

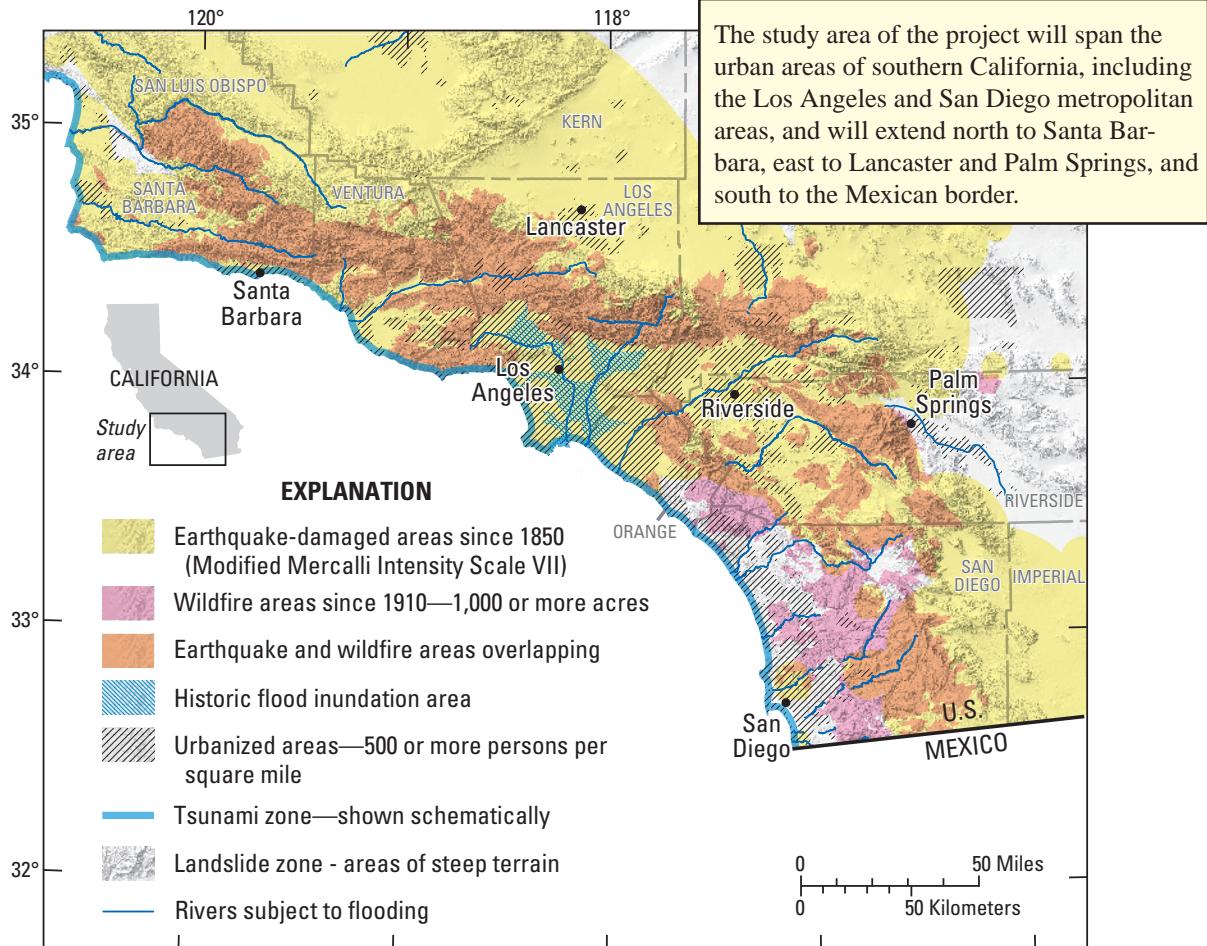
# Increasing the Resilience to Natural Hazards in Southern California

Southern California is at great risk for extreme catastrophic losses owing to numerous natural hazards, such as earthquakes, wildfires, floods, tsunamis, landslides and coastal changes, that occur in this area (fig. 1). Expected losses from these hazards are estimated to exceed \$3 billion per year in the eight counties of southern California.

## In southern California

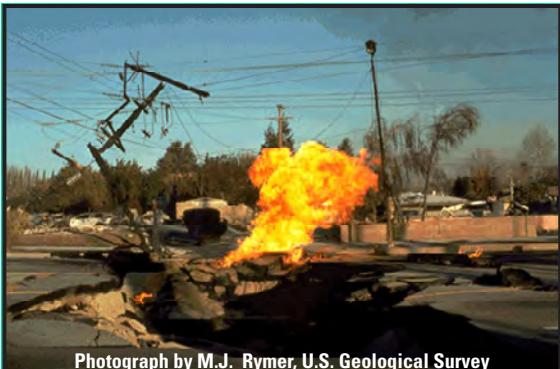
- Natural hazards have devastating consequences, including loss of life and injury, replacement costs of buildings and infrastructure, loss of function of critical facilities, service and infrastructure outages, business interruption, loss of jobs, and a decrease in the quality of life.
- Multiple natural hazards are commonplace and often overlap to create secondary hazards. For example, earthquakes can produce landslides and severe fires and heavy storms can produce debris flows.

- Every year since 2000, when the population of the eight counties of southern California was nearly 19.7 million people, an estimated 276,000 more people become at risk from primary and secondary natural hazards.
- Decision makers require different types of information at a wide range of spatial and temporal scales. The decision-making environment is dynamic and therefore decision makers need to be able to access the most recent information derived from scientific investigations that account for human and natural forces of change.
- Effective risk-reduction options depend on resources that are subject to budget constraints and on personal or organizational preferences for acceptable levels of risk; therefore, models and simulation studies are useful for quantifying options.



**Figure 1.** Geographical extent and overlap of natural hazards in southern California.





Photograph by M.J. Rymer, U.S. Geological Survey

**Natural gas pipeline broken as a result of the 1994 Northridge earthquake in southern California.**

The Multi-Hazards Demonstration Project (MHDP), initiated by the U.S. Geological Survey in 2007, brings together multiple disciplines and partners to help communities in southern California reduce death and destruction from natural hazards. To help increase the resilience of communities to future natural hazards, the project combines the knowledge of geology, water resources, geography, and biology with sound economic, engineering, social science and geospatial information capabilities to

- Create a focal point to improve communication among scientists and disaster managers and community planners.
- Plan USGS science projects with community partners. Interaction with community partners will aid the USGS in understanding community needs, improve emergency-management decisions, and guide future USGS research.
- Initiate or expand real-time hazard monitoring and warning systems.
- Provide new and easy-to-access hazards data, information, assessments, and models for use by community decision makers and researchers.
- Develop and improve new research products, tools, risk maps, and assessments. Combine geologic, hydrologic, geographic, and biologic hazard products with economic, engineering and social science research to improve emergency-management decisions.
- Use the best of what is developed for the MHDP for southern California to build a robust Urban Hazards program for the Nation.

Photograph by Rudolph R Contreras, U.S. Geological Survey



**2003 Cedar Fire, San Diego County, southern California. About 280,000-acres burned.**

**To accomplish the objectives of the Multi-Hazard Demonstration Project, the USGS will**

- Ensure that research will be useful to the communities of southern California.
- Conduct the best possible multidisciplinary scientific research.
- Work in partnership with the region's communities to support them in using the research results.



**The San Fernando earthquake of 1971 collapsed freeway overpasses in southern California.**



**Landslide at Laguna Beach, California, June 2005. The landslide occurred after record heavy rainfall in southern California in the preceding months. It occurred next to the 1978 Bluebird Canyon landslide.**

Natural-hazard information is useful to community decision makers in preparing risk-reduction strategies. To provide the best scientific information on natural hazards, the USGS will carry out research to increase the understanding of the framework of hazard possibilities, vulnerable environments, community response, and associated risk-reduction options. The vulnerable environment is in part created by humans, but natural elements such as the soils, geology, hydrology and ecology also make an environment vulnerable. The goal of the USGS activities is to provide an understanding of the relationships between human actions and environmental vulnerabilities to aid in making informed decisions about possible risk-reduction activities.

**Contacts:**

Dr. Lucile Jones U.S. Geological Survey Multi-Hazards Demonstration Project, Chief Scientist	Dale A. Cox U.S. Geological Survey Multi-Hazards Demonstration Project, Project Manager
525 South Wilson Avenue Pasadena, CA 91106	6000 J Street, Modoc Hall Sacramento, CA 95819

# Putting down roots in earthquake country



Includes the  
**Seven Steps to  
Earthquake Safety!**

Produced and distributed by:



FEMA



Cal EMA  
CALIFORNIA EMERGENCY  
MANAGEMENT AGENCY

Earthquake  
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Alliance



# Introduction

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SCEC is a research consortium supported by the National Science Foundation and the United States Geological Survey, headquartered at the University of Southern California.

*Disclaimer:* The suggestions and illustrations included in this document are intended to improve earthquake awareness and preparedness; however, they do not guarantee the safety of an individual or a structure. The writers, contributors, and sponsors of this handbook do not assume liability for any injury, death, property damage, or other effect of an earthquake.

Prepared by the Southern California Earthquake Center (SCEC) and the Department of the Interior United States Geological Survey (USGS), in cooperation with the National Science Foundation (NSF), the Department of Homeland Security Federal Emergency Management Agency (FEMA), and the California Earthquake Authority (CEA), with contributions from many members of the Earthquake Country Alliance

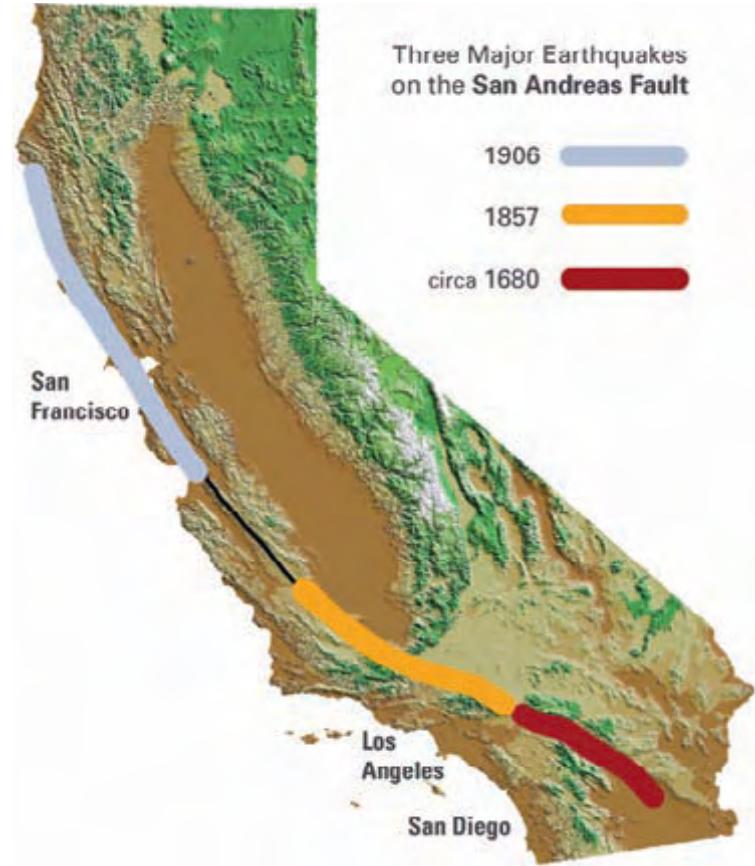
*Writers:* Lucile M. Jones, USGS and Mark Benthiem, SCEC

*Producers:* Mark Benthiem and Robert de Groot, SCEC (2004 and later editions) and Jill Andrews, SCEC (first edition)

*Contributors:* **SCEC (USC):** Ilene Cooper, Thomas Henrey, Tran Huynh, John Marquis, Glenn Song, Brion Vibber; **USGS:** Dale Cox, Kenneth Hudnut, Sue Perry, Ken Rukstales, Michael Rymer, Bob Simpson, David Wald, Lisa Wald; **FEMA:** Hassaan Sughayer, Dennis Sylvester, Doug Bausch, Jeffrey Lusk; **California Emergency Management Agency:** Greg Renick, Deborah Steffen, James Goltz, Kate Long, Terrie Monaghan; **California Geological Survey:** Jerry Treiman, Chris Wills, Charles Real; **California Seismic Safety Commission:** Fred Turner; **California Earthquake Authority:** Nancy Kinkaid; **Insurance Information Network of California:** Candy Miller; **American Red Cross:** Peggy Brutsche, Rocky Lopes; **County of Los Angeles:** Joyce Harris, Phyllis Tan, Larry Collins; **Caltech:** Vikki Appel, Egill Hauksson, Margaret Vinci; **Harvard:** Andreas Plesch, John Shaw; **Humboldt State University:** Lori Dengler; **KFWB:** Jack Popejoy; **Ready America:** Dean Reese, Brian Lowe, Jeff Primes; and many other members of the Earthquake Country Alliance

*Design:* Denton Design Associates: Margi Denton, Elizabeth Burrill

*Illustrators and Photographers:* Todd Connor (p. 16, 17, 23); Ann Elliott Cutting (p. 13, 19, 21, 22, 24, 25); Dale Glasgow (p. 26); Min Jae Hong (p. 30); Stephanie Langley (p. 4, 6, 12, 20, 22, 23, 28); Punchstock (p. 24); Jere Smith (cover, p. 2, 3, 32); Zeke Smith (p. 14); and Robert Zimmerman (p. 16, 18, 20, 22).



Why should I care?

## Southern California is Earthquake Country

- 4 Southern California earthquakes and faults
- 6 Future earthquakes
- 8 Tsunami hazards and other hazards
- 10 One plausible big one
- 12 Recovering from a big one



Generations of Californians have been “putting down roots” along one of the world’s most famous faults—the San Andreas. However, few Californians have experienced a major San Andreas earthquake. In Northern California, the last major earthquake was 100 years ago in 1906. Over 3,000 people were killed and 225,000 people were left homeless. In Southern California, the last major earthquake on the San Andreas fault was more than 150 years ago (1857), rupturing the fault from Central California to San Bernardino. Few people lived in the area, so there was very little damage.

Further south along the San Andreas fault, from San Bernardino through the Coachella Valley to the Salton Sea, more than 320 years have passed since the last major earthquake (around 1680). Another major earthquake is likely to happen on this section of the fault within our lifetime, and will shake all of Southern California. A study led by the U.S. Geological Survey describes in great detail the extensive damage and casualties that result from such an earthquake, and recommends many ways that we can keep this natural disaster from becoming a catastrophe (see pages 8-11).

While the San Andreas is most likely to be the source of our largest earthquakes, there are hundreds of other faults throughout Southern California that could also cause damaging earthquakes. Some may happen before the next San Andreas earthquake and could be even more destructive if they occur directly beneath densely populated areas.

This handbook is a resource for living in earthquake country. It provides information about why we should **care** about earthquakes in Southern California, what we should **do** to be safe and reduce damage, and also what we should **know** about earthquake basics.

## What should I do?

### The Seven Steps to Earthquake Safety

- 14** The seven steps to earthquake safety
- 16** STEP #1: Identify potential hazards in your home and begin to fix them.
- 18** STEP #2: Create a disaster-preparedness plan.
- 19** STEP #3: Prepare disaster supplies kits.
- 20** STEP #4: Identify your building's potential weaknesses and begin to fix them.
- 22** STEP #5: Protect yourself during earthquake shaking—drop, cover, and hold on.
- 23** STEP #6: After the earthquake, check for injuries and damage. Evacuate if necessary.
- 24** STEP #7: When safe, continue to follow your disaster-preparedness plan.



