billion to repair or replace damaged commercial buildings, depending on the earthquake scenario. Two-thirds of these losses occur to buildings downtown.

- $1 to $2 billion to repair or replace damaged industrial buildings, depending on the earthquake scenario. These losses are concentrated in the Bayview, Downtown, Mission Bay and Mission neighborhoods.

- More than 900 commercial buildings and 500 industrial buildings will not be occupiable after a magnitude 7.2 San Andreas scenario.

- More than 200 commercial buildings and 150 industrial buildings will be damaged beyond repair after a magnitude 7.2 San Andreas scenario. These buildings will be rebuilt differently, and could contribute to changing development patterns in some of San Francisco's neighborhoods.

Commercial buildings may get repaired more quickly than residential buildings if owners have an income source to finance repairs and are motivated to get rent paying tenants back in place. However, the pace of rebuilding is highly dependent on market conditions at the time of the earthquake. In a time of high commercial vacancy rates, it could take years before all buildings are fully functional because owners are loathe to reinvest in repairs for buildings that may be unrented or would rent at low rates. When commercial vacancy rates are low, building owners will be motivated to conduct repairs as quickly as possible, but, in the short-term, businesses will find it challenging to locate temporary space while they await repairs to their damaged buildings.

Some retail and office establishments can reopen in a new location before their original building is repaired, which means that many businesses may begin the recovery process long before their pre-earthquake location is fully functional. This might leave some buildings owners without tenants once repairs are complete. However, even businesses in buildings that remain functional and are easily repaired can be affected if their customers and employees relocate, or if the damage to nearby buildings makes the neighborhood commercially undesirable.

The City's Economy and Jobs

Businesses in San Francisco employ approximately 570,000 people, with employment well-distributed among a range of sectors. This diversity contributes to the City's economic resiliency as the employment base is not dependent on one or two sectors that might be disproportionately affected by an earthquake. Diversity allows the economy to improvise, innovate, and perform resource substitution following a disaster. As shown in Table X, the City's top five industries, which account for approximately three quarters of the City's jobs, are:

- Professional and technical services (22 percent of total);
- Government (17 percent);
- Leisure and hospitality (14 percent);
- Financial activities (10 percent), and
- Education and health services (10 percent)[28].

Table X. San Francisco and Bay Area employment by sector[1].

Industry sector	San Francisco		Bay Area		San Francisco as share of Bay Area (%)
	Jobs	% Total	Jobs	% Total	
Professional and technical services	130,000	22	590,000	18	21
Government[2]	97,000	17	450,000	13	22
Leisure and hospitality	79,000	14	340,000	10	24
Financial activities	58,000	10	190,000	6	30
Education and health services	56,000	10	380,000	11	15
Retail trade	44,000	8	330,000	10	13
Other services, except public admin.	38,000	7	160,000	5	24
Information	19,000	3	110,000	3	17
Construction	19,000	3	180,000	5	11
Wholesale trade	12,000	2	120,000	4	11
Manufacturing	11,000	2	340,000	10	3
Unclassified	2,000	0.4	12,000	0.4	18
Natural resources and mining	290	0.1	22,000	0.7	1
Utilities	([3])	([3])	5,500	0.2	([3])
Transportation and warehousing	([3])	([3])	54,000	2	([3])
Total[4]	**570,000**	**98**	**3,300,000**	**97**	**17**

1. Includes all wage and salary employment covered by unemployment insurance.
2. Government employment includes workers in all sectors, not just public administration.
3. Indicates that data have been suppressed for confidentiality reasons. The data are suppressed when there are fewer than three establishments in the industry, or if a single employer makes up more than 80 percent of that industry's employment.
4. Numbers in table have been rounded, which can make totals differ from sum of columns or rows.Totals do not sum to 100% due to suppressed data and rounding.

Source: This study, California Employment Development Department (2009).

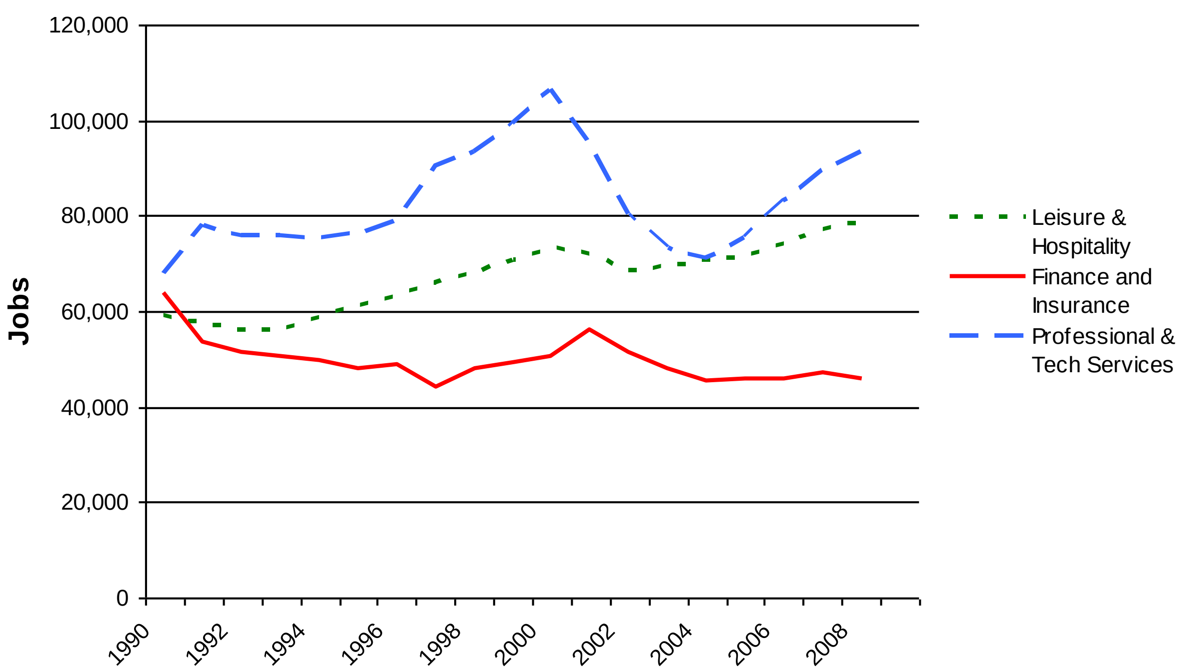
In terms of the city's economic role in the Bay Area, San Francisco serves as the regional center for the finance and professional and technical services industries. While San Francisco only has 17 percent of total Bay Area employment, it contains 30 percent of the region's financial activities jobs and 21 percent of the region's professional and technical services jobs. San Francisco has evolved into a regional finance and business hub because it offers companies an internationally recognized address and lifestyle

[28] Government includes all public sector employment, including public schools.

amenities, which appeal to workers in these sectors. In addition, its density benefits these firms, which place a high value on inter-personal interaction. San Francisco is also the regional center of the leisure and hospitality industry, containing 24 percent of Bay Area jobs in this sector. This role has evolved thanks to San Francisco's distinct urban amenities, art, culture, entertainment, retail, and dining options, which make it an international tourist destination.

Figure X illustrates the long-term historic trends associated with these three industries in San Francisco. The number of San Francisco jobs in the finance sector has generally declined since the early 1990's, with a spike in 2001 at the height of the "dot-com" boom. Meanwhile, the professional and technical services industry has been highly volatile, growing and shrinking in tandem with the economic cycle. The dot-com boom and bust led to a peak, followed by a sharp contraction in the early part of this decade. The industry subsequently recovered between 2004 and 2008. In comparison, the leisure and hospitality industry has shown more stability, growing gradually since 1990.

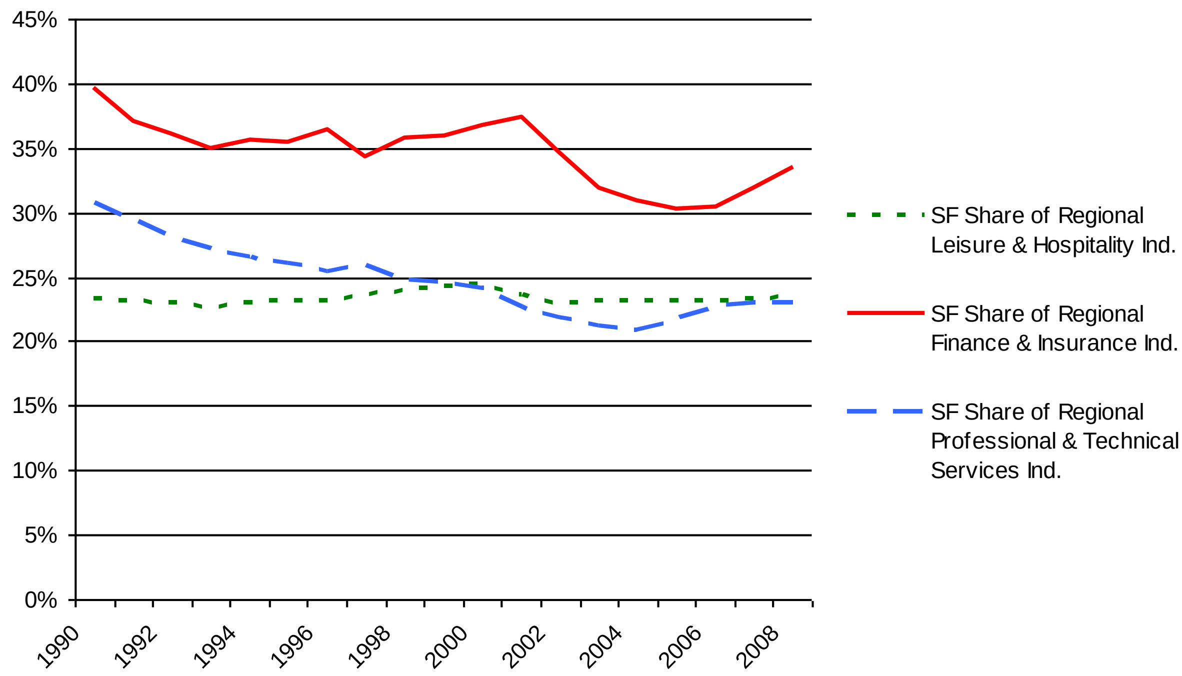
Figure X. San Francisco Jobs in Key Sectors, 1990-2008.



Source: This study, California Employment Development Department (2009).

Figure Y presents San Francisco's regional share of these three key industries over the last two decades. Since 1990, the City's share of the regional jobs in the finance and professional and technical services sectors has generally declined. This trend is a result of the maturation of Silicon Valley and other parts of the Bay Area as viable locations for these industries. As information and technology firms have emerged in San Mateo, Santa Clara, and Alameda Counties, finance and professional services firms that interface with these industries have followed their geographic lead.

Figure Y. San Francisco jobs as share of Bay Area jobs in key sectors, 1990-2008.



Source: This study, California Employment Development Department (2009).

As discussed previously, commercial space in San Francisco's Downtown—the primary location of the City's finance and professional services sectors—would experience significant damage in the scenario earthquakes studied. In a magnitude 7.2 San Andreas earthquake, 21 million square feet of commercial space in the City would suffer structural damage that makes it unsafe to occupy. These damage estimates, coupled with the long-term employment trends discussed above, suggest that while the City will generally retain its status as a regional finance and professional services center over time, a major earthquake does have the potential to accelerate the ongoing dispersal of these industries throughout the Bay Area following earthquakes. This dispersal may be more pronounced if San Francisco municipal services do not respond effectively and quickly, or if commercial buildings are rendered unsafe for an extended period of time. Under these conditions, companies may opt to maintain a San Francisco presence, but shift the bulk of workers to other parts of the Bay Area.

In contrast with the finance and professional service sectors, San Francisco's share of the regional leisure and hospitality industry has remained steady at 23 to 24 percent of total Bay Area jobs in this sector since 1990. This stability is a positive sign of the industry's economic resilience. Certainly, post-disaster studies indicate that the City should expect a decline in visitors and contraction of the tourism industry immediately following an earthquake. A study of the 2008 earthquake in Sichuan, China found significant declines in tourism following the main shock[29]. Analysis of the September 1997 earthquake in Umbria, Italy showed arrival declines up to 50 percent in city of Assisi, a major tourist destination, in the month after the earthquake, though arrivals did begin to rebound over the following year[30]. In addition, a 2007 analysis of the New Orleans economy following Hurricane Katrina showed a loss of 22,900 tourism jobs in the 10 months following the event[31]. Impacts along these lines would hurt businesses that rely heavily on tourist spending, and financially tenuous businesses may be forced to close, unable to weather the drop in revenues. Despite these impacts, however, in the long run, San Francisco would retain the unique characteristics and attractions that make it an international destination.

San Francisco benefits from being part of an economically vibrant region. Jobs are spread throughout the region, with concentrations in Alameda, San Francisco, and Santa Clara counties. This geographic distribution improves the Bay Area's economic resilience by essentially disseminating the risk of an earthquake across multiple nodes. In contrast, if a vast majority of jobs occurred in a single area, a severe disaster at that site would have a much more significant impact on the regional economy.

Small and Neighborhood Serving Businesses

One of San Francisco's unique features is the many local shopping streets with small, independent businesses that serve their neighborhood. These establishments help give each neighborhood an individual character, and contribute numerous jobs to the City's economy. Neighborhood businesses provide services, supplies and conveniences that allow for efficient living and also serve those with language or ethnic preferences. These businesses play an important role in the City's recovery by providing local services to residents and contributing to the charm and community character that makes people want to stay in San Francisco. The City has emphasized the importance of these local establishments through recent laws restricting chain stores, and programs such as small loans to establish local businesses.

Small businesses comprise the vast majority of local firms. Almost 89 percent of San Francisco's businesses have 10 or fewer employees, and another six percent have 11 to 25 employees. Altogether, firms with 25 or fewer workers contain 38 percent of the city's total jobs, as shown in Table X.

Table X. San Francisco firms and jobs by number of employees in firm

[29] Yang, Weiqiong, Guojie Chen andDaojie Wang. et al., 2008.
[30] Mazzocchi, Mario andAnna Montini. 2001.
[31] Dolfman, Michael L., Solidelle Fortier Wasser and Bruce Bergman. 2007.

Number of employees	Firms		Jobs	
	Number	% of total	Number	% of total
0 – 4	56,000	76	100,000	16
5 – 10	9,300	13	64,000	10
11 – 25	4,700	6	79,000	12
26 – 50	2,000	3	73,000	11
51 – 75	510	1	32,000	5
76 – 125	500	1	48,000	7
126 +	500	1	250,000	39
Total[1]	**73,000**	**100%**	**660,000**	**100%**

1. Numbers in table have been rounded, which can make totals differ from sum of columns or rows.Total may be inconsistent with other tables due to varying data sources and enumeration methodologies.

Source: This study, Dun and Bradstreet (2008).

Small businesses are more vulnerable than large firms to distruption following a natural disaster, as they are less likely to carry insurance and are rarely diversified in terms of products and services. They also often lack the resources to address equipment and inventory damage and interruptions in utility service and transportation networks. Damage to other nearby businesses and residences may also reduce customer traffic, further compounding the economic hardship. In addition, locally-owned businesses face greater difficulty in recovering from disasters compared to their chain competitors, whose profits are not dependent on a single store.

Small retailers appear to be the most vulnerable to major earthquakes. Following the southern California Northridge earthquake, businesses reported that for some time after the earthquake, residents changed their spending patterns, disrupting operations. The highest job loss resulting from the Northridge earthquake was in the retail industry (24 percent of total losses). Some small businesses failed as a result of the Northridge earthquake two years after the event[32].

A study of the 2001 Nisqually Earthquake in Washington state also highlighted the vulnerability of small retailers[33]. Of the 13 industries surveyed, retail businesses reported higher rates of both direct physical losses (buildings and equipment) and reduced revenue as a result of lost inventory. This was attributed to the fact that retailers have a higher portion of their assets invested in inventory than most businesses.