### What should I know?

### Earthquake Basics

- 26** Earthquakes and faults
- 28** Locating and measuring earthquakes
- 30** Earthquake shaking
- 31** Information available after earthquakes



### Web Resources (back cover)

## Southern California is Earthquake Country

We know that the San Andreas fault produces large earthquakes and that many other faults are also hazardous. However, it is often difficult to understand how to incorporate this information into our lives. Should we care only if we live near the San Andreas fault? Is every place just as dangerous? This section describes where earthquakes have occurred in the past and where they may likely occur in the future, how the ground will shake when they do, and what may happen in a plausible “big one” on the San Andreas.



### MYTH #1 Don't be fooled!



#### “BIG EARTHQUAKES ALWAYS HAPPEN IN THE EARLY MORNING”

This myth may be so common because we want it to be true. Several recent damaging earthquakes have been in the early morning, so many people believe that all big earthquakes happen then. In fact, earthquakes occur at all times of day. The 1933 Long Beach earthquake was at 5:54 pm and the 1940 Imperial Valley event was at 8:37 pm. More recently, the 1992 Joshua Tree earthquake was at 9:50 pm and the 2003 San Simeon event was at 11:15 am. It is easy to notice the earthquakes that fit the pattern and forget the ones that don't.

#### What does it mean?

To become familiar with earthquake vocabulary, you may want to read the “What Should I Know” section first.

## SOUTHERN CALIFORNIA EARTHQUAKES AND FAULTS

The earthquakes of California are caused by the movement of huge blocks of the earth's crust – the Pacific and North American plates. The Pacific plate is moving northwest, scraping horizontally past North America at a rate of about 50 millimeters (2 inches) per year. About two-thirds of this movement occurs on the San Andreas fault and some parallel faults—the San Jacinto, Elsinore, and Imperial faults (see map). Over time, these faults produce about half of the significant earthquakes of our region, as well as many minor earthquakes.

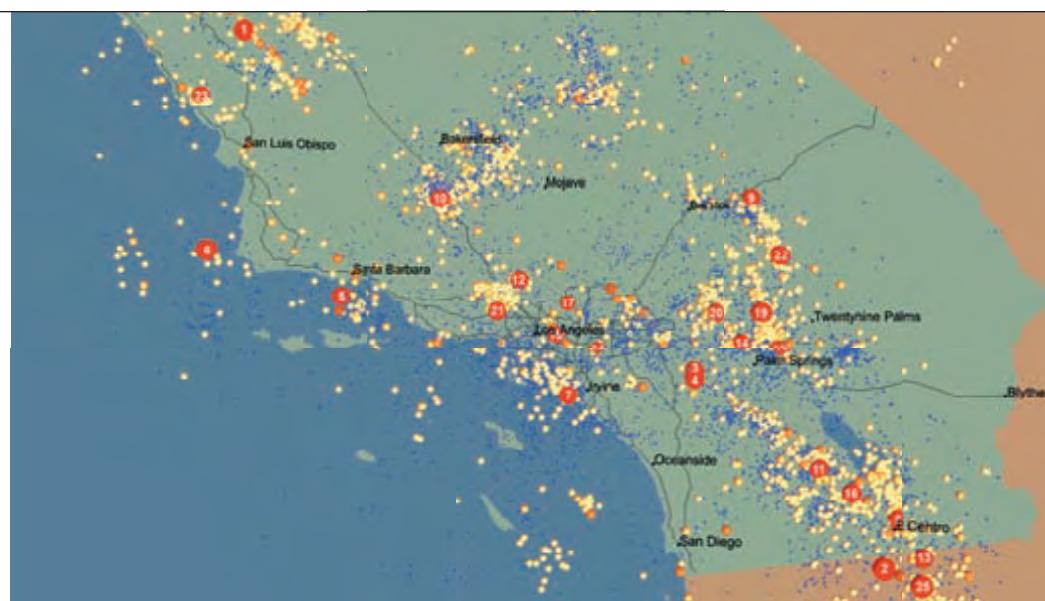
The last significant earthquake on the Southern California stretch of the San Andreas fault was in 1857, and there has not been a rupture of the fault along its southern end from San Bernardino to the Salton Sea since 1690. It is still storing energy for some future earthquake.

But we don't need to wait for a “big one” to experience earthquakes. Southern California has thousands of smaller earthquakes every year. A few may cause damage, but most are not even felt. And most of these are not on the major faults listed above. The earthquake map at top right shows that earthquakes can occur almost everywhere in the region, on more than 300 additional faults that can cause damaging earthquakes, and countless other small faults.

This is mostly due to the “big bend” of the San Andreas fault, from the southern end of the San Joaquin Valley to the eastern end of the San Bernardino mountains (see diagram at right). Where the fault bends, the Pacific and North American plates push into each other, compressing the earth's crust into the mountains of Southern California and creating hundreds of additional faults (many more than shown in the fault map). These faults produce thousands of small earthquakes each year, and the other half of our significant earthquakes. Examples include the 1994 Northridge and 1987 Whittier Narrows earthquakes.

### Significant Southern California earthquakes since 1857

Date	Time	Location	Magnitude
1. 01.09.1857	8:24 am	Fort Tejon	7.9
2. 02.24.1892	11:20 pm	Laguna Salada	7.3
3. 12.25.1899	4:25 am	San Jacinto/Hemet	6.7
4. 04.21.1918	2:31 pm	San Jacinto	6.8
5. 06.29.1925	7:42 am	Santa Barbara	6.8
6. 11.04.1927	5:51 pm	Offshore Lompoc	7.1
7. 03.10.1933	5:54 pm	Long Beach	6.4
8. 05.18.1940	8:37 pm	Imperial Valley	6.9
9. 04.10.1947	7:58 am	Manix	6.5
10. 07.21.1952	3:52 am	Kern County	7.5
11. 04.09.1968	6:29 pm	Borrego Mountain	6.6
12. 02.09.1971	6:01 am	San Fernando	6.6
13. 10.15.1979	4:16 pm	Imperial Valley	6.4
14. 07.08.1986	2:21 am	North Palm Springs	5.7
15. 10.01.1987	7:42 am	Whittier Narrows	5.9
16. 11.24.1987	5:15 am	Superstition Hills	6.6
17. 06.28.1991	7:43 am	Sierra Madre	5.8
18. 04.22.1992	9:50 pm	Joshua Tree	6.1
19. 06.28.1992	4:57 am	Landers	7.3
20. 06.28.1992	8:05 am	Big Bear	6.3
21. 01.17.1994	4:30 am	Northridge	6.7
22. 10.16.1999	2:46 am	Hector Mine	7.1
23. 12.22.2003	11:15 am	San Simeon	6.5
24. 07.29.2008	11:42 am	Chino Hills	5.4
25. 04.04.2010	3:40 pm	Northern Baja	7.2



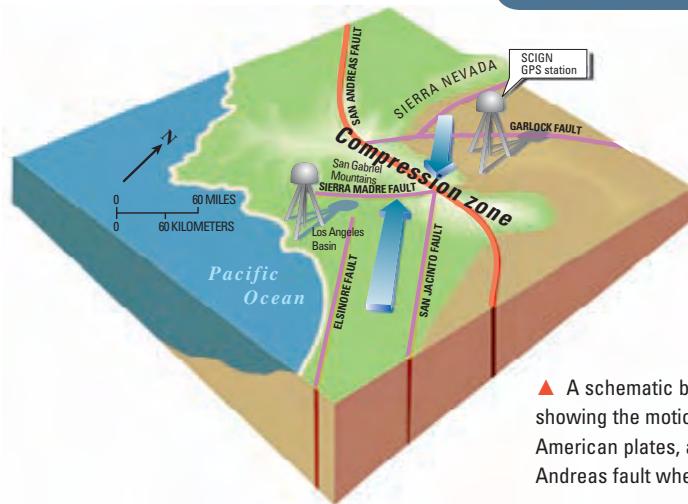
▲ Earthquakes plotted on this map (at their epicenters) include: significant earthquakes since 1850 as red numbered circles corresponding to the table at left; earthquakes larger than magnitude 5.5 (1850-1932) and magnitude 4 (1933-2008) as orange and red small circles; and earthquakes smaller than magnitude 4 (1933-2008) as blue dots. While there are thousands of earthquakes shown, this is only a very small window on the earthquake history of Southern California! For maps of recent earthquake information see page 31.

### Geologic rates

The rate of plate movement along the San Andreas fault, 33 millimeters (1.3 inches) each year, is about how fast your fingernails grow. As a result, Los Angeles City Hall is now 2.7 meters (9 feet) closer to San Francisco than when it was built in 1924. It would take a mere (geologically speaking) 2 million years for your nails to extend 100 kilometers (60 miles) from San Bernardino to Palmdale. It took many millions of years of movement on faults (earthquakes) to shape Southern California's current landscape.



- 1 San Andreas fault
- 2 San Jacinto fault
- 3 Elsinore fault
- 4 Imperial fault



▲ A schematic block model of Southern California showing the motion of the Pacific and North American plates, and the big bend of the San Andreas fault where the plates squeeze together.

▲ SCEC Community Fault Model This map shows the 3-dimensional structure of major faults beneath Southern California. Vertical faults such as the San Andreas (red band from top left to bottom right) are shown as a thin strip. Faults that are at an angle to the surface are shown as wider ribbons as they lie beneath broad areas (the nearest fault to you might be a few miles beneath your home). Areas that seem to have few faults can still experience strong shaking from earthquakes on unmapped faults or from large earthquakes on distant faults.

**MYTH #2** Don't be fooled!**"AND THE EARTH OPENED..."**

A popular literary device is a fault that opens during an earthquake to swallow up an annoying character. But unfortunately for principled writers, gaping faults exist only in novels. The ground moves across a fault during an earthquake, not away from it. If the fault could open, there would be no friction. Without friction, there would be no earthquake.

**FUTURE EARTHQUAKES**

We know that Southern California is subject to frequent—and sometimes very destructive—earthquakes. Forecasts of future quakes help us prepare for these inevitable events. But scientists cannot yet make precise predictions of their date, time, and place, so earthquake forecasts are in the form of probabilities that quakes of certain sizes will occur over longer periods of time.

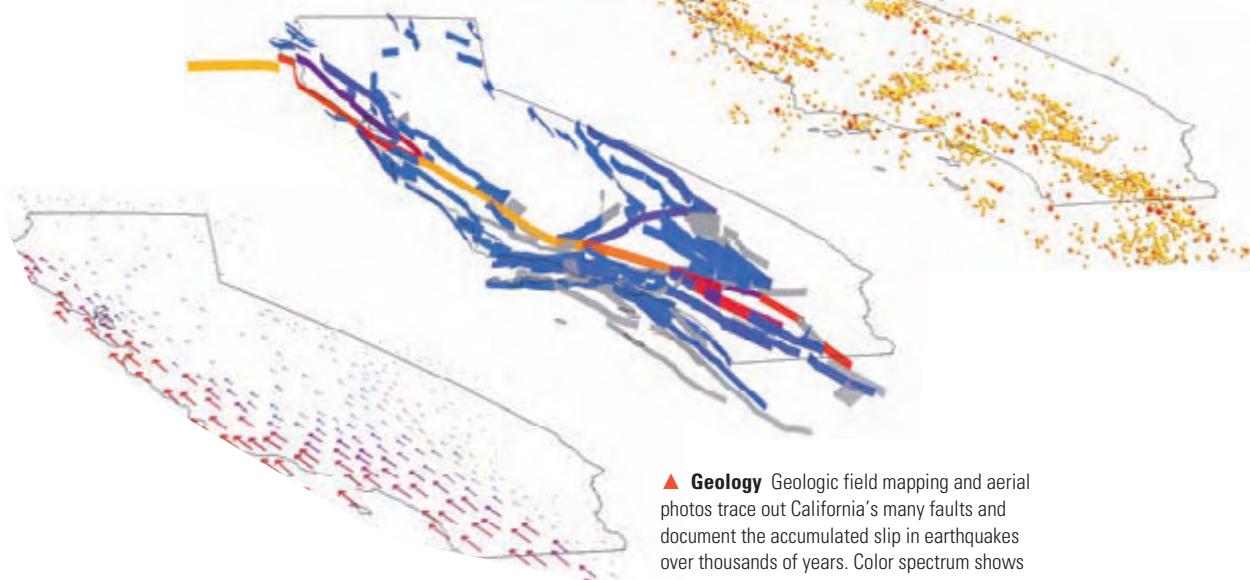
The most comprehensive statewide analysis of earthquake probabilities (see below), determined that the chance of having one or more magnitude 6.7 or larger earthquakes in California over the next 30 years is 99.7% (see map at lower right). The fault with the highest probability of such earthquakes is the southern San Andreas—59% in the next 30 years. For powerful quakes of magnitude 7.5 or greater, there is a 37% chance that one or

more will occur in the next 30 years in Southern California.

These results are incorporated into national seismic hazard maps, used for implementing building codes, setting earthquake insurance rates, and prioritizing emergency preparedness activities. These maps combine earthquake rupture forecasts with formulas for how shaking varies with distance and factors such as distance from the epicenter and local soil conditions (see page 30).

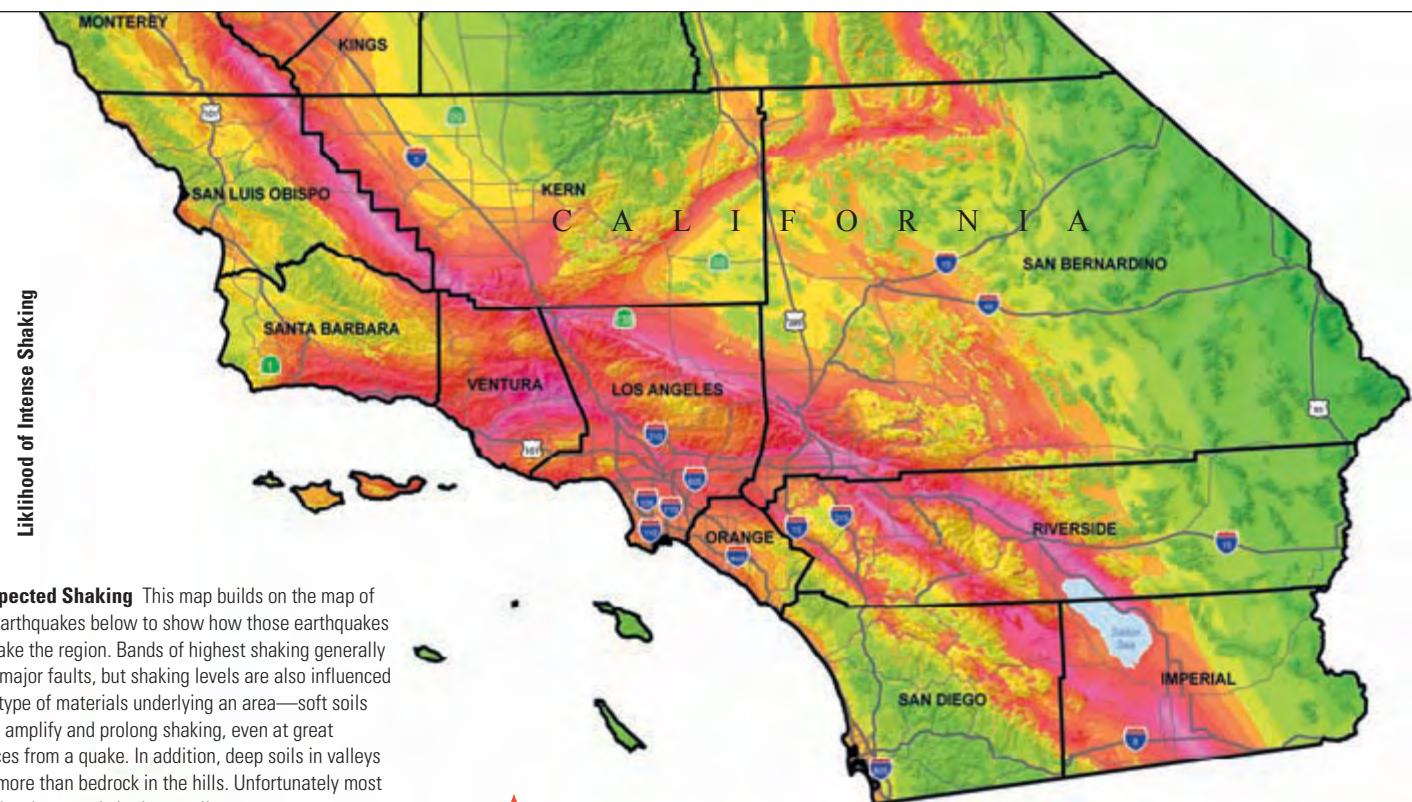
A seismic hazard map produced by the California Geological Survey is shown at top right. Areas in red and pink are more likely to experience strong earthquake shaking. The map adds together shaking from all potential earthquakes. Smaller earthquakes will only cause shaking locally, while larger earthquakes may cause strong shaking throughout Southern California.

▼ **Seismology** Monitoring instruments provide a record of California earthquakes during recent historical times—where and when they occur and how strong they are.

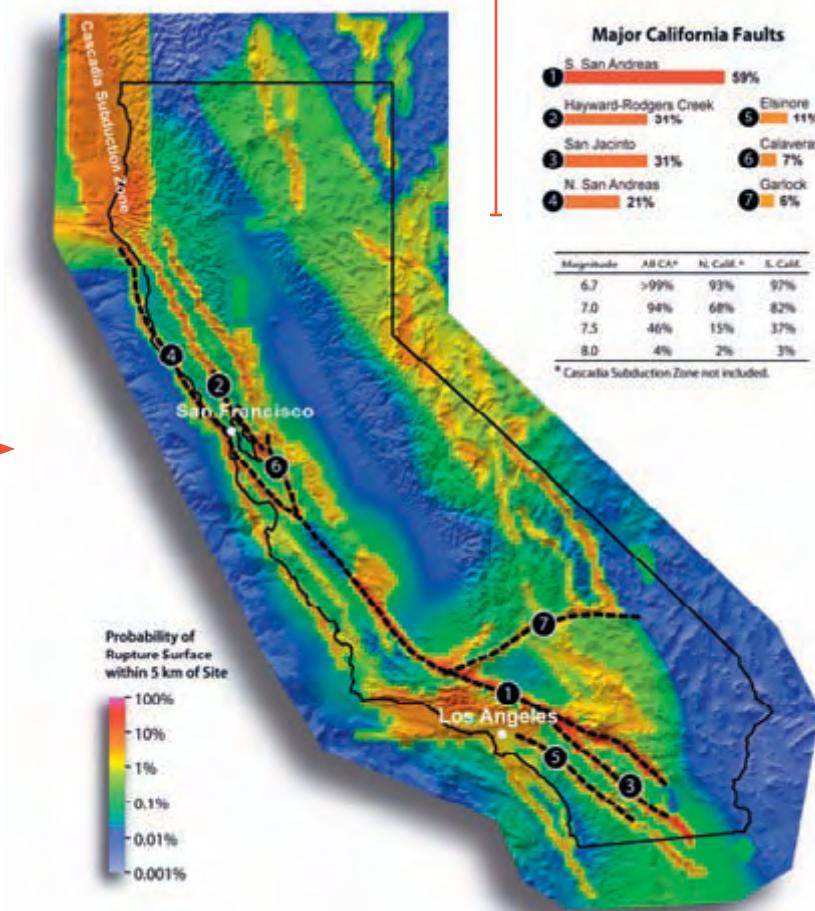


▲ **Geodesy** Global positioning system (GPS) observations by satellite document how fast various points in California are moving (arrows) in response to the steady motion of the Pacific and North American tectonic plates.

▲ **Geology** Geologic field mapping and aerial photos trace out California's many faults and document the accumulated slip in earthquakes over thousands of years. Color spectrum shows rates of slip, from fast (purple and red) to very slow (dark blue).



► **Expected Shaking** This map builds on the map of likely earthquakes below to show how those earthquakes will shake the region. Bands of highest shaking generally follow major faults, but shaking levels are also influenced by the type of materials underlying an area—soft soils tend to amplify and prolong shaking, even at great distances from a quake. In addition, deep soils in valleys shake more than bedrock in the hills. Unfortunately most urban development is in these valleys.



## Earthquake Forecast

Multidisciplinary groups of scientists and engineers, each known as a “Working Group on California Earthquake Probabilities (WGCEP)” have developed earthquake forecasts since 1988. The 2007 WGCEP was commissioned to develop an updated, statewide forecast. The result is the *Uniform California Earthquake Rupture Forecast*, available for download at [www.scec.org/ucerf](http://www.scec.org/ucerf). Organizations sponsoring WGCEP 2007 include the USGS, California Geological Survey, the Southern California Earthquake Center, and the California Earthquake Authority. The comprehensive new forecast builds on previous studies and also incorporates abundant new data and improved scientific understanding of earthquakes.

### ► The Composite Forecast—UCERF

The final forecast results from evaluating and integrating several types of scientific data. This map shows the likelihood of having a nearby earthquake rupture (within 3 or 4 miles) for all areas of California. Areas along major faults (numbered) stand out as having the highest probabilities for earthquake rupture.



## TSUNAMI HAZARDS

A tsunami is a series of waves or surges most commonly caused by an earthquake beneath the sea floor. Tsunamis can cause great loss of life and property damage in coastal areas. Very large tsunamis can cause damage to coastal regions thousands of miles away from the earthquake that caused them.

- Beaches, lagoons, bays, estuaries, tidal flats and river mouths are the most dangerous places to be. It is rare for a tsunami to penetrate more than a mile inland.
- Tsunami waves are unlike normal coastal waves. Tsunamis are more like a river in flood or a sloping mountain of water and filled with debris. Tsunamis cannot be surfed. They have no face for a surfboard to dig into and are usually filled with debris.
- Large tsunamis may reach heights of twenty to fifty feet along the coast and even higher in a few locales. The first tsunami surge is not the highest and the largest surge may occur hours after the first wave. It is not possible to predict how many surges or how much time will elapse between waves for a particular tsunami.
- The entire California Coast is vulnerable to tsunamis. The tsunami generated by the 2011 Tohoku earthquake off the coast of Japan caused damage to harbors and ports all along California's coast. A dozen people were killed in California following the 1964 Alaska earthquake. Tsunamis from local sources are also possible.



There are two ways to find out if a tsunami may be coming. These natural and official warnings are equally important. Respond to whichever comes first.

**Natural warning.** Strong ground shaking, a loud ocean roar, or the water receding unusually far exposing the sea floor are all nature's warnings that a tsunami may be coming. If you observe any of these warning signs, immediately go to higher ground or inland. A tsunami may arrive within minutes and may last for eight hours or longer. Stay away from coastal areas until officials announce that it is safe to return.

**Official warning.** You may hear that a Tsunami Warning has been issued. Tsunami Warnings might come via radio, television, telephone, text message, door-to-door contact by emergency responders, NOAA weather radios, or in some cases by outdoor sirens. Move away from the beach and seek more information on local radio or television stations. Follow the directions of emergency personnel who may request you to evacuate beaches and low-lying coastal areas. Use your phone only for life-threatening emergencies.

## TSUNAMIwatch

### When should I evacuate?

Evacuation should not be automatic. Before evacuating you should determine if you are in a hazard zone and consider possible hazards that may exist along your evacuation route. Visit [www.tsunami.ca.gov](http://www.tsunami.ca.gov) to find out if you live, work, or play in a tsunami hazard zone.

**COUNT** how long the earthquake lasts. If you feel more than 20 seconds of very strong ground shaking and are in a tsunami hazard zone, evacuate as soon as it is safe to do so. If you are on the beach or in a harbor and feel an earthquake —no matter how small—immediately move inland or to high ground.

**GO ON FOOT.** Roads and bridges may be damaged. Avoid downed power lines. If evacuation is impossible, go to the third or higher floor of a sturdy building or climb a tree. This should only be used as a last resort.

If you hear that a tsunami warning has been issued but did not feel an earthquake, get more information. Listen to the radio, television or other information sources and follow the instructions of emergency personnel.

If you are outside of a tsunami hazard zone, take no action. You are safer staying where you are.

### ► How Tsunamis are Formed

- 1 Gravity pulls the offshore Gorda and Juan de Fuca plates beneath the North American Plate. Most of the time the two plates are firmly stuck together along the boundary (red zone).



- 2 Over time, the North American plate is squeezed and bulges up as the Gorda plate moves beneath it.

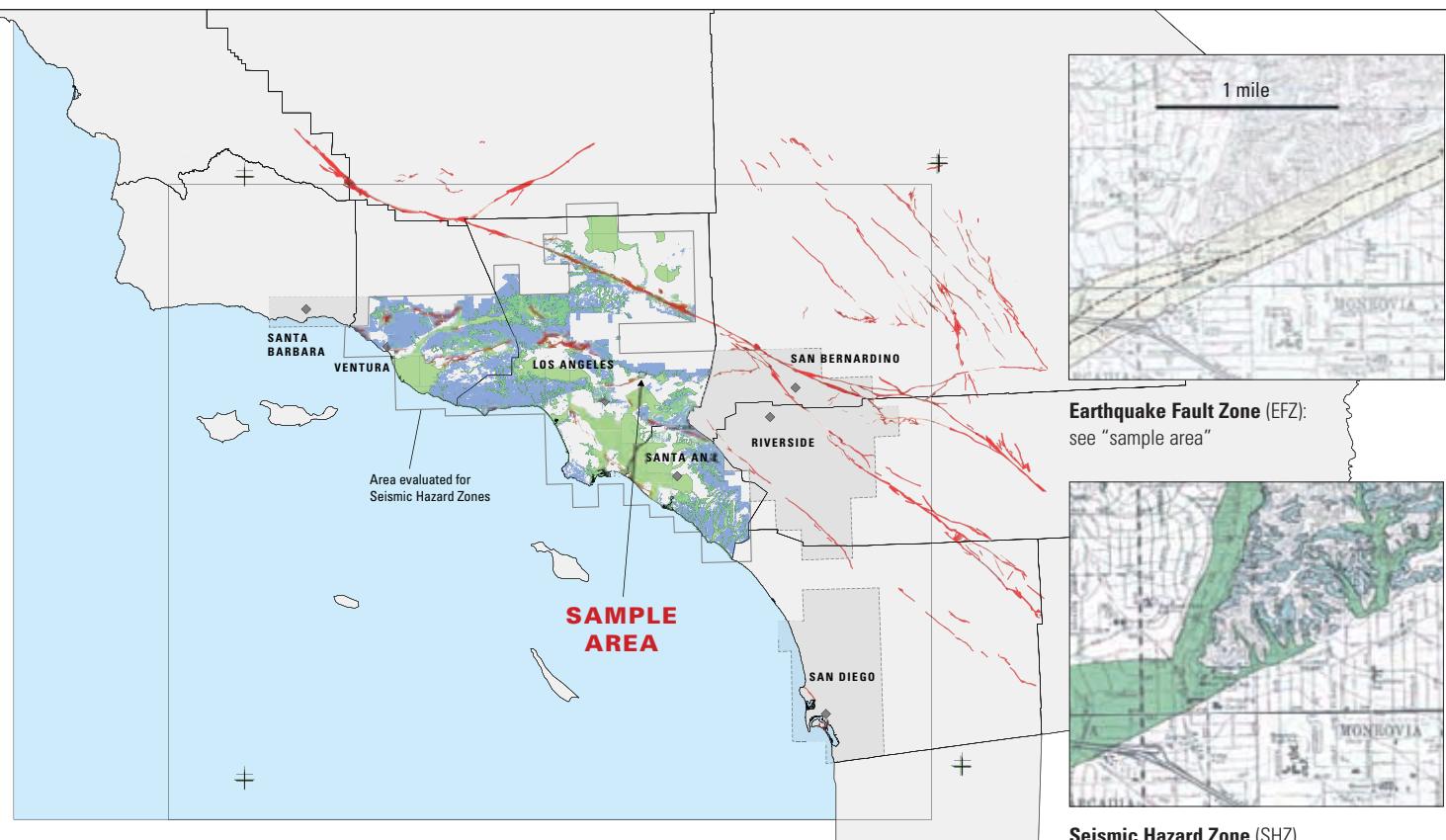


- 3 Eventually the stuck area breaks along the boundary, causing a large earthquake. Like a spring, the overriding North American Plate jumps upward and seaward, lifting the water above it.



- 4 The water bulge sends waves both east towards the coast and west into the Pacific. The first waves reach nearby shores only minutes after the earthquake. The other set of waves may damage distant coastal areas many hours later.





**Faults, liquefaction, and landslides:** Red zones are Earthquake Fault Zones with potential for surface faulting. Blue and green zones are Seismic Hazard Zones with a potential for landslides and liquefaction, respectively. Shaded areas indicate future Seismic Hazard evaluation and zoning.

## OTHER HAZARDS

In addition to strong shaking during earthquakes and the potential for tsunamis along the coast, there are location-specific hazards that can cause additional damage: surface rupture, liquefaction, and landslides. The California Geological Survey produces maps that identify Earthquake Fault Zones and Seismic Hazard Zones where these hazards may occur. State laws require that every person starting to “put down roots” by buying a home or real property in California be told if the property is in one of these zones. You can also visit [myhazards.ca.legis.ca.gov](http://myhazards.ca.legis.ca.gov) which has an interactive map for learning about the hazards where you live or work.

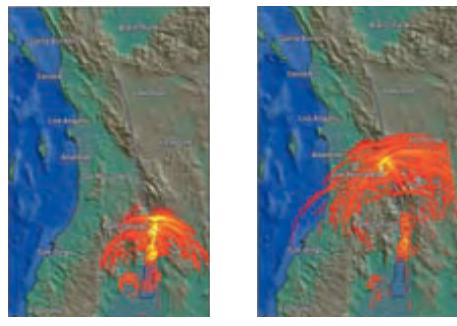
**Seismic Hazard Zones (SHZs)** identify areas that may be prone to liquefaction or landsliding triggered by earthquake shaking. Liquefaction is a temporary loss of strength in the ground that can occur when certain water saturated soils are shaken during a strong earthquake. When this occurs buildings can settle, tilt, or shift. Landsliding can occur during an earthquake where shaking reduces the strength of the slope. These hazards can usually be reduced or eliminated through established engineering methods. The law requires that property being developed within these zones be evaluated to determine if a hazard exists at the site. If so, necessary design changes must be made before a permit is granted for residential construction. Being in an SHZ does not mean that all structures in the zone are in danger. The hazard may not exist on each property or may have been mitigated. Mapping new SHZs in urban and urbanizing areas is ongoing statewide. Current zones, as established by the California Geological Survey, are indexed at [www.consrv.ca.gov/cgs](http://www.consrv.ca.gov/cgs).

**Earthquake Fault Zones (EFZs)** recognize the hazard of surface rupture that might occur during an earthquake where an active fault meets the earth’s surface. Few structures can withstand fault rupture directly under their foundations. The law requires that within an EFZ most structures must be set back a safe distance from identified active faults. The necessary setback is established through geologic studies of the building site. EFZs are narrow strips along the known active surface faults wherein these studies are required prior to development. Being located in an EFZ does not necessarily mean that a building is on a fault. Most of the important known faults in California have been evaluated and zoned, and modifications and additions to these zones continue as we learn more.