Worker Access to Jobs

Following an earthquake, workers' ability to get to their jobs is a key component of a community's recovery. Returning to work allows workers to receive a paycheck, provides residents and firms access to necessary goods and services, and generally restarts the local economic engine.

32 Petak , William J,. and Shirin Elahi. 2000.

33 Meszaros, Jacqueline and Mark Fiegener. 2002.

Table X shows commute patterns in San Francisco, as reported by the 2000 Census[34]. Approximately 77 percent of San Francisco's employed residents work in the City, suggesting that the majority of San Francisco residents will be able to reach their jobs following an earthquake. However, 45 percent of San Francisco jobs are held by someone who lives outside the City. To the extent transportation systems are damaged and inoperable after an earthquake, this could have a significant short-term impact on the local economy, and could slow recovery. Job access also depends on workers having access to support systems, such as day care and elder care.

Table X. San Francisco commute patterns

Where San Francisco residents work	Number	%	Where San Francisco workers live	Number	%
San Francisco	320,000	77	San Francisco	320,000	55
Oakland	8,900	2	Oakland	30,000	5
South San Francisco	8,800	2	Daly City	25,000	4
Redwood City	5,200	1	Berkeley	9,800	2
San Mateo	4,600	1	South San Francisco	8,500	1
Palo Alto	3,700	0.9	Pacifica	7,125	1
Burlingame	3,600	0.9	Richmond	6,900	1
San Jose	3,400	0.8	Alameda	6,900	1
Berkeley	3,200	0.8	San Mateo	5,800	1
Other Bay Area[1]	43,000	10	Other Bay Area[1]	130,000	23
Other places in CA	11,000	3	Other places in CA	28,000	5
Out of state	1,600	0.4	Out of state	4,000	0.7
Total[3]	**420,000**	**87**	**Total[3]**	**590,000**	**100**
San Francisco residents out-commuting	**95,000**	**23**	**San Francisco workers In-commuting**	**270,000**	**45**

1. Other Bay Area includes other areas in Alameda, Contra Costa, Marin, Napa, San Mateo, Santa Clara, Solano and Sonoma counties that are not specifically listed.
2. Out of State includes Census Designated Places (CDP's) that cannot be broken down into localities.
3. Figures may not match other tables due to different source materials.

Source: This study, U.S. Census (2000), Census Transportation Planning Package (CTPP).

Communications technology does offer some workers the ability to telecommute, assuming utilities remain operational. Looking at San Francisco's major industries, the financial activities and professional services sectors could operate more effectively though telecommuting than sectors that require employees to be present for direct contact with customers or physical activities. Workers in the government, leisure and hospitality, education and health services industries would be less able to function remotely.

Damaged areas benefit economically from increased employment in the construction trades and an influx of workers and government and private recovery funds from outside the area. Recovery will require trained workers and contractors from outside the region. Temporary workers, insurance adjustors, and state and federal recovery workers will need nearby housing and transportation. Some of

[34] Latest available data.

these people may relocate permanently, but most will send much of the money they earn home and will purchase and transport some construction supplies, furnishings and other materials from outside the region.

City government plays a big role in getting damaged privately-owned buildings repaired or replaced quickly, making the community function again. However, damage to privately-owned buildings also affects how well the City government functions. The next chapter looks at how the damage estimated in this report might affect the City government's ability to do its job.

Chapter Eight: Impacts on City Government

San Francisco will need strong leaders and capable City institutions to help the City respond to, rebuild after and recover from future earthquakes. However, it is important to recognize that a large earthquake will affect the ability of the City government to function effectively, much as it affects housing, businesses and other elements of the City. This report focuses only on damage to privately owned buildings, which means that facilities owned and used by the City have not been evaluated[35]. Damage to private buildings, however, will significantly impact City government.

After an earthquake, the City will see a decline in key revenue sources. This decline will occur at a time when many residents are most in need of assistance from the City. San Francisco City government receives revenues from a variety of sources, including taxes on property, sales, payroll, hotels and parking. Table X shows the major sources of City revenue for the fiscal year ending in June 2009. The income from a number of these sources could go down after a damaging earthquake.

Table X. Sources of revenue for San Francisco General Fund in 2008/2009.

Revenue source	**Amount (millions $)**	**Percent**
Property taxes	1,000	37
Business taxes	390	14
Sales and use tax	100	4
Hotel room tax	160	6
Utility users tax	90	3
Other local taxes	130	5
Licenses, permits and franchises	25	0.9
Fines, forfeitures and penalties	5.6	0.2
Interest and investment income	9.2	0.3
Rents and concessions	19	0.7
Intergovernmental	650	24
Charges for services	140	5
Other	11	0.4
TOTAL	**$2,700**	**100**

Source: San Francisco Controller's Office (2009).

Property tax revenues are generated from taxes levied on the assessed value of buildings and land. In fiscal year 2007/08 [what year?], properties in San Francisco had a net taxable value of $XX billion, roughly $YY billion or ZZ percent of which is attributable to building or improvement value. After an earthquake, the assessed value for land would likely remain the same for most properties. However, if a building was significantly damaged, the property owner could file an appeal for a reduction in property taxes due to the decline in the value of the building from this damage. Once reconstruction occurs, the property would be reassessed, but there would be a short-term loss in property taxes. Some people may

[35] In recent years, San Francisco has invested significant resources into improving the seismic safety of key City buildings and infrastructure, particularly facilities needed for emergency response, but known vulnerabilities remain.

default on tax payments. This study does not estimate how quickly property tax revenues might recover in the City, and property tax revenue restoration will depend on factors such as the number and type of buildings that are repaired and reconstructed, the speed of the City's reconstruction effort, and how quickly and on what basis properties will be re-assessed once they are rebuilt.

Similarly, other sources of City revenue can be expected to decline in the short and medium term after an earthquake. Many retail establishments would be forced to close due to building and fire damage. While some of these establishments could be relocated or could re-open once their buildings are repaired, there will likely be both short- and long-term losses in retail sales tax. Impacts on businesses could result in reductions in payroll taxes. It is likely that the City will see fewer visitors for some period of time after a large earthquake, resulting in lower revenues from hotel taxes. Parking revenues would decrease. Other revenue sources could be affected, as well.

The City will receive some funds from the federal government. The Stafford Act provides funds for the repair of state and local government and certain non-profit facilities on a matching basis, and for other emergency response expenses. However, these funds are likely to cover only a fraction of the City's increased expenses due to an earthquake, and very little federal funding supports owners suffering losses to the privately-owned buildings studied in this report.

It is important to note that during the current economic downturn, both the state and the City had to lay off and/or furlough workers to reduce their budgets. Reduced staffing or financial capacity may affect their ability to respond to an emergency like a significant earthquake. While municipal and State finances will eventually recover in tandem with the economic cycle, the current fiscal concerns represent a weakness.

The City's pace of recovery depends on how quickly buildings—homes, offices, stores, etc.—get repaired or rebuilt and back in service. The speed with which this happens is directly linked to the ability of City departments—Building Inspection, Planning, and others—to review plans and issue permits for the many thousands of buildings that will need work. After a magnitude 7.2 earthquake on the San Andreas, it is reasonable to assume that up to two-thirds of all buildlings in the City will require permits for repair or demolition and reconstruction work, although some building owners with moderately damaged buildings will choose to do the work without permits or cover up damage rather than repair it. These permits will come with increased revenue in permit fees; however, it will take the City time to engage and train additional staff to cover this increased workload.

In addition to financial impacts, a large earthquake will set the City government back in meeting important policy goals. Programs on homeless, health, environment, and other issues important to San Francisco's people will likely suffer consequences. Possible environmental impacts of an earthquake can be used to illustrate this. Currently, the City has nearly met its goal of diverting 75 percent of its waste stream from landfills by 2010. A magnitude 7.2 San Andreas scenario is estimated to result in 6.8 million tons of debris from damaged buildings. Although some of this debris may be recyclable, it is probable that the need to clear debris quickly so rebuilding can start will mean that most of it is sent to landfills. A magnitude 7.2 earthquake would equate to nearly 13 years of trash generation[36]. Rebuilding damaged buildings will require resources, as well, in the form of newly harvested lumber and other construction materials. Newly constructed buildings will probably be very energy efficient, complying with San Francisco's stringent green building requirements. However, specialists estimate that XX percent of a building's energy consumption during its lifespan occurs during the production of raw materials for the building and the building's construction. This means that, typically, saving an existing building is much more energy efficient than constructing the most energy efficient new building. A final example environmental impact from an earthquake could be the release of hazardous materials. There were numerous hazardous materials releases in San Francisco due to the moderate shaking in Loma Prieta, including spills of chemicals, paints, pesticides, and mercury[37]. A larger earthquake could cause much more significant releases that harm the people, land, water, flora and fauna of the City and region.

Future earthquakes will damage the City's buildings and affect its housing supply, businesses and government functions. Can San Francisco rebound from this damage? The next chapter puts all of the pieces together to examine how resilient San Francisco's people are to recover after the scenario earthquakes studied.

[36] Calculation based on figures from SF Environment website (sfenvironment.org)
[37] Perkins and Wyatt, DATE

Chapter Nine: The Resilience of San Francisco and its People

The analysis presented in this report makes it clear that future large earthquakes wouldill damage thousands of San Francisco's buildings and have significant repercussions on the activities that occur inside them. This chapter looks at what this damage means for San Francisco. How will the people of San Francisco cope? Will the City be able to rebound and thrive after such an event? This analysis suggests that, yes, in the long-term the City will continue to thrive after a large earthquake. San Francisco is a strong and robust City situated in a strong and robust region. It will, however, take time for the City to recover, and not all of the City's residents will recover to the same degree. After a large earthquake, the City will change. Some people will lose their assets, with ramifications on their lifestyle, such as the inability to afford college or loss of homeownership. Others will thrive and help shape the new City.

Factors that Affect San Francisco's Recovery

Many issues contribute to how quickly and how well San Franciscans will recover from the next earthquake. Some key components of this—housing and business activity—were explored in previous chapters. Another important factor is the ability of San Francisco's people and organizations, governmental and non-governmental, to adapt to changing conditions after a disaster and mobilize resources to address problems. Whether San Francisco's residents choose and are able to remain in the City after a disaster makes a big difference in what the City's recovery looks like. San Francisco has a large number of highly-educated, wealthy and innovative residents, but it also has a large number of residents with modest and fixed incomes, first generation immigrants and people with disabilities. People desire to live in the City. The factors that make the City economically successful and socially desirable are likely to be maintained in the long-term. This section of the report discusses a few factors that influence whether businesses and people want to and can remain in San Francisco, and how they relate to post-earthquake recovery.

Educational Institutions

The San Francisco Bay Area is home to a strong network of public and private educational institutions. The region's world-class research universities include the University of California campuses in San Francisco and Berkeley, and Stanford University. In addition, the California State University system has campuses in San José, the East Bay, and San Francisco. There are dozens of smaller private institutions such as the Academy of Art, the University of San Francisco and the San Francisco Art Institute in San Francisco, and others located throughout the region.

Historically, these institutions have played a vital role in establishing the region as a global hub of economic activity and technological development. They act as economic engines and draw employers by creating a highly-educated populace, spawning businesses, and conducting groundbreaking research. Even after a major earthquake, they will continue to attract and produce intellectual and monetary capital, contributing to San Francisco's economy and community.

Universities will suffer damage in a large Bay Area earthquake that could affect their ability to educate students and conduct research. This study has not evaluated the vulnerability of these critical institutions. The University of California and Stanford University have invested heavily in upgrading their buildings and developing plans in preparation for future earthquakes. However, these institutions rely on the private sector for housing and neighborhood support, on local businesses and suppliers. After a large earthquake, it may take time before universities in the region resume their function of drawing economic activity to San Francisco.

Quality of Life

Urban theorists have postulated that economic development in a post-industrial economy requires a strong "Creative Class" of workers[38]. The Creative Class includes scientists, academics, designers, artists and others whose economic function is to create new ideas, technology and creative content, the drivers of today's information economy. Analysts emphasize that quality of life factors such as the arts, recreational opportunities, educational institutions, cultural diversity, and attractive urban environments play a crucial role in attracting, cultivating, and maintaining a Creative Class.

The Bay Area benefits from a rich array of quality of life features that have helped it become an international center for the Creative Class. These include outdoor amenities (e.g., The Golden Gate National Recreation Area; local, regional and state parks; the Lake Tahoe Basin), a world-class food and wine culture, a strong network of cultural and arts organizations, a wide range of housing types, and cultural diversity. The Bay Area would largely retain these amenities in the event of an earthquake, keeping it a location of choice for the Creative Class.

Household Incomes

San Francisco's resilience is affected by the resilience of the region. The Bay Area's strong economy has supported a relatively affluent region. In 2009, the regional median household income was $76,900 [define region, cite], 28 percent higher than the statewide figure, and 50 percent higher than the national figure. With these higher incomes comes greater social resilience, as households are able to withstand temporary downturns in the economy following an earthquake, and repair physical damage to their homes. Many San Francisco residents would be able to afford to repair or rebuild their homes, replace their possessions, and rent temporary space while construction is underway.

However, it is important to recognize that many San Francisco residents have limited or fixed incomes that would not easily accommodate the expenses associated with disruption after an earthquake. Lower-income households will have more difficulty weathering a loss in employment following a disaster, and are less able to rebuild damaged property, particularly with high construction costs in the Bay Area. Moreover, lower-income households are more likely to rent their homes. As discussed previously, rental properties are rebuilt at a slower rate than owner-occupied properties. Demolished rental units may be replaced by condominiums that are unlikely to be affordable to the previous occupants. An earthquake could lead to increased gentrification in San Francisco: households with

[38] Florida, R. 2002.

ample resources could afford to pick up the pieces and stay, and households with fewer resources may need to move somewhere less expensive, perhaps permanently.

Cost-of-Living

The region's affluence has led to a relatively high cost-of-living in the Bay Area. As of September 2009 San Francisco's median home price was $675,000, compared to the statewide median home price of $251,000. Looking at the Consumer Price Index (CPI) shows that on average, between 1975 and 2008, inflation rose faster in the Bay Area than the nation 57 percent of the time, or 20 out of 35 years. The CPI measures the change in prices on a general basket of consumer goods over time, and serves as an indicator of the cost-of-living. Higher rates of inflation suggest that the cost-of-living in the Bay Area increases faster than the nation as a whole, depending on the rate of annual wage increases relative to prices.

As another measure of the cost-of-living, Sperling's BestPlaces.net uses data from the Council for Community and Economic Research to compare the cost of living between US cities. According to Sperling, the cost of living in San Francisco is 87 percent higher than the national average – mostly because of housing costs.

This high cost-of-living may prove a negative factor for San Francisco's recovery following an earthquake. For example, higher construction costs may slow the rebuilding process. Again, the region's high housing costs may also compel households to leave the Bay Area altogether, if their residences are severely damaged.