## ONE PLAUSIBLE BIG ONE

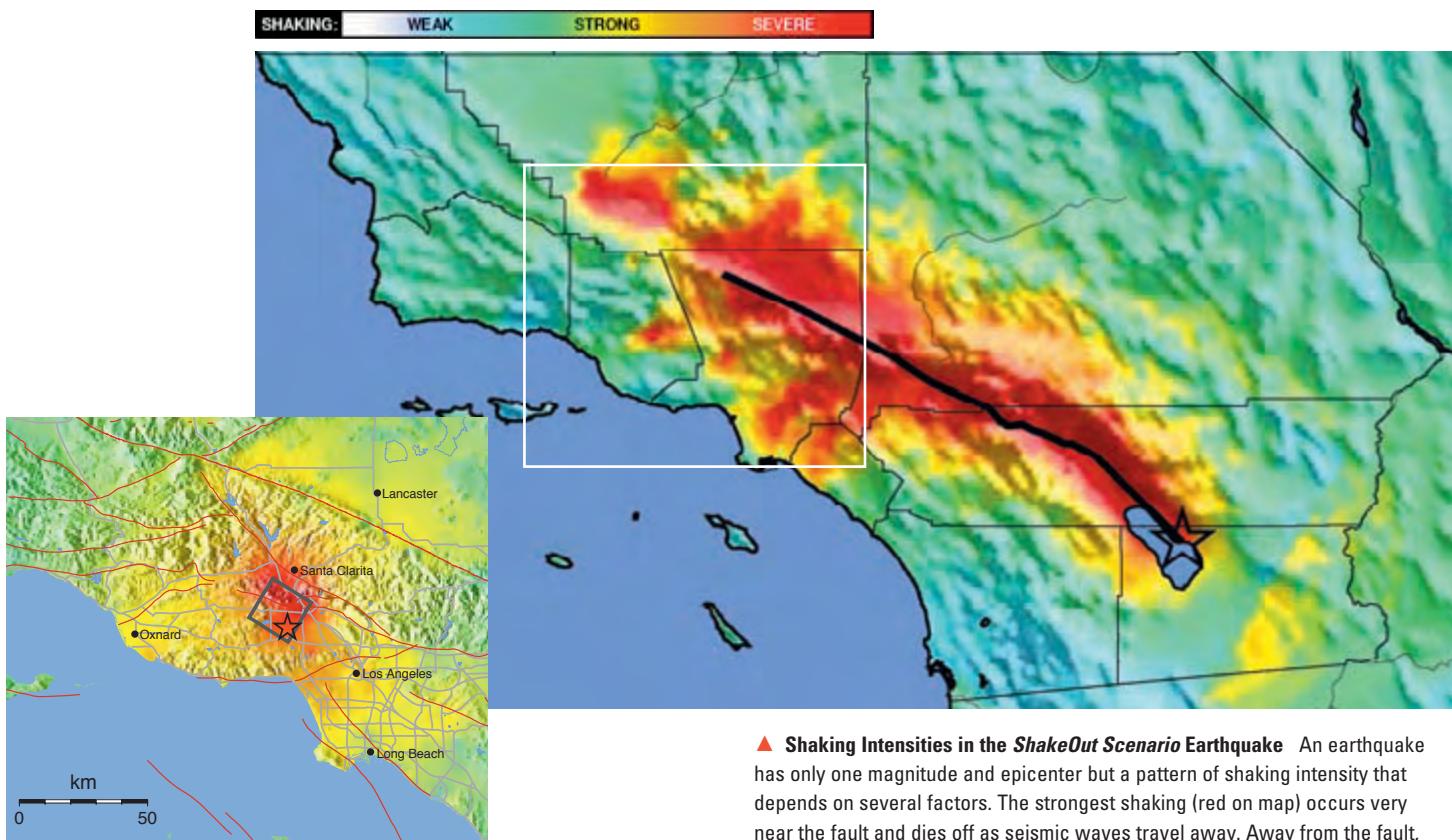
As shown on the previous page, it is only a matter of time before an earthquake strikes Southern California that is large enough to cause damage throughout the entire region. What will that earthquake be like, and what will its impacts be? Could this be Southern California's version of Hurricane Katrina? What could be done now to reduce these impacts? These are the kinds of questions that motivated the development of the *ShakeOut Earthquake Scenario*, a comprehensive study of a magnitude 7.8 earthquake, led by the U.S. Geological Survey with the Southern California Earthquake Center, California Geological Survey, and hundreds of experts. The study was the basis of The Great Southern California ShakeOut, the largest earthquake readiness campaign in U.S. history.



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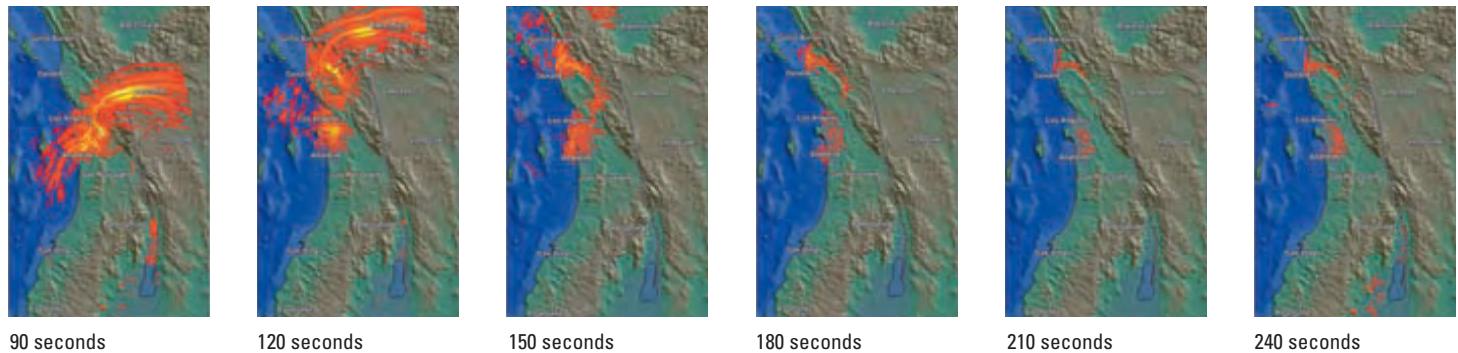
60 seconds

The "what if?" earthquake modeled in this study ruptures the southern San Andreas Fault for more than 200 miles (black line on map below). The epicenter is on the northeast side of the Salton Sea in Imperial County, though strong shaking will be produced all along the fault as it ruptures through the Coachella Valley, into San Bernardino, across the Cajon Pass and further to the northwest until ending near Lake Hughes west of Lancaster.



**▲ Shaking Intensities in the Northridge Earthquake** During the 1994 magnitude 6.7 Northridge earthquake, intense shaking affected a much smaller area and millions fewer people. Northridge was not a major earthquake and very few people have experienced one. Even for Scenario experts it is hard to imagine what one would be like. Even for Scenario experts, it proved challenging to think outside the "Northridge box" while studying a much larger earthquake. [Map credit: USGS]

**▲ Shaking Intensities in the *ShakeOut Scenario* Earthquake** An earthquake has only one magnitude and epicenter but a pattern of shaking intensity that depends on several factors. The strongest shaking (red on map) occurs very near the fault and dies off as seismic waves travel away. Away from the fault, in natural basins filled with sediments, some waves get trapped and reverberate, causing pockets of strong shaking (red and orange) that in this earthquake persist for as long as a minute. Ground shaking continues as the waves travel away, and in this earthquake, total shaking lasts for more than 3 minutes. [Map credit: USGS]



90 seconds

120 seconds

150 seconds

180 seconds

210 seconds

240 seconds

As the rupture progresses it will offset the ground along the fault by more than 20 feet in places, and bend or break any road, railroad, pipeline, aqueduct, or other lifeline that crosses the fault. Overall the rupture will produce more than 100 seconds of shaking throughout Southern California. As shown in the large ShakeMap at left, shaking will be strong along the fault but also further away where soil type, thickness of sediments, and other factors amplify earthquake shaking. In some areas, the ground will shift violently back and forth, moving nearly 2 meters (6 feet) in each second—shoving houses off foundations, sending unsecured furniture and objects flying.

The overall shaking in this earthquake will be more than 50 times the shaking produced by the Northridge earthquake (see inset at left). In addition, large earthquakes create earthquake waves that are never created by smaller earthquakes like Northridge. These *long period* waves can cause damage very far from the fault, and are especially damaging to tall buildings or certain infrastructure.

Finally, damage may also result when strong shaking occurs in areas prone to landslides and in materials that are susceptible to liquefaction whenever the groundwater is close enough to the surface. Maps of areas where landslides and liquefaction are possible in future earthquakes are available at [www.consrv.ca.gov/cgs](http://www.consrv.ca.gov/cgs).

**▲ Earthquake Shaking Animation** These computer-generated snapshots show maximum velocity of ground motion as the earthquake waves move out from the fault and travel through Southern California. Snapshots are taken at 30, 60, 90, 120, 150, 180, 210, and 240 seconds after the fault starts rupturing. Yellow indicates the most damaging level, with orange and red also likely to cause damage. Note the persistent shaking in sedimentary basins where waves have gotten trapped and reverberate. To view the complete movie, visit [urbanearth.usgs.gov/scenario08](http://urbanearth.usgs.gov/scenario08). [Images credit: Simulation by Rob Graves, URS Corporation, for the Southern California Earthquake Center on high-performance computers at the University of Southern California; images courtesy of Geoff Ely, University of California San Diego/San Diego Supercomputer Center]

## How to Use the *ShakeOut Scenario*

The Scenario describes a *what if* earthquake, not a prediction. More than 300 experts from research, government, and private industry, led by the U.S. Geological Survey, collaborated to identify the physical, social and economic consequences of one plausible earthquake on the San Andreas fault. The full report is available at [urbanearth.usgs.gov/scenario08](http://urbanearth.usgs.gov/scenario08). While this particular earthquake may never occur, that doesn't limit the value of the study.

Looking in detail at one major earthquake provides insight into how to prepare for the other earthquakes that may occur instead. Thus, **appropriate uses of the *ShakeOut Scenario*** include:

- Urban planning;
- Emergency response training;
- School, business, and public earthquake drills;
- Prioritization of preparedness efforts;
- Understanding potential impacts on financial and social systems; and
- Identifying possible vulnerabilities of infrastructure, especially due to interactions among systems that are usually considered separately.

When a major earthquake does occur, it may be on a different fault, or create a different pattern of ground shaking and damage. Thus, **inappropriate uses of the *ShakeOut Scenario*** include:

- Deciding where to live or work;
- Concluding you don't have an earthquake problem;
- Changing building codes; or
- Evaluating cost-effectiveness of mitigation.

**MYTH #3** Don't be fooled!**"BEACHFRONT PROPERTY IN ARIZONA"**

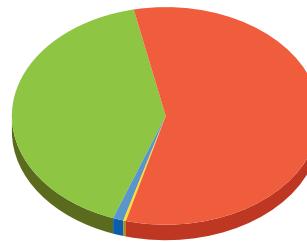
The idea of California falling into the ocean has had an enduring appeal to those envious of life in the Golden State. Of course, the ocean is not a great hole into which California can fall, but it is itself land at a somewhat lower elevation with water above it. The motion of plates will not make California sink—western California is moving horizontally along the San Andreas fault and up around the Transverse ranges.

**RECOVERING FROM A BIG ONE**

The *ShakeOut Scenario* evaluated all aspects of the major earthquake described on the previous page to estimate damages to buildings and infrastructure. From these estimates all other aspects of the study emerged, including emergency response in the critical first week after the earthquake, casualties, mental health and sheltering needs, and the impacts on different sectors of the region's diverse economy.

The study estimates that should it occur, this earthquake will cause some 1,800 deaths and 53,000 injuries. Yet this terrible tragedy could be considerably worse. By comparison, the similarly sized, 2008 Sichuan, China earthquake may have caused 100,000 fatalities.

The *ShakeOut Scenario*'s casualty numbers are a testament to decades of life safety improvements in California's building codes, which have evolved as understanding has grown regarding building performance in earthquakes. The intent of the building codes is to protect people during an earthquake, not to keep buildings functional after the quake. Nor do the building codes fix existing buildings that are now recognized to do poorly in earthquakes—it takes retrofitting to do that.

**Replacement Costs**

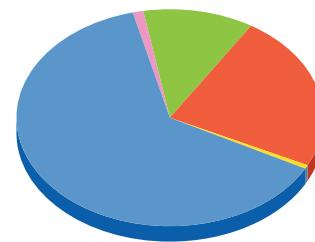
- Shaking Damage to Buildings and Contents
- Fire Damage to Buildings and Contents
- Highway Damage
- Pipeline Damage

Thousands of older buildings will collapse in the ShakeOut earthquake, and another 45,000 will be complete economic losses.

Earthquakes start fires in numerous ways, and earthquake damages to phones, roads, and buildings enable fires to spread before help can arrive. In areas where there is strong shaking to start fires, and tightly spaced wood buildings that allow fire to spread, the fires will grow into conflagrations, burning tens to hundreds of blocks. **Fires account for half of the ShakeOut Scenario casualty and loss estimates.**

This earthquake's economic losses total \$213 billion, due to shaking damage and several other factors. Because fire damage is so complete, the fires have the worst impact on the costs of replacing buildings and contents. However, disruption of utilities is the main reason that it will take a long time for business to get back to normal.

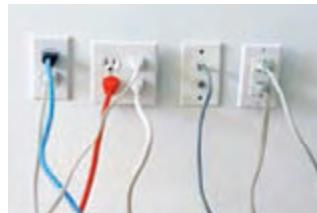
One important result of the *ShakeOut Scenario* study is that the key to recovery lies with infrastructure: the essential facilities like roads, hospitals and dams; and the lifelines that supply water, power, gas, and communication. The more damage there is to infrastructure, the slower the recovery.

**Business Interruption**

- Shaking Damage
- Fire Damage
- Transportation Disruption
- Utilities Disruption
- Ports Disruption

▲ The ShakeOut earthquake will cause many shocks to Southern California's regional economy. Understanding and comparing the impact of these shocks is important to recovery planning. When considering the cost of replacing lost buildings, building contents, and infrastructure, fire creates the biggest shock to the economic system, bigger than shaking, fault rupture, landslides, and liquefaction combined. This makes sense, because fire can destroy so completely. However, when considering the length of time that normal business will be interrupted, disruption of utility service creates the biggest shock. This makes sense, because few businesses can function without water or power.

## Lifelines and Facilities — The Key to Recovery



**Power** will go out immediately, everywhere, and restoration times vary. In the most heavily damaged areas, **electricity** will remain out for weeks or longer. Some residences will suffer broken **gas** lines when their houses slip from unbolted foundations.



**Water** will stop flowing in many taps for weeks or months. In many communities, strong ground shaking will break old, brittle water pipes and connectors, and there will be so many breaks that it will prove cheaper and faster to replace the entire conveyance system, rather than hunt and repair every break. The process will be neither cheap nor fast, and communities will compete for repair priority.



Many **wastewater** pipes are also old and brittle, and run alongside water pipes under the streets. Broken sewer pipes will contaminate broken water pipes, and in some places, tap water will be unsafe to drink for as long as a year.



**Telecommunications** will be out for at least a day, because of some damage and much overuse. Phone systems will be oversaturated because millions are trying to make calls at once. How cell phone towers are affixed to buildings is not regulated, so towers will be damaged by shaking. Two thirds of the region's internet lines will be ruptured by the fault.



**Transportation** by road and rail will be disrupted by fault rupture and landslides, and take months to repair. Retrofitting of state highway bridges prevents their collapse, but not those under most local jurisdictions. For months, getting around the southland will take longer, and travel time delays add more than \$4 billion to economic losses.



**Hospitals** in the hardest hit counties of Riverside, San Bernardino, and Los Angeles will be operating at reduced functionality. At a time when thousands of disaster victims need hospital care, some hospital buildings will be closed by structural damage; many others will be unusable because of non-structural damage such as broken water pipes and unsecured equipment.



**Public schools**—grades K-12 and community colleges—are protected by the Field Act, legislation that sets special construction and inspection standards. Structurally, public schools will hold up well, although non-structural and contents damage will pose problems. Private schools and universities are not protected by the Field Act and some will suffer both structural and non-structural damage.



The **Ports** of Los Angeles and Long Beach are important contributors to the region's economy. They will not suffer much damage from this far-away earthquake, but their flow of goods will be disrupted for months, as many principal train routes and truck routes are damaged by fault rupture.



▲ To bounce back quickly from a disaster, communities need to become resilient. Community resilience depends on how many individuals, businesses, schools, agencies, and organizations are prepared. It is a lot like voting, where personal decisions and actions can affect everyone: an individual learns about the issues (learns about the earthquake impacts and mitigation strategies), decides how to vote (decides which mitigation efforts will best protect loved ones and financial security), then casts a ballot (takes action to increase preparedness). If enough people vote the same way (get prepared), they will have a winning platform (they will have a resilient community)!

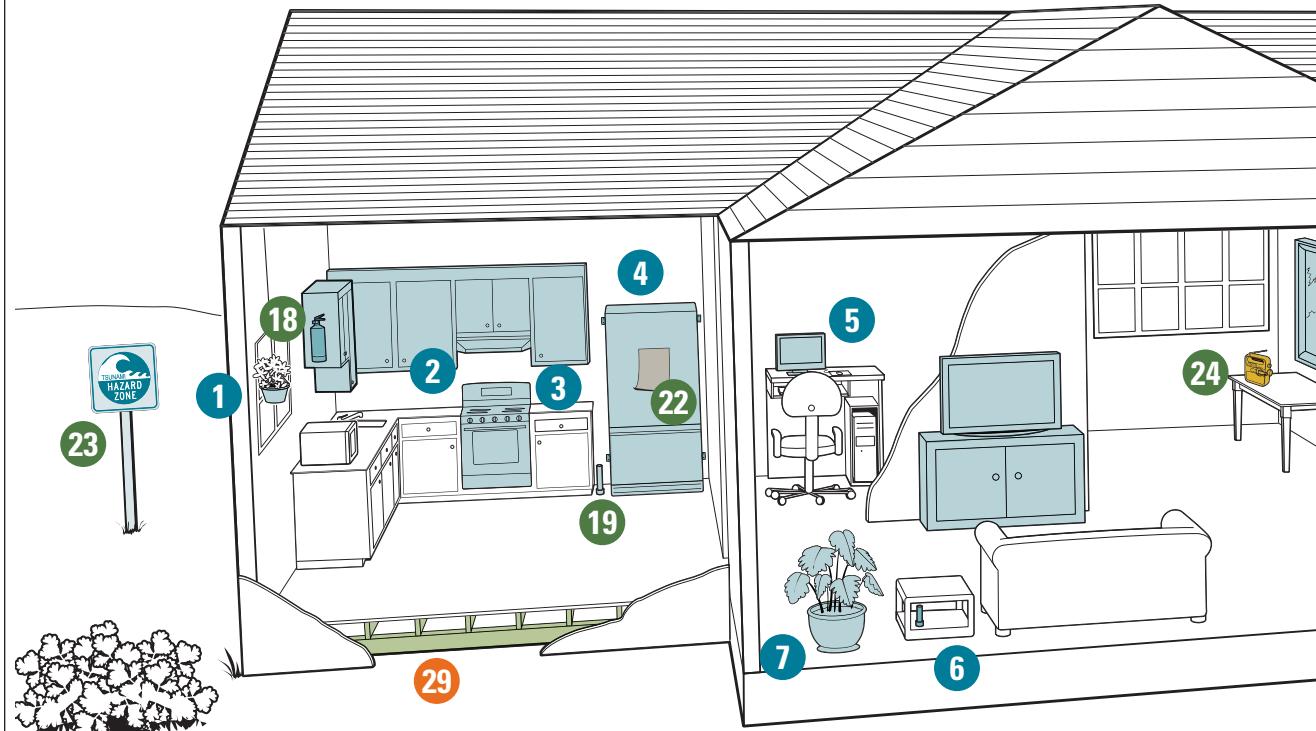


## The Seven Steps to Earthquake Safety

Earthquakes and tsunamis are inevitable but the damage is not—even in a very large earthquake. Preparing for the next damaging earthquake can help you and your family to survive and recover.

The seven steps that follow include actions to keep you and your loved ones safe, reduce potential damage and recover quickly. These steps should also be followed in schools, workplaces, and other facilities. By following them, countless casualties can be avoided and millions of dollars saved.

Preparation is the key to surviving a disaster—that much is clear—but where should you start? Start by talking—talk to your family, friends, neighbors and co-workers about what you've learned in this handbook about earthquakes and tsunamis in Southern California. Then discuss what you have done to prepare and together plan your next steps.



Many people are overwhelmed by the mere prospect of a natural disaster and, as a result, don't prepare at all. Do not fall into that trap. You can start today by following these seven steps.

### PREPARE

**before an earthquake or tsunami:**

1. Secure your space (see illustration below and page 16)
2. Create a plan (page 18)
3. Prepare disaster kits (page 19)
4. Strengthen your home (page 20)

### SURVIVE

**during an earthquake:**

5. Drop, cover, and hold on (page 22)

### RECOVER

**after an earthquake or tsunami:**

6. Check for injuries and damage (page 23)
7. Follow your plan (page 24)

**STEP 1****Secure your space**

- 1 Hang plants in lightweight pots with closed hooks, well secured to a joist or stud and far away from windows.
- 2 Install strong latches on kitchen cabinets.
- 3 Use flexible connections where gas lines meet appliances.
- 4 Remove or lock refrigerator wheels, secure to studs.
- 5 Secure valuable electronics items such as computers and televisions.
- 6 Keep breakables in low or secure cabinets with latches.
- 7 Move heavy plants and other large items to floor or low shelves.
- 8 Hang mirrors and pictures on closed hooks.
- 9 Secure free-standing woodstove or fireplace insert.
- 10 Keep heavy unstable objects away from doors and exit routes.
- 11 Place bed away from windows or items that may fall.
- 12 Secure knick knacks and other small valuables with museum putty.
- 13 Brace overhead light fixtures.
- 14 Place only light weight/soft items over bed.
- 15 Secure top-heavy furniture to studs.
- 16 Secure water heater with metal straps attached to studs.
- 17 Trim hazardous tree limbs.

**STEP 2****Create a plan**

- 18 Store fire extinguisher (type ABC) in easily accessible location.
- 19 Keep several flashlights in easily accessible places around the house.
- 20 Keep wrench or turn-off tool in water proof wrap near gas meter.
- 21 Know the location of your main electrical switch (fuse box or circuit breaker).
- 22 Have your emergency plan accessible and discuss with all family members.
- 23 Know whether you live, work or play in a tsunami hazard zone.
- 24 Obtain a NOAA Weather Radio with the Public Alert feature to notify you of tsunamis and other hazards.
- 25 Keep flashlight, slippers and gloves next to beds.
- 26 Keep gas tank at least half full.

**STEP 3****Prepare disaster kits**

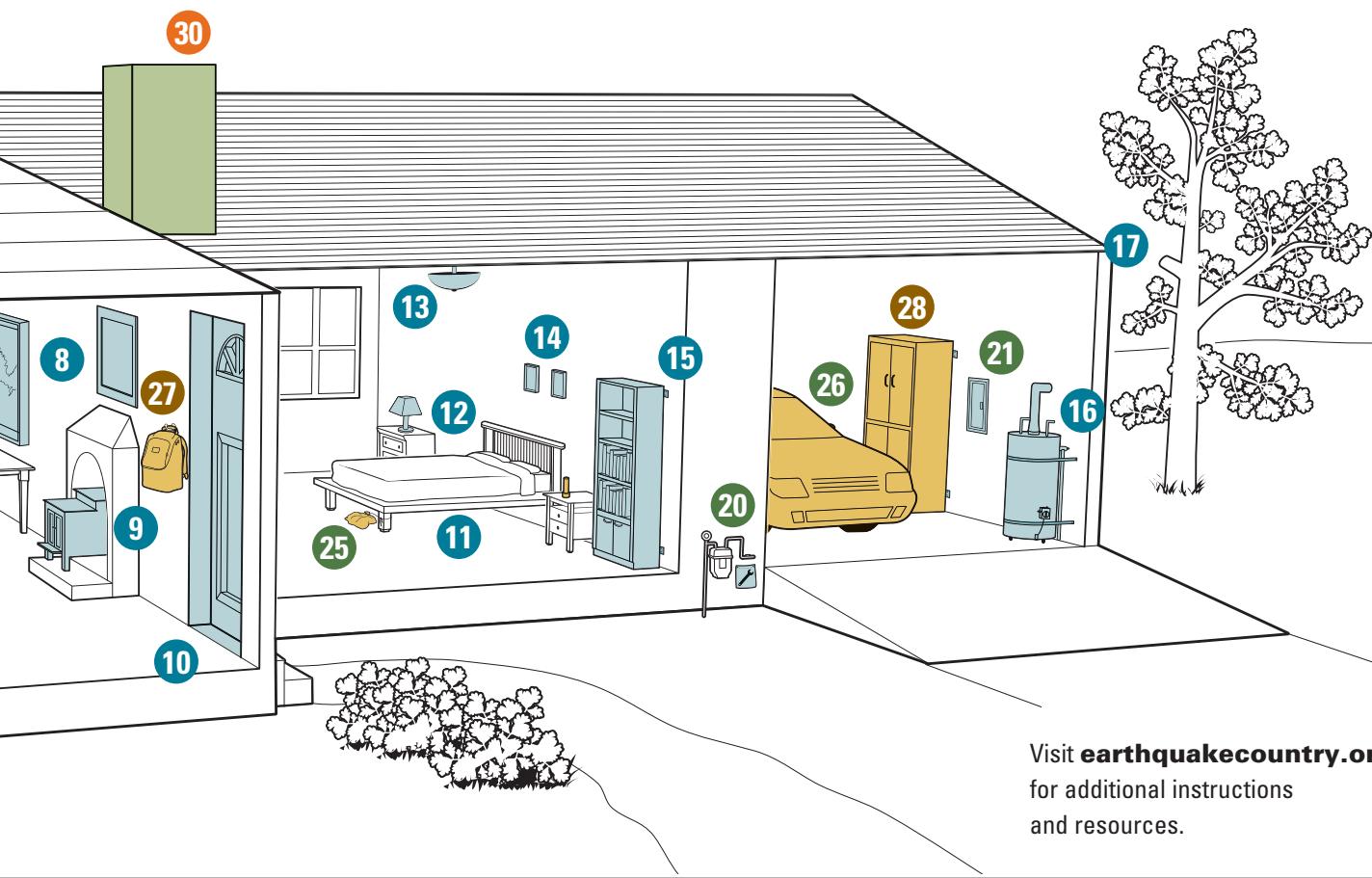
- 27 Keep an emergency backpack with copies of important documents near the door to grab and go.
- 28 Store emergency food and water supplies in a dry accessible area. Include first aid kit, extra cash, portable radio, extra batteries, medications and other necessary supplies.

**STEP 4****Strengthen your home**

- 29 Use anchor bolts every 4 to 6 feet to secure home to foundation.
- 30 Reinforce brick chimneys

**STEPS 5-7****During and after the earthquake**

see pages 22–25



Visit [earthquakecountry.org](http://earthquakecountry.org)  
for additional instructions  
and resources.



## 1

**IDENTIFY POTENTIAL HAZARDS IN YOUR HOME AND BEGIN TO FIX THEM.**

Earthquake safety is more than minimizing damage to buildings. We must also secure the contents of our buildings to reduce the risk to our lives and our pocketbooks.

Several people died and thousands were injured in the Northridge earthquake because of unsecured building contents such as toppling bookcases. Many billions of dollars were lost due to this type of damage. Much of this damage and injury could have been prevented in advance through simple actions to secure buildings and contents.

You should secure anything 1) heavy enough to hurt you if it falls on you, or 2) fragile or expensive enough to be a significant loss if it falls. In addition to contents within your living space, also secure items in other areas, such as your garage, to reduce damage to vehicles or hazardous material spills.

There may be simple actions you can do right now that will protect you if an earthquake happens tomorrow. START NOW by moving furniture such as bookcases away from beds, sofas, or other places where people sit or sleep. Move heavy objects to lower shelves. Then begin to look for other items in your home that may be hazardous in an earthquake.

Some of the actions recommended on this page may take a bit longer to complete, but all are relatively simple. Most hardware stores and home centers now carry earthquake safety straps, fasteners, and adhesives.

**In the kitchen**

Unsecured cabinet doors fly open during earthquakes, allowing glassware and dishes to crash to the floor. Many types of latches are available to prevent this: child-proof latches, hook and eye latches, or positive catch latches designed for boats. Gas appliances should have flexible connectors to reduce the risk of fire. Secure refrigerators and other major appliances to walls using earthquake appliance straps.

**Objects on open shelves and tabletops**

Collectibles, pottery objects, and lamps can become deadly projectiles. Use either hook and loop fasteners on the table and object, or non-damaging adhesives such as earthquake putty, clear quake gel, or microcrystalline wax to secure breakables in place. Move heavy items and breakables to lower shelves.

**step 1 PREPARE before the earthquake**

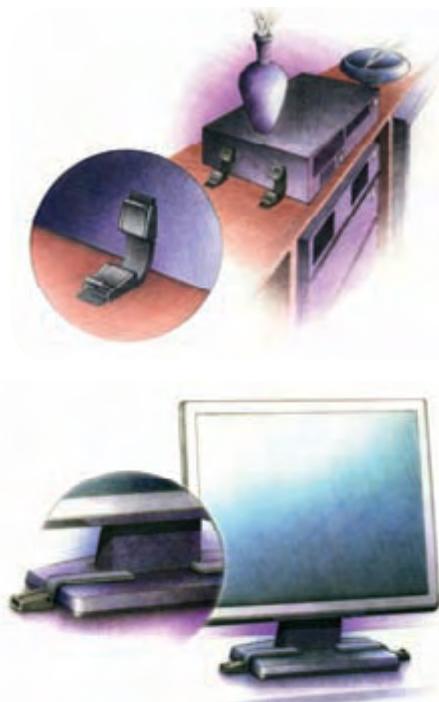


### Hanging objects

Mirrors, framed pictures, and other objects should be hung from closed hooks so that they can't bounce off the walls. Pictures and mirrors can also be secured at their corners with earthquake putty. Only soft art such as tapestries should be placed over beds or sofas.

### Electronics

Televisions, stereos, computers and microwaves and other electronics are heavy and costly to replace. They can be secured with flexible nylon straps and buckles for easy removal and relocation.



### Furniture

Secure the tops of all top-heavy furniture, such as bookcases and file cabinets, to a wall. Be sure to anchor to the stud, and not just to the drywall. Flexible fasteners such as nylon straps allow tall objects to sway without falling over, reducing the strain on the studs. Loose shelving can also be secured by applying earthquake putty on each corner bracket.

### In the garage or utility room

Items stored in garages and utility rooms can fall, causing injuries, damage, and hazardous spills or leaks. They can also block access to vehicles and exits. Move flammable or hazardous materials to lower shelves or the floor.