Resilience of San Francisco's Neighborhoods

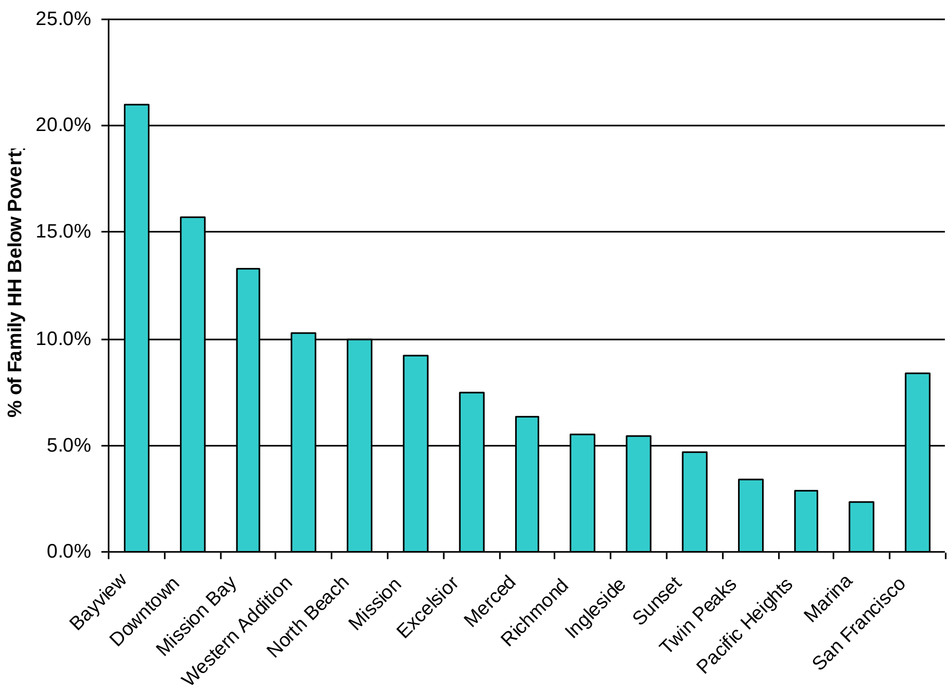
Although San Francisco is a generally affluent city, not all residents are affluent and some neighborhoods are less disaster resilient than others due to their socioeconomic characteristics. Displacement after an earthquake is most difficult for those City residents who are elderly, disabled, or poor. These residents often have limited resources to rebound when they lose their home and possessions, even temporarily. It can be a hardship for them to be separated from services and community members they rely on. Nearly eight percent of residents (over 60,000 people) are physically disabled[39]. These people could be significantly impacted if they need to vacate their homes. Even elderly and disabled residents who can remain in their homes could suffer severe consequences after an earthquake if utilities, such as electricity, gas, water and sewer, do not function, or if neighborhood services, such as pharmacies and grocery stores, are not open.

The percent of households living below the federal poverty threshold serves as one indicator of a neighborhood's socioeconomic resiliency[40]. Again, lower-income households have fewer resources to allow them to recover from injuries, damage to their homes and possessions, and any downturn in the economy following a major earthquake. As shown in Figure X, approximately eight percent of San

[39] Claritas, 2009.
[40] The federal poverty threshold was originally developed in 1963-1964 by the Social Security Administration based on U.S. Department of Agriculture's economy food plan, and is updated each year by the Census Bureau. Although it presents methodological problems, particularly in a high cost region such as the Bay Area, it remains the official federal definition of "poverty" and serves as a useful benchmark for comparing neighborhood profiles for this study.

Francisco households live below the poverty threshold[41]. In comparison, Bayview, Downtown, Mission Bay, Western Addition, and North Beach, all have at least 10 percent of households below the federal poverty threshold.

Figure X. Percent of households living below federal poverty threshold in 2009 by neighborhood[1] [why left side of title cut off?]



1. Only includes family households.

Source: Claritas, 2009; Bay Area Economics, 2009.

Homeownership is another element of how quickly recovery occurs. As noted earlier, homes occupied by their owners tend to be rebuilt at a faster rate than multifamily rental housing following an earthquake. Table Z presents homeownership rates and housing types by neighborhood in San Francisco. As shown, nearly two thirds of residents in the City are renters. Only 35 percent of San Francisco households own their homes. Homeownership rates are lowest in Downtown, North Beach, and the Western Addition, all neighborhoods with a heavy concentration of multifamily housing. Conversely, the Sunset, Excelsior, Twin Peaks, and Ingleside have relatively high homeownership rates and a greater incidence of single-family homes.

Table Z. San Francisco unit types and homeownership rates

Neighborhood	Unit Type		Tenure	
	Single family	Multifamily	Owner occupied	Renter occupied

[41] Only includes family households.

	(%)	(%)	(%)	(%)
Downtown	2	98	8	92
North Beach	5	95	19	81
Western Addition	12	88	21	79
Marina	11	89	21	79
Pacific Heights	14	85	28	72
Merced	41	59	28	72
Mission	28	72	33	67
Mission Bay	13	84	35	65
Richmond	30	70	36	64
Bayview	67	32	52	48
Sunset	66	34	56	44
Excelsior	82	17	68	32
Twin Peaks	72	28	68	32
Ingleside	90	9	74	26
Citywide	**31**	**69**	**35**	**65**

Source: This study, Claritas (2009).

[Note: Bayview line is disagrees with table Z in housing chapter. Need to find out which one is correct. North Beach and Pac Heights also slightly vary, assume due to rounding.]

Socio-economic resilience varies significantly by neighborhood. In general, neighborhoods with higher income households, greater homeownership rates, and more single-family homes will likely recover and rebuild faster than lower-income areas with more renters and multifamily units. Table X provides a perspective on how these factors compare across neighborhoods, based on the data presented above. The analysis assigns a "resilience score" to each neighborhood according to its poverty rates, homeownership rate, and the percent of units in multifamily buildings. Neighborhoods with greater rates of poverty, renters, and multifamily housing receive lower resilience scores. The findings suggest that the City's most socially resilient neighborhoods include Ingleside, the Excelsior, and the Sunset. Its least socio-economically resilient neighborhoods include Downtown, North Beach, and the Western Addition.

Table X. Social Resilience Index, San Francisco Neighborhoods

Neighborhood	Poverty[1]	Home ownership[2]	Multifamily housing[3]	Average resilience score
Ingleside	3	3	3	3.00
Excelsior	2	3	3	2.67
Sunset	3	3	2	2.67
Twin Peaks	3	3	2	2.67
Bayview	1	3	2	2.00
Merced	2	2	2	2.00
Mission	2	2	2	2.00
Pacific Heights	3	2	1	2.00
Richmond	2	2	2	2.00
Marina	3	1	1	1.67

Mission Bay	1	2	1	1.33
Downtown	1	1	1	1.00
North Beach	1	1	1	1.00
Western Addition	1	1	1	1.00

1.	Poverty rate, 2009	Resilience score
	0-5%	3
	6%-10%	2
	>10%	1
2.	Homeownership rate, 2009	Resilience score
	>50%	3
	26%-50%	2
	0%-25%	1
3.	% multifamily, 2009	Resilience score
	0-25%	3
	26%-75%	2
	>75%	1

Source: This study, Claritas (2009).

Damage by Neighborhood

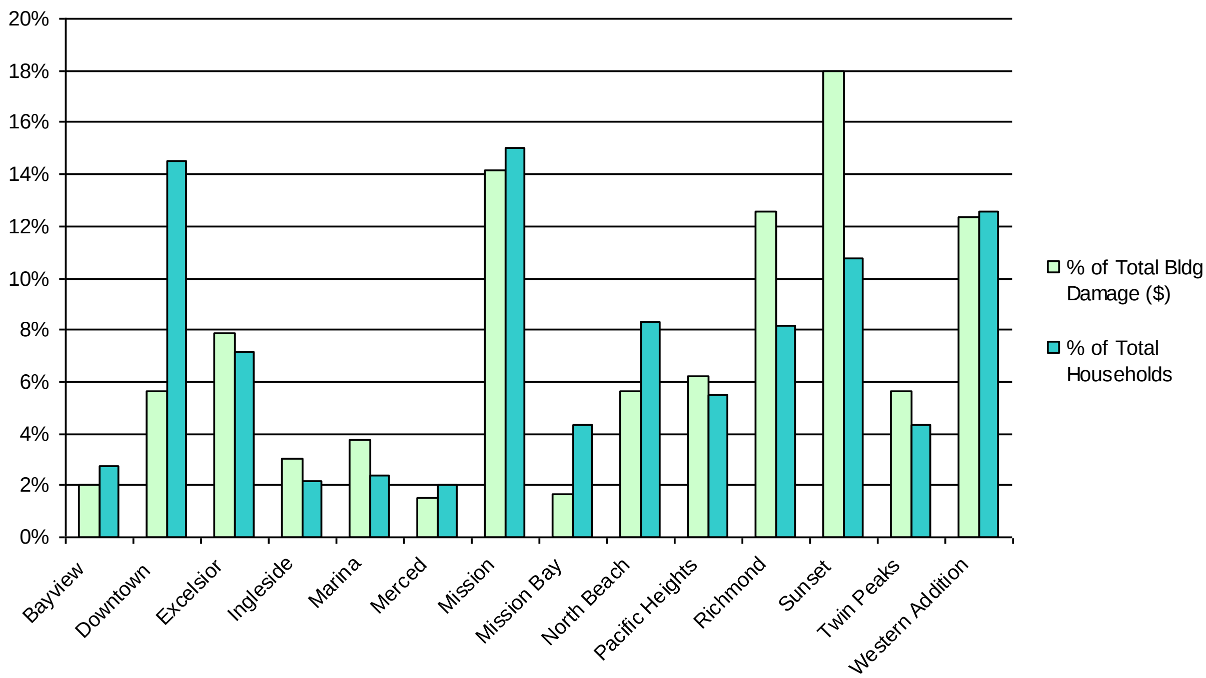
All neighborhoods will be heavily damaged by the four scenario earthquakes examined in this report. Looking at two of the scenarios in detail—a magnitude 7.2 San Andreas earthquake that shakes the City from the west and a magnitude 6.9 Hayward fault earthquake that shakes the City from the east—shows how damage may vary by neighborhood in these events. The amount of damage each neighborhood experiences, combined with the resiliency of the people living there, has implications for how each area will recover.