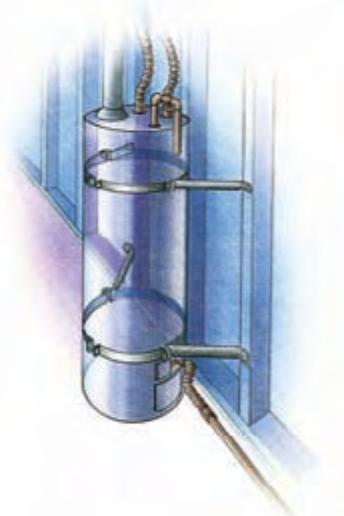
### Water heater

Unsecured water heaters often fall over, rupturing rigid water and gas connections. If your water heater does not have two straps around it that are screwed into the studs or masonry of the wall, then it is not properly braced. This illustration shows one method of bracing a water heater. Bracing kits are available that make this process simple. Have a plumber install flexible (corrugated) copper water connectors, if not already done.



Additional information, including how-to instructions, is available at

[www.earthquakecountry.org](http://www.earthquakecountry.org)  
[www.quakeinfo.org](http://www.quakeinfo.org)





## 2

**CREATE A DISASTER-PREPAREDNESS PLAN.**

Will everyone in your household do the right thing during the violent shaking of a major earthquake? Before the next earthquake, get together with your family or housemates to plan now what each person will do before, during and after.

Once the earthquake is over, we will have to live with the risk of fire, the potential lack of utilities and basic services, and the certainty of aftershocks. By planning now, you will be ready. This plan will also be useful for other emergencies.

**TSUNAMI watch**

Does your community:

- have plans to notify you if a tsunami warning is issued?
- have a designated evacuation zone and posted tsunami hazard signs?
- practice evacuation drills?
- conduct tsunami education and awareness campaigns?

Your community can do all of the above and more if it has been recognized by the National Weather Service as TsunamiReady. The TsunamiReady program sets guidelines for adequate tsunami readiness, including the ability to receive and send out tsunami warnings, designation of tsunami hazard zones and evacuation routes, and outreach programs that address both natural and official warnings. Find out if your community is recognized as TsunamiReady at [tsunamiready.noaa.gov](http://tsunamiready.noaa.gov). If it isn't, find out what you can do to encourage your community to gain this recognition

**Am I at risk?**

Find out if your home or business is at risk to for earthquakes, tsunami's, and related hazards. Earthquakes can occur everywhere in California which means all Californians live with an earthquake risk. In addition to the shaking caused by earthquakes, other things can occur such as landslides, surface fault ruptures and liquefaction—all of which may cause injury or property damage. In addition, some areas within California are vulnerable to tsunamis should an earthquake occur off the coast. Use signs and maps to find out which areas are hazardous. On the open coast areas 100 feet or more in elevation and low areas more than two miles inland are safe.

Visit [myhazards.calema.ca.gov](http://myhazards.calema.ca.gov) to create a map of the hazards you may face in your community, and contact your local city or county government for further details on how to be prepared where you live. Then quickly create a plan to reduce your risks.

**Plan NOW to be safe during an earthquake:**

- Practice "drop, cover, and hold on." (See Step 5, page 22)
- Identify safe spots in every room, such as under sturdy desks and tables.
- Learn how to protect yourself no matter where you are when an earthquake strikes.



[www.dropcoverholdon.org](http://www.dropcoverholdon.org)

**Plan NOW to respond after an earthquake:**

- Keep shoes and a flashlight next to each bed.
- Get a fire extinguisher for your home. Your local fire department can train you and your family to use it properly.
- Teach everyone in your household to use emergency whistles and/or to knock three times repeatedly if trapped. Rescuers are trained to listen for such sounds.
- Identify the needs of household members and neighbors with special requirements or situations, such as use of a wheelchair, walking aids, special diets, or medication.
- Take a Red Cross first aid and cardiopulmonary resuscitation (CPR) training course. Learn who else in your neighborhood is trained.
- Know the location of utility shutoffs and keep needed tools nearby. Know how to turn off the gas, water, and electricity to your home. Only turn off the gas if you smell or hear leaking gas.
- Install smoke alarms and test them monthly. Change the battery once a year, or when the alarm emits a "chirping" sound (low-battery signal).
- Work with your neighbors to identify who has skills and resources that will be useful in an emergency, and who may need special attention (children, elderly, disabled, etc.)
- Check with your city or county to see if there is a Community Emergency Response Team (CERT) in your area. If not, ask how to start one.

**Plan NOW to communicate and recover after an earthquake:**

- Select a safe place outside of your home to meet your family or housemates after the shaking.
- Designate an out-of-area contact person who can be called by everyone in the household to relay information. Obtain a NOAA Weather Radio with the Public Alert feature to notify you of tsunamis and other hazards.
- Provide all family members with a list of important contact phone numbers.
- Determine where you might live if your home cannot be occupied after a disaster.
- Know about the earthquake plan developed by your children's school or day care. Keep school emergency release card(s) current.
- Keep copies of essential documents, such as identification, insurance policies, and financial records, in a secure, waterproof container, and keep with your disaster supplies kits. Include a household inventory (a list and photos or video of your belongings).
- You may have to take additional steps, especially if someone has a disability or other access and functional needs. Register with your local fire department for assistance so needed help can be provided.

The Great California ShakeOut each October is an opportunity to practice your plan. Be sure to share your plan with people who take care of your children, pets, or home.

**step 2 PREPARE** before the earthquake

# 3

## PREPARE DISASTER SUPPLIES KITS.

### Personal disaster supplies kits

Everyone should have personal disaster supplies kits. Keep them where you spend most of your time, so they can be reached even if your building is badly damaged. The kits will be useful for many emergencies, and especially if you need to evacuate out of a tsunami hazard zone.

Keep one kit in your **home**, another in your **car**, and a third kit at **work**. Backpacks or other small bags are best for your disaster supplies kits so you can take them with you if you evacuate. Include at least the following items:

- Medications, prescription list, copies of medical cards, doctor's name and contact information
- Medical consent forms for dependents
- First aid kit and handbook
- Examination gloves (non-latex)
- Dust mask
- Spare eyeglasses or contact lenses and cleaning solution
- Bottled water
- Whistle (to alert rescuers to your location)
- Sturdy shoes
- Emergency cash (ATMs might not work)  
Small bills and coins are best.
- Copies of personal identification (drivers license, work ID card, etc.)
- Road maps
- List of emergency out-of-area contact phone numbers
- Snack foods, high in water and calories
- Working flashlight with extra batteries and light bulbs, or light sticks
- Personal hygiene supplies
- Comfort items such as games, crayons, writing materials, teddy bears
- Toiletries and special provisions you need for yourself and others in your family including elderly, disabled, small children, and animals.
- If you have difficulty communicating, keep a notebook, pencils, etc. in several locations

### Household disaster supplies kit

Electrical, water, transportation, and other vital systems can be disrupted for several days or much longer in some places after a large earthquake. Emergency response agencies and hospitals could be overwhelmed and unable to provide you with immediate assistance. Providing first aid and having supplies will save lives, will make life more comfortable, and will help you cope after the next earthquake.

In addition to your personal disaster supplies kits, store a **household** disaster supplies kit in an easily accessible location (in a large watertight container that can be easily moved), with a supply of the following items to last at least 3 days and ideally for 2 weeks:

- Water (minimum one gallon a day for each person and pet, for drinking, cooking, and sanitation)
- Wrenches to turn off gas and water supplies
- Work gloves and protective goggles
- Heavy duty plastic bags for waste, and to serve as tarps, rain ponchos, and other uses
- Portable radio with extra batteries (or hand crank for charging)
- Additional flashlights or light sticks
- Non-powered corded phone (if only cordless phones are normally used)
- Canned and packaged foods
- Charcoal or gas grill for outdoor cooking and matches if needed
- Cooking utensils, including a manual can opener
- Pet food and pet restraints. Include supplies for seeing eye, hearing, or companion dogs.
- Comfortable, warm clothing including extra socks
- Blankets or sleeping bags, and perhaps even a tent
- Copies of vital documents such as insurance policies

Use and replace perishable items like water, food, medications and batteries on a yearly basis. Keep special medical or mobility equipment (ventilators, oxygen tanks, extra cane, etc.) where they can be easily reached.

### A special note about children

If earthquakes scare us because we feel out of control, think how much more true this must be for children, who already must depend on adults for so much of their lives. It is important to spend time with children in your care before the next earthquake to explain why earthquakes occur. Involve them in developing your disaster plan, prepare disaster supplies kits, and practice "drop, cover, and hold on." Consider simulating post-earthquake conditions by going without electricity or tap water.

After the earthquake, remember that children will be under great stress. They may be frightened, their routine will probably be disrupted, and the aftershocks won't let them forget the experience. Adults may need to leave their children in order to deal with the many demands of the emergency, but this can be devastating to children. Extra contact and support from parents in the early days will pay off later. Whenever possible, include them in the recovery process.



**step 3 PREPARE** before the earthquake



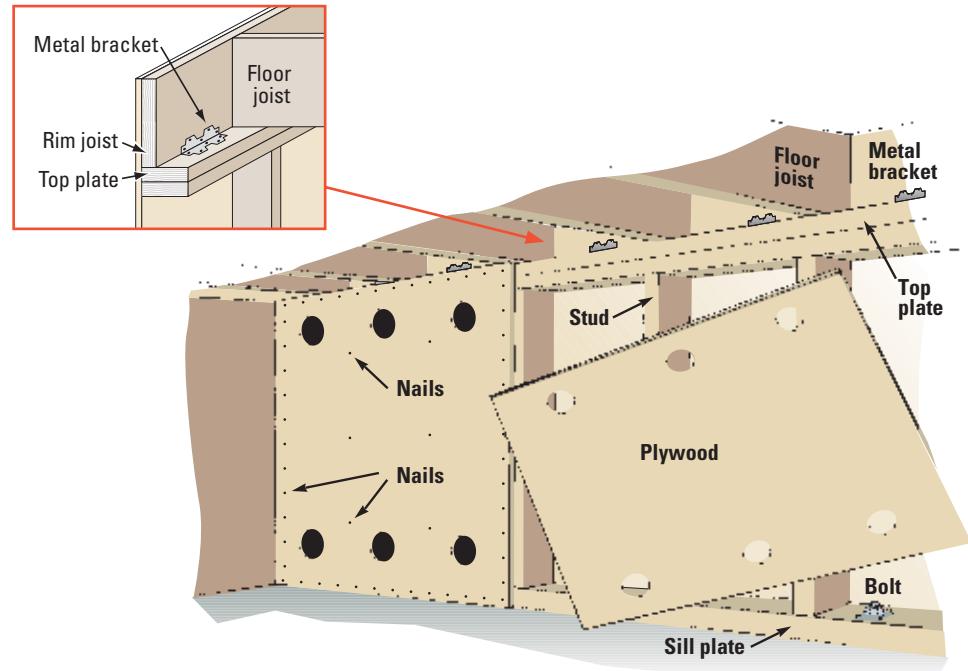
## 4



## IDENTIFY YOUR BUILDING'S POTENTIAL WEAKNESSES AND BEGIN TO FIX THEM.

Buildings are designed to withstand the downward pull of gravity, yet earthquakes shake a building in all directions—up and down, but most of all, sideways. There are several common issues that can limit a building's ability to withstand this sideways shaking.

Additional information, including how-to instructions, is available at [www.earthquakecountry.org](http://www.earthquakecountry.org)



▲ This cutaway diagram shows how weak cripple walls can be strengthened by properly attached plywood sheets. [Illustration credit: San Leandro EQ Retrofit Program]

### MYTH #4 Don't be fooled!



**"WE HAVE GOOD BUILDING CODES SO WE MUST HAVE GOOD BUILDINGS."**

The best building codes in the world do nothing for buildings built before a code was enacted. While the codes have been updated, the older buildings are still in place. Fixing problems in older buildings—retrofitting—is the responsibility of the building's owner.

### Common building problems

Most houses are not as safe as they could be. The following presents some common structural problems and how to recognize them. Once you determine if your building has one or more of these problems, prioritize how and when to fix them, and get started.

**Inadequate foundations.** Look under your house at your foundation. If the foundation is damaged or built in the "pier and post" style, consult a contractor or engineer about replacing it with a continuous perimeter foundation. Look for bolts in the mudsills. They should be no more than 1.8 meters (6 feet) apart in a single story and 1.2 meters (4 feet) apart in a multistory building. Adding bolts to unsecured houses is one of the most important steps toward earthquake safety. This can be done by a contractor or by someone skilled at home maintenance.

**Unbraced cripple walls.** Homes with a crawl space should have panels of plywood connecting the studs of the short "cripple" walls (see figure). You or a contractor can strengthen the cripple walls relatively inexpensively.

**Soft first stories.** Look for larger openings in the lower floor, such as a garage door or a hillside house built on stilts. Consult a professional to determine if your building is adequately braced.

**Unreinforced masonry.** All masonry (brick or block walls) should be reinforced. Some communities have a program for retrofitting buildings made of unreinforced masonry. If your house has masonry as a structural element consult a structural engineer to find what can be done. Inadequately braced chimneys are a more common problem. Consult a professional to determine if your chimney is safe.

### step 4 PREPARE before the earthquake

## Structural-Safety Quiz for Single-Family Home or Duplex

If you live in a single-family home or duplex, the strength of your home depends on when it was built, its style of construction, and its location.

*My score*

**1. When was your home built?**

- Before 1960 = 5 points
- 1961–1978 = 3 points
- After 1978 = 1 point

**2. How tall is your home?**

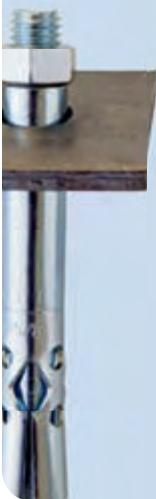
- 2 or more stories with living area above a garage = 5 points
- Split level, on a hillside or gentle slope = 6 points
- 1 story, 3 or more steps up to the front door = 4 points
- 1 story, less than 3 steps up to the front door = 1 point

**3. How hard is the ground likely to shake under your home?**

- Portions of Southern California shown as yellow or green in color on the shaking hazard map (page 7) = 5 points
- Elsewhere in Southern California = 7 points

**TOTAL POINTS**

*If your home scores 13 or more points on the quiz, you probably should have an engineer, architect, or contractor evaluate it unless it has been strengthened in the past few years.*



### For those who rent

As a renter, you have less control over the structural integrity of your building, but you do control which apartment or house you rent:

- Structures made of unreinforced brick or block walls can collapse and cause great loss of life.
- Apartment buildings with “tuck-under” parking space openings can also collapse.
- Foundation and cripple wall failures can cause expensive damage but less loss of life.
- Objects attached to the sides of buildings, such as staircases, balconies, and decorations, can break off in earthquakes.

Ask your landlord these questions:

- What retrofitting has been done on this building?
- Have the water heaters been strapped to the wall studs?
- Can I secure furniture to the walls?

### If you live in a mobile home...

Look under your home. If you only see a metal or wood “skirt” on the outside with concrete blocks or steel tripods or jacks supporting your home, you need to have an “engineered tie-down system” or an “earthquake-resistant bracing system” (ERBS) installed. An ERBS should have a label on the bracing that says, “Complies with the California Administrative Code, Title 25, Chapter 2, Article 7.5.”

### Earthquake insurance in California

If you own your home it is probably your biggest single asset. You have worked hard to secure your piece of the American Dream by becoming a homeowner. In seconds, your dream can become a nightmare when an earthquake strikes and damages your home and personal belongings. Even if you follow the steps in this handbook, it is likely your home will still have some level of damage, and you will need to repair or replace belongings. One option for managing these potential costs is to buy earthquake insurance.

Earthquake insurance in California is typically not part of your homeowners insurance policy; it is generally a separate policy you can purchase when buying homeowners insurance. All insurance companies that sell residential property insurance in California are required by law to offer earthquake insurance to homeowners when the policy is first sold and then every two years thereafter.

The cost of the earthquake policy you are offered is based on a number of factors, including your home’s location, age, construction type, and value. It is up to each homeowner to consider their individual risk factors and then weigh the cost of earthquake coverage against the benefits that coverage may offer after a devastating earthquake.

Many companies issue California Earthquake Authority (CEA) insurance policies, which are designed to rebuild your home if it suffers significant damage from an earthquake.

You may purchase a CEA policy only through the CEA’s participating insurers. A complete list is on the CEA web site at [www.earthquakeauthority.com](http://www.earthquakeauthority.com), which has an online premium calculator.

Contact your homeowners insurance company or agent to help you evaluate your earthquake risk factors and then consider whether earthquake insurance is a good choice for you.





## 5

## PROTECT YOURSELF DURING EARTHQUAKE SHAKING—DROP, COVER, AND HOLD ON.

The previous pages have concentrated on getting ready for the next earthquake. What should you do during and after earthquakes?

The area near the exterior walls of a building is the most dangerous place to be. Windows, facades and architectural details are often the first parts of the building to collapse. To stay away from this danger zone, stay inside if you are inside and outside if you are outside.

Learn more about what to do (and what not to do) to protect yourself during earthquakes at [www.dropcoverholdon.org](http://www.dropcoverholdon.org).



### If you are...

#### **Indoors:** Drop, cover, and hold on.

Drop to the floor, take cover under a sturdy desk or table, and hold on to it firmly. Be prepared to move with it until the shaking stops. If you are not near a desk or table, drop to the floor against the interior wall and protect your head and neck with your arms. Avoid exterior walls, windows, hanging objects, mirrors, tall furniture, large appliances, and kitchen cabinets with heavy objects or glass. Do not go outside!

**In bed:** If you are in bed, hold on and stay there, protecting your head with a pillow. You are less likely to be injured staying where you are. Broken glass on the floor has caused injury to those who have rolled to the floor or tried to get to doorways.

**In a wheelchair:** Lock the wheels once you are in a safe position. If unable to move quickly, stay where you are. Cover your head and neck with your arms.

**Outdoors:** Move to a clear area if you can safely do so; avoid power lines, trees, signs, buildings, vehicles, and other hazards.

**Driving:** Pull over to the side of the road, stop, and set the parking brake. Avoid overpasses, bridges, power lines, signs and other hazards. Stay inside the vehicle until the shaking is over. If a power line falls on the car, stay inside until a trained person removes the wire.

#### **In a high-rise:** Drop, cover, and hold on.

Avoid windows and other hazards. Do not use elevators. Do not be surprised if sprinkler systems or fire alarms activate.

**In a stadium or theater:** Stay at your seat and protect your head and neck with your arms. Don't try to leave until the shaking is over. Then walk out slowly watching for anything that could fall in the aftershocks.

**Below a dam:** Dams can fail during a major earthquake. Catastrophic failure is unlikely, but if you live downstream from a dam, you should know flood-zone information and have prepared an evacuation plan.



## TSUNAMI watch

How will I know if an earthquake is big enough to cause a tsunami?

Get into the habit of COUNTING how long the earthquake lasts. If you count 20 seconds or more of shaking and are in a tsunami hazard zone, evacuate to a safe area as soon as you can safely walk. Even if you aren't in a tsunami zone, counting is a good idea—it will help to keep you calm.

### MYTH #5 Don't be fooled!



#### "HEAD FOR THE DOORWAY."

An enduring earthquake image of California is a collapsed adobe home with the door frame as the only standing part. From this came our belief that a doorway is the safest place to be during an earthquake. True—if you live in an old, unreinforced adobe house. In modern houses, doorways are no stronger than any other part of the house. You are safer under a table.

### step 5 SURVIVE during the earthquake

# 6

## AFTER THE EARTHQUAKE, CHECK FOR INJURIES AND DAMAGE

First take care of your own situation.

Remember your emergency plans.

Aftershocks may cause additional damage or items to fall, so get to a safe location.

Take your disaster supplies kit.

If you are trapped by falling items or a collapse, protect your mouth, nose, and eyes from dust. If you are bleeding, put pressure on the wound and elevate the injured part. Signal for help with your emergency whistle, a cell phone, or knock loudly on solid pieces of the building, three times every few minutes. Rescue personnel will be listening for such sounds.

Once you are safe, help others and check for damage. Protect yourself by wearing sturdy shoes and work gloves, to avoid injury from broken glass and debris. Also wear a dust mask and eye protection.

### Check for injuries

- Check your first aid kit or the front pages of your telephone book for detailed instructions on first aid measures.
- If a person is bleeding, put direct pressure on the wound. Use clean gauze or cloth, if available.
- If a person is not breathing, administer rescue breathing.
- If a person has no pulse, begin CPR (cardiopulmonary resuscitation).
- Do not move seriously injured persons unless they are in immediate danger of further injury.
- Cover injured persons with blankets or additional clothing to keep them warm.
- Get medical help for serious injuries.
- Carefully check children or others needing special assistance.

### Check for damage

**Fire.** If possible, put out small fires in your home or neighborhood immediately. Call for help, but don't wait for the fire department.

**Gas Leaks.** Shut off the main gas valve only if you suspect a leak because of broken pipes or the odor or sound of leaking natural gas. Don't turn it back on yourself—wait for the gas company to check for leaks. The phone book has detailed information on this topic.



### step 6 RECOVER after the earthquake

#### EVACUATE if you are in a tsunami hazard zone.

For a large local earthquake, feeling strong ground shaking may be the only warning you will get that a tsunami is on its way. Use tsunami hazard maps and posted hazard zone signs to identify safe evacuation areas.

- > **If you are at the beach**, move to higher ground immediately—no matter how small the earthquake.
- > **If you are in a tsunami hazard zone and the earthquake is very strong**, immediately gather your family members, grab your tsunami disaster kit, and WALK to a safe area.
- > **If evacuation is impossible**, go to the upper floor of a sturdy building or climb a tree. This should only be a last resort.
- > Do not wait for an official warning

#### STAY WHERE YOU ARE if you are not in a tsunami hazard zone.

You are not at risk of a tsunami. Unnecessary evacuation will put you at risk and hamper the evacuation of people who really need to get away from danger.

**Damaged Electrical Wiring.** Shut off power at the main breaker switch if there is any damage to your house wiring. Leave the power off until the damage is repaired.

**Broken Lights and Appliances.** Unplug these as they could start fires when electricity is restored.

**Downed Power Lines.** If you see downed power lines, consider them energized and stay well away from them. Keep others away from them. Never touch downed power lines or any objects in contact with them.

**Fallen Items.** Beware of items tumbling off shelves when you open closet and cupboard doors.

**Spills.** Use extreme caution. Clean up any spilled medicines, drugs, or other non-toxic substances. Potentially harmful materials such as bleach, lye, garden chemicals, and gasoline or other petroleum products should be isolated or covered with an absorbent such as dirt or cat litter. When in doubt, leave your home.

**Damaged Masonry.** Stay away from chimneys and walls made of brick or block. They may be weakened and could topple during aftershocks. Don't use a fireplace with a damaged chimney. It could start a fire or let poisonous gases into your home.

### MYTH #6 Don't be fooled!



#### "EVERYONE WILL PANIC DURING THE BIG ONE!"

A common belief is that people always panic and run around madly during and after earthquakes, creating more danger for themselves and others. Actually, research shows that people usually take protective actions and help others both during and after the shaking. Most people don't get too shaken up about being shaken up!



## 7

## WHEN SAFE, CONTINUE TO FOLLOW YOUR DISASTER PREPAREDNESS PLAN.

Once you have met your and your family's immediate needs after an earthquake, continue to follow the plan you prepared in advance (*see Step 2, page 18*). Aftershocks will continue to happen for several weeks after major earthquakes. Some may be large enough to cause additional damage. Always be ready to drop, cover, and hold on.

Your recovery period can take several weeks to months or longer. Take the actions listed below to be safe and to minimize the long-term effects of the earthquake on your life.



### The first days after the earthquake...

Use the information you put together in your disaster plan and the supplies you organized in your disaster kits. Until you are sure there are no gas leaks, do not use open flames (lighters, matches, candles, or grills) or operate any electrical or mechanical device that can create a spark (light switches, generators, motor vehicles, etc.). Never use the following indoors: camp stoves, gas lanterns or heaters, gas or charcoal grills, or gas generators. These can release deadly carbon monoxide or be a fire hazard in aftershocks.

### The first weeks after the earthquake...

This is a time of transition. Although aftershocks may continue, you will now work toward getting your life, your home and family, and your routines back in order. Emotional care and recovery are just as important as healing physical injuries and rebuilding a home. Make sure your home is safe to occupy and not in danger of collapse in aftershocks. If you were able to remain in your home or return to it after a few days, you will have a variety of tasks to accomplish:

- If your gas was turned off, you will need to arrange for the gas company to turn it back on.
- If the electricity went off and then came back on, check your appliances and electronic equipment for damage.
- If water lines broke, look for water damage.
- Locate and/or replace critical documents that may have been misplaced, damaged, or destroyed.
- Contact your insurance agent or company right away to begin your claims process.
- Contact the Federal Emergency Management Agency (FEMA) to find out about financial assistance by visiting [www.fema.gov/assistance](http://www.fema.gov/assistance).

### *Be in communication*

- Turn on your portable or car radio for information and safety advisories.
- Place all phones back on their cradles.
- Call your out-of-area contact, tell them your status, then stay off the phone. Emergency responders need to use the phone lines for life-saving communications.
- Check on the condition of your neighbors.

### *Food and water*

- If power is off, plan meals to use up refrigerated and frozen foods first. If you keep the door closed, food in your freezer may be good for a couple of days.
- Listen to your radio for safety advisories.
- If your water is off or unsafe, you can drink from water heaters, melted ice cubes, or canned vegetables. Avoid drinking water from swimming pools or spas.
- Do not eat or drink anything from open containers that are near shattered glass.



▲ Sleeping bags and flashlights may be quite handy in the days or weeks after a major earthquake.

## TSUNAMIwatch

- > Stay away from the coast until officials reopen the area for you to return.
- > The first surge is almost never the largest. The largest waves may arrive hours after the first. Successive surges will arrive at irregular intervals spaced minutes to tens of minutes apart. The danger period may last eight hours or longer.
- > Never go to the coast to watch a tsunami.
- > Tsunamis move faster than a person can run. Incoming traffic hampers safe and timely evacuation of coastal areas.
- > Listen to the radio for updates on the hazard and for instructions on what to do.

## step 6 RECOVER after the earthquake

### If you cannot stay in your home...

If your home is structurally unsafe or threatened by a fire or other hazard, you need to evacuate. However, shelters may be overcrowded and initially lack basic services, so do not leave home just because utilities are out of service or your home and its contents have suffered moderate damage.

If you evacuate, tell a neighbor and your out-of-area contact where you are going. As soon as possible, set up an alternative mailing address with the post office. Take the following, if possible, when you evacuate:

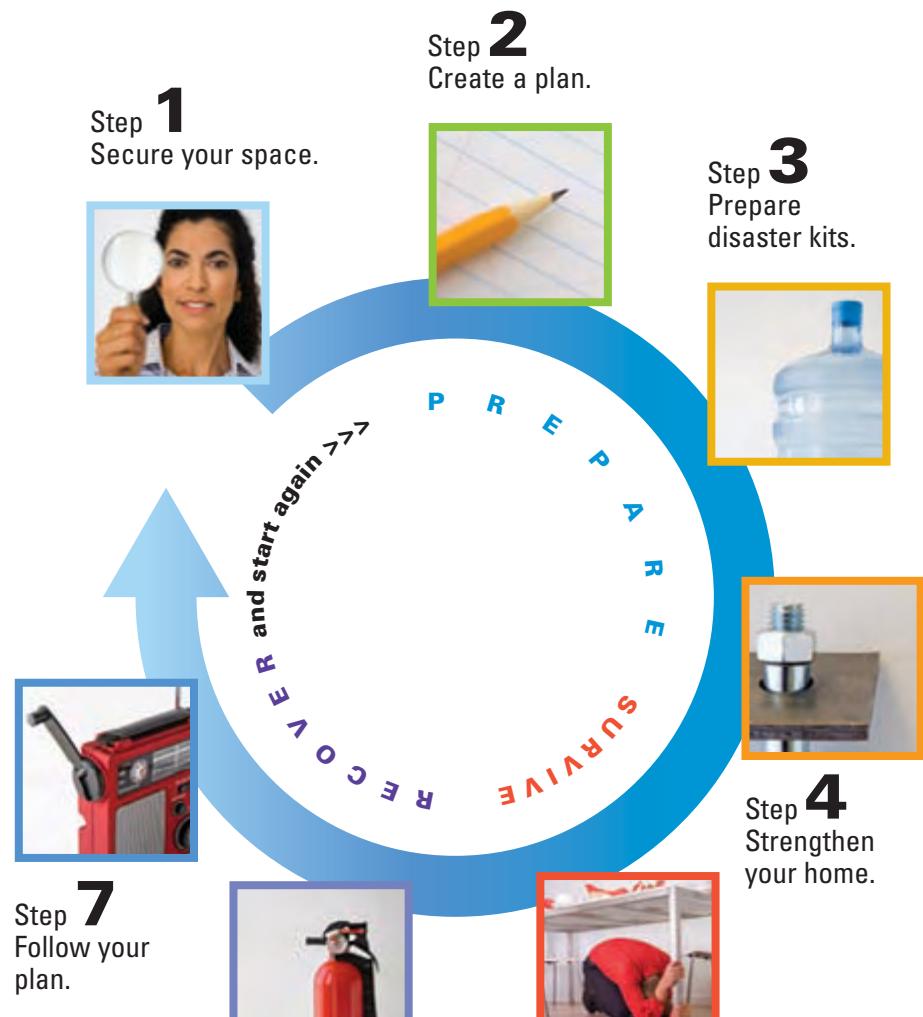
- Personal disaster supplies kits
- Medications and eyewear
- Supply of water, food, and snacks
- Blanket/pillow/air mattress or sleeping pad
- Change of clothing and a jacket
- Towel and washcloth
- Diapers, food, and other supplies for infants
- A few family pictures or other comfort items
- Personal identification and copies of household and health insurance information.

### Do not take to a shelter:

- Pets (Service animals for people with disabilities are allowed; take food for them. Have a plan for your pets in advance.)
- Large quantities of unnecessary clothing or other personal items
- Valuables that might be lost, stolen, or take up needed space

Once a Presidential Declaration has been issued, FEMA may activate the Individuals and Households Program ([www.fema.gov/assistance](http://www.fema.gov/assistance)). This program includes:

- Home-repair cash grants; the maximum Federal grant available (as of 2005) is \$26,200
- Housing Assistance in the form of reimbursement for short-term lodging at a hotel
- Rental assistance for as long as 18 months in the form of cash payment
- If no other housing is available, FEMA may provide mobile homes or other temporary housing



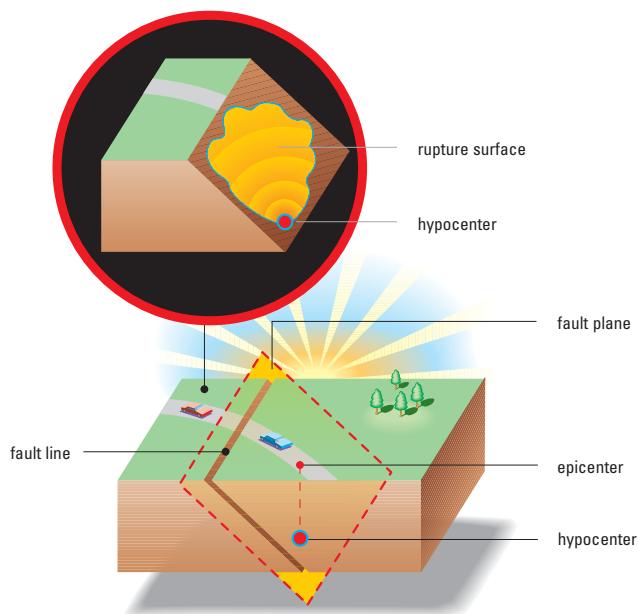
**Once you have recovered from the earthquake,** go back to Step 1 and do the things you did not do before, or do them more thoroughly. Learn from what happened during the earthquake so you will be safer and recover more quickly next time.