Figure Y presents the damage estimates, summarizing each neighborhood's share of total residential building damage in the City, compared with each neighborhood's share of the total households in the City for the magnitude 7.2 scenario[42, 43]. This comparison helps identify areas where the level of damage (i.e., share of total damage in the City) appears out of scale with the neighborhood's size.

As shown, the Sunset, Mission, and Western Addition are expected to suffer the greatest share of the City's residential building damage. The level of projected damage in the Western Addition and Mission is consistent with these neighborhood's share of the City's total households. However, a number of neighborhoods show an inordinate degree of damage. Notably, the Sunset would experience 18 percent of the total residential building damage, while only containing 11 percent of the City's households. Similarly, the Richmond is expected to suffer 13 percent of the total residential building damage in San Francisco, but only contains eight percent of total households. The Marina would also experience damage out of scale with its share of total households. Conversely, Downtown, which has 15 percent of the City's households, would only experience six percent of total residential building damage in San Francisco.

[42] Residential buildings include single family, two unit and three or more unit residences.
[43] In this analysis, damage is expressed as the estimated cost to repair or replace damaged buildings.

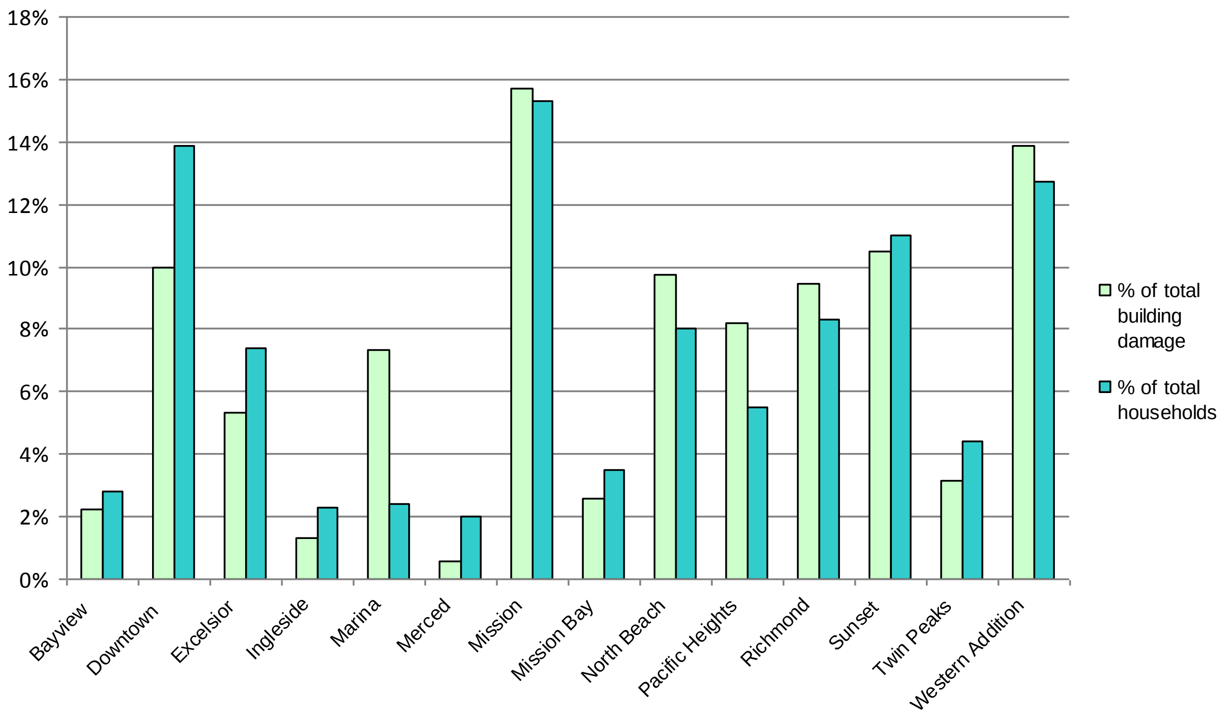
Figure X. Share of Total Residential Building Damage vs. Share of Total Households by Neighborhood for M7.2 San Andreas scenario[1]



Source: This study, Bay Area Economics.

Figure Z shows similar results for the magnitude 6.9 Hayward scenario earthquake. This scenario shakes the City's eastern neighborhoods more strongly than its western ones. In this scenario, damage in the Sunset and Richmond neighborhoods is in line with the percent of households in those areas. The Marina, notably, experiences a much higher share of the damage to residences than the percent of households located there. Again, residences Downtown show less damage per household than other areas.

Figure Z. Share of total residential building damage versus share of total households by neighborhood for M6.9 Hayward scenario



It is important to note that the large neighborhoods defined for this study obscure impacts to particular pockets within each neighborhood. For example, some downtown residences are in modern buildings while others are in older vulnerable buildings. Areas with many older buildings, such as Chinatown and the Tenderloin, are expected to experience higher rates of damage than the neighborhood as a whole.

The next major earthquake that strikes San Francisco will change the City and its people. San Francisco is a world-class city with many special attributes that draw businesses, innovative people who want to live here, and visitors from around the world. In the long-term, San Francisco will recover and thrive, but it will be a different San Francisco. It is likely that the new, post-earthquake San Francisco will have less socio-economic diversity. The destruction of many affordable housing options, exacerbated by a limited housing market in the years it will take to rebuild the City, will make it difficult for middle and low income people to remain in San Francisco. Earthquake damage will stress businesses and the jobs they provide, particularly the many small and independent businesses in the City. It will change the way the City looks, with some of the most interesting and beautiful buildings and neighborhoods changed forever. Despite the damage, San Francisco will retain many of the elements that make it an economically successful and socially desirable place – physical beauty, cultural amenities, and proximity to world-class universities, to name a few.

The scenarios described in this report present what is likely to happen if San Francisco makes no changes to its preparations for earthquakes. Much of this damage may be preventable. It is up to San Franciscans to decide how much to invest in steps to reduce the consequences of the next major earthquake.

References

[Note: Reference section is still under construction. References are missing and incomplete.]

California Department of Education, [cite reference].

Comerio, et al., 1994.

Comerio, 1998.

Dolfman, Michael L., Solidelle Fortier Wasser, Bruce Bergman. “The effects of Hurricane Katrina on the New Orleans economy.” Monthly Labor Review. June 2007.

Earthquake Spectra, May 1990. [cite]

FEMA/NIBS (2002), *Earthquake Loss Estimation Methodology, HAZUS-99 Service Release 2 (SR2) Technical Manual*, prepared by the National Institute of Building Sciences for the Federal Emergency Management Agency, Washington, D.C.

FEMA/NIBS HAZUS-MH manual.

Florida, R. The Rise of the Creative Class: And How It’s Transforming Work, Leisure, Community and Everyday Life. New York: Perseus Book Group. 2002.

Kornfield, Laurence. Presentation to CAPSS Advisory Committee at October 14, 2009 meeting.

Mayor’s Office of Housing, 2010.

Mazzocchi, Mario, Anna Montini. **“**Earthquake effects on tourism in central Italy.” Annals of Tourism Research. August 2001.

Meszaros, Jacqueline and Mark Fiegener. 2002. *Effects of the 2001 Nisqually Earthquake on Small Businesses in Washington State.* Prepared for the Economic Development Administration, U.S. Department of Commerce, Seattle Regional Office.

Perkins and Wyatt, DATE

Petak , William J,. and Shirin Elahi. The Northridge Earthquake, USA and its Economic and Social Impacts. EuroConference on Global Change and Catastrophe Risk Management Earthquake Risks in Europe, IIASA, Laxenburg Austria, July 6-9, 2000.

Risk Management Solutions, 2010.

Rose et al, [DATE]

Sfenvironment.org

Yang, Weiqiong, Guojie Chen, Daojie Wang. “Impact of the Wenchuan Earthquake on tourism in Sichuan, China.” Journal of Mountain Science. September 2008.

Project Participants

Appendix A. Detailed data and loss estimates

[Note: the goal is to include additional data and results of interest to non-technical readers. Input on what should be included is appreciated. More will be included in the technical companion volume.]

This appendix provides tables with more detail than provided in the main body of the report. Additional data, results and discussion about technical methods appear in a companion report, [Title of technical volume].

A.1. San Francisco's Buildings

Tables X – Z show the best estimates developed by this study with information about the number, value, location and structure types of the City's buildings. Numbers in the table are based on a variety of sources combined with expert judgment and should be considered as estimates.

Table X. Estimated number of buildings by neighborhood and building use.

Neighborhood	Single family residence	Two unit residence	Three or more unit residence	Other residences	Commercial buildings	Industrial buildings	Other	Total
Bayview								
Downtown								
Excelsior								
Ingleside								
Marina								
Merced								
Mission								
Mission Bay								
North Beach								
Pacific Heights								
Richmond								
Sunset								
Twin Peaks								
Western Addition								
Total								

1. [Various table notes]

Source: XXX

Table Y. Estimated replacement value of buildings by neighborhood and building use.

Neighborhood	Single family residence	Two unit residence	Three or more unit residence	Other residences	Commercial buildings	Industrial buildings	Other	Total

Bayview								
Downtown								
Excelsior								
Ingleside								
Marina								
Merced								
Mission								
Mission Bay								
North Beach								
Pacific Heights								
Richmond								
Sunset								
Twin Peaks								
Western Addition								
Total								

1. [Various table notes]

Source: XXX

Table Z. Estimated number of buildings by neighborhood and structure type[1].

Neighborhood	Res wood frame opening	Res wood frame no opening	Concrete pre mid-1970's	Modern concrete	Steel moment, braced frame	URM	Other	Total
Bayview								
Downtown								
Excelsior								
Ingleside								
Marina								
Merced								
Mission								
Mission Bay								
North Beach								
Pacific Heights								
Richmond								
Sunset								
Twin Peaks								
Western Addition								
Total								

1. A more detailed breakdown of estimated structural types is available in the technical companion volume.
2. [Various table notes]

Source: XXX

Table Q. Estimated cost per square foot to construct various building uses, 2009.

Detailed building use	Estimated square foot replacement cost

A.2. Earthquake Damage to Buildings

Estimated damage to buildings is presented in greater detail for each scenario.

A.2.1. Magnitude 7.2 San Andreas Scenario

Table X. Estimated cost to repair and replace damaged buildings, by neighborhood and building use

Neighborhood	Single family residence	Two unit residence	Three or more unit residence	Other residences	Commercial buildings	Industrial buildings	Other	Total
Bayview								
Downtown								
Excelsior								
Ingleside								
Marina								
Merced								
Mission								
Mission Bay								
North Beach								
Pacific Heights								
Richmond								
Sunset								
Twin Peaks								
Western Addition								
Total								

1. [Various table notes]

Source: XXX

Table Y. Estimated cost to repair and replace damaged buildings, by neighborhood and structure type

Neighborhood	Res wood frame opening	Res wood frame no opening	Concrete pre mid-1970's	Modern concrete	Steel moment, braced frame	URM	Other	Total
Bayview								
Downtown								
Excelsior								
Ingleside								
Marina								

Merced								
Mission								
Mission Bay								
North Beach								
Pacific Heights								
Richmond								
Sunset								
Twin Peaks								
Western Addition								
Total								

1. A more detailed breakdown of estimated structural types is available in the technical companion volume.
2. [Various table notes]

Source: XXX

Table Z. Damage ratio[1] by neighborhood and structure type

Neighborhood	Res wood frame opening	Res wood frame no opening	Concrete pre mid-1970's	Modern concrete	Steel moment, braced frame	URM	Other	Total
Bayview								
Downtown								
Excelsior								
Ingleside								
Marina								
Merced								
Mission								
Mission Bay								
North Beach								
Pacific Heights								
Richmond								
Sunset								
Twin Peaks								
Western Addition								
Total								

1. [define damage ratio]
2. A more detailed breakdown of estimated structural types is available in the technical companion volume.
3. [Various table notes]

Source: XXX

Table A. HAZUS structural damage state distribution by use

Building occupancy					
	None	Slight	Moderate	Extensive	Complete

Single Family Residences					
Two unit residences					
Three or more unit residences					
Other Residences[2]					
Commercial Buildings					
Industrial Buildings					
Other[3]					
Average					

1. [Various table notes]

Source: XXX

Table B. HAZUS structural damage state distribution by neighborhood

Neighborhood	None	Slight	Moderate	Extensive	Complete
Bayview					
Downtown					
Excelsior					
Ingleside					
Marina					
Merced					
Mission					
Mission Bay					
North Beach					
Pacific Heights					
Richmond					
Sunset					
Twin Peaks					
Western Addition					
Average					

1. [Various table notes]

Source: XXX

A.2.2. Magnitude 6.5 San Andreas Scenario

Table X. Estimated cost to repair and replace damaged buildings, by neighborhood and building use

Neighborhood	Single family residence	Two unit residence	Three or more unit residence	Other residences	Commercial buildings	Industrial buildings	Other	Total
Bayview								
Downtown								
Excelsior								
Ingleside								
Marina								

Merced								
Mission								
Mission Bay								
North Beach								
Pacific Heights								
Richmond								
Sunset								
Twin Peaks								
Western Addition								
Total								

1. [Various table notes]

Source: XXX

Table Y. Estimated cost to repair and replace damaged buildings, by neighborhood and structure type

Neighborhood	Res wood frame opening	Res wood frame no opening	Concrete pre mid-1970's	Modern concrete	Steel moment, braced frame	URM	Other	Total
Bayview								
Downtown								
Excelsior								
Ingleside								
Marina								
Merced								
Mission								
Mission Bay								
North Beach								
Pacific Heights								
Richmond								
Sunset								
Twin Peaks								
Western Addition								
Total								

1. A more detailed breakdown of estimated structural types is available in the technical companion volume.
2. [Various table notes]

Source: XXX

Table Z. Damage ratio[1] by neighborhood and structure type

Neighborhood	Res wood frame opening	Res wood frame no opening	Concrete pre mid-1970's	Modern concrete	Steel moment, braced frame	URM	Other	Total

Bayview								
Downtown								
Excelsior								
Ingleside								
Marina								
Merced								
Mission								
Mission Bay								
North Beach								
Pacific Heights								
Richmond								
Sunset								
Twin Peaks								
Western Addition								
Total								

1. [define damage ratio]
2. A more detailed breakdown of estimated structural types is available in the technical companion volume.
3. [Various table notes]

Source: XXX

A.2.3. Magnitude 7.9 San Andreas Scenario

Table X. Estimated cost to repair and replace damaged buildings, by neighborhood and building use

Neighborhood	**Single family residence**	**Two unit residence**	**Three or more unit residence**	**Other residences**	**Commercial buildings**	**Industrial buildings**	**Other**	**Total**
Bayview								
Downtown								
Excelsior								
Ingleside								
Marina								
Merced								
Mission								
Mission Bay								
North Beach								
Pacific Heights								
Richmond								
Sunset								
Twin Peaks								
Western Addition								
Total								

1. [Various table notes]

Source: XXX

Table Y. Estimated cost to repair and replace damaged buildings, by neighborhood and structure type

Neighborhood	Res wood frame opening	Res wood frame no opening	Concrete pre mid-1970's	Modern concrete	Steel moment, braced frame	URM	Other	Total
Bayview								
Downtown								
Excelsior								
Ingleside								
Marina								
Merced								
Mission								
Mission Bay								
North Beach								
Pacific Heights								
Richmond								
Sunset								
Twin Peaks								
Western Addition								
Total								

1. A more detailed breakdown of estimated structural types is available in the technical companion volume.
2. [Various table notes]

Source: XXX

Table Z. Damage ratio[1] by neighborhood and structure type

Neighborhood	Res wood frame opening	Res wood frame no opening	Concrete pre mid-1970's	Modern concrete	Steel moment, braced frame	URM	Other	Total
Bayview								
Downtown								
Excelsior								
Ingleside								
Marina								
Merced								
Mission								
Mission Bay								
North Beach								
Pacific Heights								
Richmond								
Sunset								
Twin Peaks								

Western Addition								
Total								

1. [define damage ratio]
2. A more detailed breakdown of estimated structural types is available in the technical companion volume.
3. [Various table notes]

Source: XXX

A.2.1. Magnitude 6.9 Hayward Scenario

Table X. Estimated cost to repair and replace damaged buildings, by neighborhood and building use

Neighborhood	Single family residence	Two unit residence	Three or more unit residence	Other residences	Commercial buildings	Industrial buildings	Other	Total
Bayview								
Downtown								
Excelsior								
Ingleside								
Marina								
Merced								
Mission								
Mission Bay								
North Beach								
Pacific Heights								
Richmond								
Sunset								
Twin Peaks								
Western Addition								
Total								

1. [Various table notes]

Source: XXX

Table Y. Estimated cost to repair and replace damaged buildings, by neighborhood and structure type

Neighborhood	Res wood frame opening	Res wood frame no opening	Concrete pre mid-1970's	Modern concrete	Steel moment, braced frame	URM	Other	Total
Bayview								
Downtown								
Excelsior								
Ingleside								
Marina								
Merced								

Mission								
Mission Bay								
North Beach								
Pacific Heights								
Richmond								
Sunset								
Twin Peaks								
Western Addition								
Total								

1. A more detailed breakdown of estimated structural types is available in the technical companion volume.
2. [Various table notes]

Source: XXX

Table Z. Damage ratio[1] by neighborhood and structure type

Neighborhood	**Res wood frame opening**	**Res wood frame no opening**	**Concrete pre mid-1970's**	**Modern concrete**	**Steel moment, braced frame**	**URM**	**Other**	**Total**
Bayview								
Downtown								
Excelsior								
Ingleside								
Marina								
Merced								
Mission								
Mission Bay								
North Beach								
Pacific Heights								
Richmond								
Sunset								
Twin Peaks								
Western Addition								
Total								

1. [define damage ratio]
2. A more detailed breakdown of estimated structural types is available in the technical companion volume.
3. [Various table notes]

Source: XXX

A.3. Total Direct Economic Losses

This section provides more detail on the estimate total direct economic losses for the four scenario earthquakes. This includes [list all types of losses].

A.3.1. Magnitude 7.2 San Andreas Scenario

Table Q. Estimated total direct economic losses, by neighborhood and building use

Neighborhood	Single family residence	Two unit residence	Three or more unit residence	Other residences	Commercial buildings	Industrial buildings	Other	Total
Bayview								
Downtown								
Excelsior								
Ingleside								
Marina								
Merced								
Mission								
Mission Bay								
North Beach								
Pacific Heights								
Richmond								
Sunset								
Twin Peaks								
Western Addition								
Total								

1. [Various table notes]

Source: XXX

Table R. Total direct economic losses, by neighborhood and structure type

Neighborhood	Res wood frame opening	Res wood frame no opening	Concrete pre mid-1970's	Modern concrete	Steel moment, braced frame	URM	Other	Total
Bayview								
Downtown								
Excelsior								
Ingleside								
Marina								
Merced								
Mission								
Mission Bay								
North Beach								
Pacific Heights								
Richmond								
Sunset								
Twin Peaks								
Western Addition								

Total								

1. A more detailed breakdown of estimated structural types is available in the technical companion volume.
2. [Various table notes]

Source: XXX

A.3.1. Magnitude 6.5 San Andreas Scenario

Table Q. Estimated total direct economic losses, by neighborhood and building use

Neighborhood	**Single family residence**	**Two unit residence**	**Three or more unit residence**	**Other residences**	**Commercial buildings**	**Industrial buildings**	**Other**	**Total**
Bayview								
Downtown								
Excelsior								
Ingleside								
Marina								
Merced								
Mission								
Mission Bay								
North Beach								
Pacific Heights								
Richmond								
Sunset								
Twin Peaks								
Western Addition								
Total								

1. [Various table notes]

Source: XXX

Table R. Total direct economic losses, by neighborhood and structure type

Neighborhood	**Res wood frame opening**	**Res wood frame no opening**	**Concrete pre mid-1970's**	**Modern concrete**	**Steel moment, braced frame**	**URM**	**Other**	**Total**
Bayview								
Downtown								
Excelsior								
Ingleside								
Marina								
Merced								
Mission								

Mission Bay								
North Beach								
Pacific Heights								
Richmond								
Sunset								
Twin Peaks								
Western Addition								
Total								

1. A more detailed breakdown of estimated structural types is available in the technical companion volume.
2. [Various table notes]

Source: XXX

A.3.1. Magnitude 7.9 San Andreas Scenario

Table Q. Estimated total direct economic losses, by neighborhood and building use

Neighborhood	Single family residence	Two unit residence	Three or more unit residence	Other residences	Commercial buildings	Industrial buildings	Other	Total
Bayview								
Downtown								
Excelsior								
Ingleside								
Marina								
Merced								
Mission								
Mission Bay								
North Beach								
Pacific Heights								
Richmond								
Sunset								
Twin Peaks								
Western Addition								
Total								

1. [Various table notes]

Source: XXX

Table R. Total direct economic losses, by neighborhood and structure type

Neighborhood	Res wood frame	Res wood frame no	Concrete pre mid-1970's	Modern concrete	Steel moment, braced	URM	Other	Total

	opening	opening			frame			
Bayview								
Downtown								
Excelsior								
Ingleside								
Marina								
Merced								
Mission								
Mission Bay								
North Beach								
Pacific Heights								
Richmond								
Sunset								
Twin Peaks								
Western Addition								
Total								

1. A more detailed breakdown of estimated structural types is available in the technical companion volume.
2. [Various table notes]

Source: XXX

A.3.1. Magnitude 6.9 Hayward Scenario

Table Q. Estimated total direct economic losses, by neighborhood and building use

Neighborhood	Single family residence	Two unit residence	Three or more unit residence	Other residences	Commercial buildings	Industrial buildings	Other	Total
Bayview								
Downtown								
Excelsior								
Ingleside								
Marina								
Merced								
Mission								
Mission Bay								
North Beach								
Pacific Heights								
Richmond								
Sunset								
Twin Peaks								
Western Addition								
Total								

1. [Various table notes]

Source: XXX

Table R. Total direct economic losses, by neighborhood and structure type

Neighborhood	**Res wood frame opening**	**Res wood frame no opening**	**Concrete pre mid-1970's**	**Modern concrete**	**Steel moment, braced frame**	**URM**	**Other**	**Total**
Bayview								
Downtown								
Excelsior								
Ingleside								
Marina								
Merced								
Mission								
Mission Bay								
North Beach								
Pacific Heights								
Richmond								
Sunset								
Twin Peaks								
Western Addition								
Total								

1. A more detailed breakdown of estimated structural types is available in the technical companion volume.
2. [Various table notes]

Source: XXX

A.4. Characteristics of San Francisco Residents

[Could put various demographic and economic data here.]