## Earthquake Basics

Epicenter, hypocenter, aftershock, foreshock, fault, fault plane, seismograph, P-waves, magnitude, intensity, peak acceleration, amplification...

We hear them. After big earthquakes, we say them. But what do these terms mean? What do they mean for what we felt and what we will feel the next time? Do we really understand what seismologists are saying?

This section describes how earthquakes happen and how they are measured. It also explains why the same earthquake can shake one area differently than another area. It finishes with information we expect to learn after future earthquakes.



## EARTHQUAKES AND FAULTS

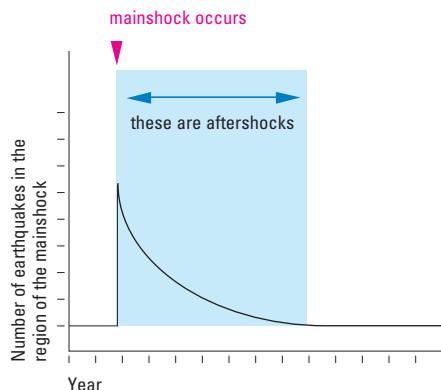
### What is an earthquake?

An earthquake is caused by a sudden slip on a fault, much like what happens when you snap your fingers. Before the snap, you push your fingers together and sideways. Because you are pushing them together, friction keeps them from moving to the side. When you push sideways hard enough to overcome this friction, your fingers move suddenly, releasing energy in the form of sound waves that set the air vibrating and travel from your hand to your ear, where you hear the snap.

The same process goes on in an earthquake. Stresses in the earth's outer layer push the sides of the fault together. The friction across the surface of the fault holds the rocks together so they do not slip immediately when pushed sideways. Eventually enough stress builds up and the rocks slip suddenly, releasing energy in waves that travel through the rock to cause the shaking that we feel during an earthquake.

Just as you snap your fingers with the whole area of your fingertip and thumb, earthquakes happen over an area of the fault, called the rupture surface. However, unlike your fingers, the whole fault plane does not slip at once. The rupture begins at a point on the fault plane called the hypocenter, a point usually deep down on the fault. The epicenter is the point on the surface directly above the hypocenter. The rupture keeps spreading until something stops it (exactly how this happens is a hot research topic in seismology).

## How do we know it's an aftershock?



### Aftershocks

Part of living with earthquakes is living with aftershocks. Earthquakes come in clusters. In any earthquake cluster, the largest one is called the mainshock; anything before it is a foreshock, and anything after it is an aftershock.

Aftershocks are earthquakes that usually occur near the mainshock. The stress on the mainshock's fault changes during the mainshock and most of the aftershocks occur on the same fault. Sometimes the change in stress is great enough to trigger aftershocks on nearby faults as well.

An earthquake large enough to cause damage will probably produce several felt aftershocks within the first hour. The rate of aftershocks dies off quickly. The day after the mainshock has about half the aftershocks of the first day. Ten days after the mainshock there are only a tenth the number of aftershocks. An earthquake will be called an aftershock as long as the rate of earthquakes is higher than it was before the mainshock. For big earthquakes, this might go on for decades.

Bigger earthquakes have more and larger aftershocks. The bigger the mainshock, the bigger the largest aftershock, on average, though there are many more small aftershocks than large ones. Also, just as smaller earthquakes can continue to occur for many years after a mainshock, there is still a chance for a large aftershock long after an earthquake.

### Foreshocks

Sometimes what we think is a mainshock is followed by a larger earthquake. Then the original earthquake is considered a foreshock. The chance of this happening dies off quickly with time just like aftershocks. After three days the risk is almost gone.

Sometimes, the chance that an event is a foreshock seems higher than average—usually because of its proximity to a major fault. The California Emergency Management Agency will then issue an advisory based on scientists' recommendations. These are the only officially recognized short-term “predictions.”

### What is a fault?

Earthquakes occur on faults. A fault is a thin zone of crushed rock separating blocks of the earth's crust. When an earthquake occurs on one of these faults, the rock on one side of the fault slips with respect to the other. Faults can be centimeters to thousands of kilometers long. The fault surface can be vertical, horizontal, or at some angle to the surface of the earth. Faults can extend deep into the earth and may or may not extend up to the earth's surface.

### How do we know a fault exists?

- Past fault movement has brought together rocks that used to be farther apart;
- Earthquakes on the fault have left surface evidence, such as surface ruptures or fault scarps (cliffs made by earthquakes);
- Earthquakes recorded by seismographic networks are mapped and indicate the location of a fault.

Some faults have not shown these signs and we will not know they are there until they produce a large earthquake. Several damaging earthquakes in California have occurred on faults that were previously unknown.

## How do we study faults?

Surface features that have been broken and offset by the movement of faults are used to determine how fast the faults move and thus how often earthquakes are likely to occur.

For example, a streambed that crosses the San Andreas fault near Los Angeles is now offset 83 meters (91 yards) from its original course. The sediments in the abandoned streambed are about 2,500 years old. If we assume movement on the San Andreas has cut off that streambed within the last 2,500 years, then the average slip rate on the fault is 33 millimeters (1.3 inches) per year. This does not mean the fault slips 33 millimeters each year. Rather, it stores up 33 millimeters of slip each year to be released in infrequent earthquakes. The last earthquake offset the streambed another 5 meters (16 feet). If we assume that all earthquakes have 5 meters (5000 millimeters) of slip, we will have earthquakes on average every 150 years: 5000 millimeters divided by 33 millimeters per year equals 150 years. This does not mean the earthquakes will be exactly 150 years apart. While the San Andreas fault has averaged 150 years between events, earthquakes have occurred as few as 45 years and as many as 300 years apart.

Carrizo Plain National Monument along the San Andreas fault



**MYTH #7** Don't be fooled!**"IT'S HOT AND DRY — EARTHQUAKE WEATHER!"**

Many people believe that earthquakes are more common in certain kinds of weather. In fact, no correlation with weather has been found. Earthquakes begin many kilometers below the region affected by surface weather. People tend to notice earthquakes that fit the pattern and forget the ones that don't. Also, every region of the world has a story about earthquake weather, but the type of weather is whatever they had for their most memorable earthquake.

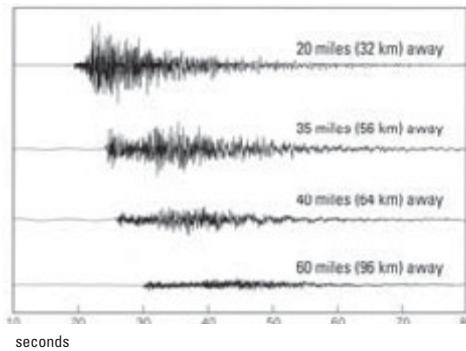
## LOCATING AND MEASURING EARTHQUAKES

### Where and when was the earthquake?

Earthquakes are recorded by a seismic network. Each seismic station in the network measures the movement of the ground at that site. In an earthquake, the slip of a block of rock over another releases energy that makes the ground vibrate. That vibration pushes the adjoining piece of ground, causing it to vibrate, and thus the energy travels out from the earthquake in a wave. As the wave passes by a seismic station, that piece of ground vibrates and this vibration is recorded.

Earthquakes produce two main types of waves—the P-wave (a compressional wave), and the S-wave (a shear wave). The S-wave is slower but larger than the P-wave and does most of the damage. Scientists have used knowledge of the differences between these and other seismic waves to learn a great deal about the interior of the earth.

Knowing how fast seismic waves travel through the earth, seismologists can calculate the time when the earthquake occurred and its location by comparing the times when shaking was recorded at several stations. This process used to take almost an hour when done manually.



▲ These seismograms show how the ground moved at four seismic stations during an earthquake. The time when ground starts shaking is the arrival of the P-wave. The ground starts shaking sooner and shakes more at sites nearer the earthquake.

Now computers determine this information automatically within minutes. Within a few more hours the shape and location of the entire portion of the fault that moved can be calculated.

We name earthquakes after map locations near epicenters to have a convenient way to refer to them, but this can be misleading. We define the epicenter of an earthquake with the latitude and longitude of a point, but the earthquake is bigger than that point. The fault's rupture surface can be hundreds of kilometers long and several kilometers wide, and even the epicenter can only be determined within a few tenths of a kilometer. Therefore, giving the location of an earthquake in terms of city streets is like giving the location of your city by the address of City Hall.

### How big was the earthquake?

Why do scientists have problems coming up with a simple answer to this simple question? Many people have felt this frustration after earthquakes, as seismologists often seem to contradict one another. In fact, earthquakes are very complex. Measuring their size is something like trying to determine the "size" of an abstract modern sculpture with only one use of a tape measure. Which dimension do you measure?

Magnitude is the most common way of describing an earthquake's size. In the 1930s, Beno Gutenberg and Charles Richter at the California Institute of Technology developed a method to describe all sizes of earthquakes using a small range of numbers. Using recordings from seismographs, they measured how fast the ground moved at a set distance from earthquakes. If the maximum acceleration of the ground in one earthquake is 10 times the maximum acceleration in another earthquake, then the first earthquake is said to be one unit of magnitude larger than the second. The Richter Scale, as it became known, is not a device, but the range of numbers used to compare earthquakes.

A magnitude 6.0 earthquake has about 32 times more energy than a magnitude 5.0 and about 1,000 times more energy than a magnitude 4.0 earthquake. This does not mean there will be 1,000 times more shaking at your home. A bigger earthquake will last longer and release its energy over a much larger area.

Seismologists have since developed a new measurement of earthquake size, called moment magnitude. Moment is a physical quantity more closely related to the total energy released in the earthquake than Richter magnitude. It can be estimated by geologists examining the geometry of a fault in the field or by seismologists analyzing a seismogram. Because the units of moment are very large, it has been converted to the more familiar range of magnitude values for communication to the public.

Moment magnitude has many advantages over other magnitude scales. First, all earthquakes can be compared on the same scale. (Richter magnitude is only precise for earthquakes of a certain size and distance from a seismometer.) Second, because it can be determined either instrumentally or from geology, it can be used to measure old earthquakes and compare them to instrumentally recorded earthquakes. Third, by estimating how large a section of fault will likely move in the future, the magnitude of that earthquake can be calculated with confidence.

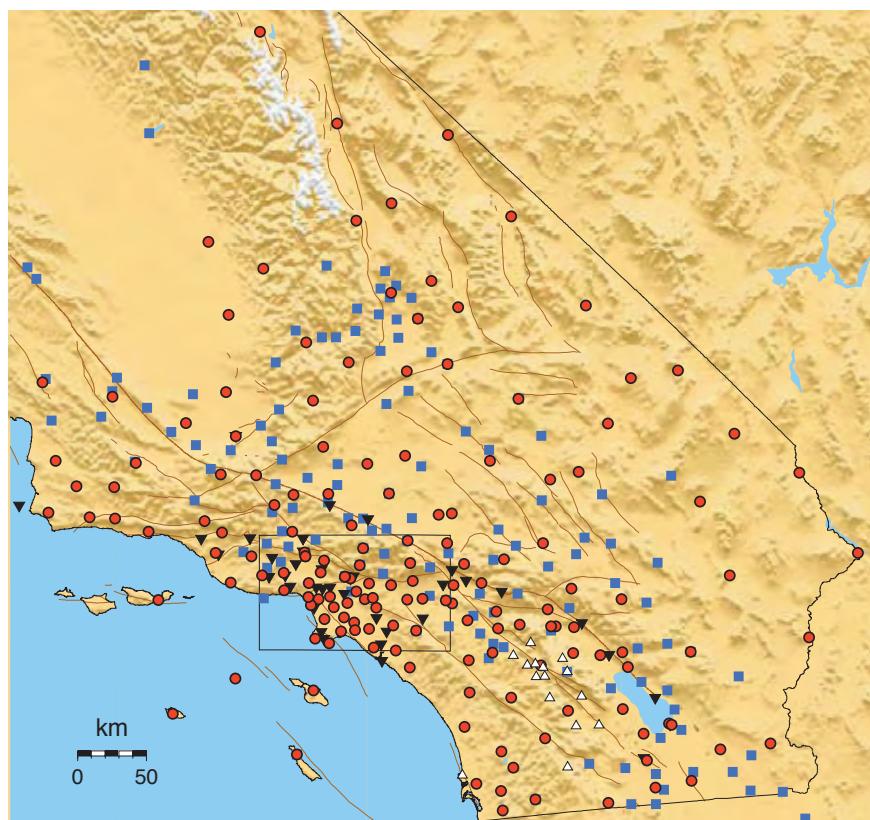
### **Who monitors California's earthquakes?**

Earthquake monitoring for California is done by the California Integrated Seismic Network (CISN), a partnership among the U.S. Geological Survey (USGS), University of California Berkeley, Caltech, the California Geological Survey, and the Governor's Office of Emergency Services. CISN is part of a USGS national seismic monitoring program called the Advanced National Seismic System (ANSS). For more information go to:

[www.cisn.org/](http://www.cisn.org/) or [www.anss.org/](http://www.anss.org/).

### **A longer fault can produce a bigger earthquake that lasts a longer time.**

Magnitude	Date	Location	Rupture Length (kilometers)	Duration (seconds)
9.1	December 26, 2004	Sumatra, Indonesia	1200	500
7.9	January 9, 1857	Fort Tejon, CA	360	130
7.9	May 12, 2008	Sichuan, China	300	120
7.8	April 18, 1906	San Francisco, CA	400	110
7.3	June 28, 1992	Landers, CA	70	24
7.3	August 17, 1959	Hebgen Lake, MT	44	12
7.0	October 17, 1989	Loma Prieta, CA	40	7
7.0	October 28, 1983	Borah Peak, ID	34	9
6.8	February 28, 2001	Nisqually, WA	20	6
6.7	January 17, 1994	Northridge, CA	14	7
6.4	March 10, 1933	Long Beach, CA	15	5
5.9	October 1, 1987	Whittier Narrows, CA	6	3
5.4	July 29, 2008	Chino Hills, CA	5	1

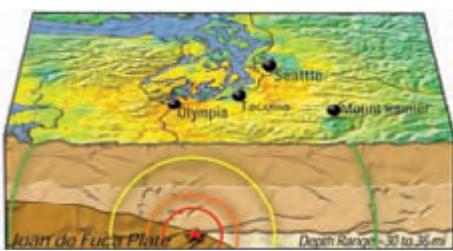


▲ The Southern California Seismic Network (SCSN) records data from more than 370 seismic stations. Each station records seismic waves from both near and distant earthquakes. All the data are transmitted automatically to Caltech/USGS in Pasadena for processing and distribution of information such as epicenters, magnitudes, and ShakeMaps. The SCSN is also part of the California Integrated Seismic Network (CISN) that coordinates earthquake monitoring statewide. The symbols indicate different types of seismic stations.

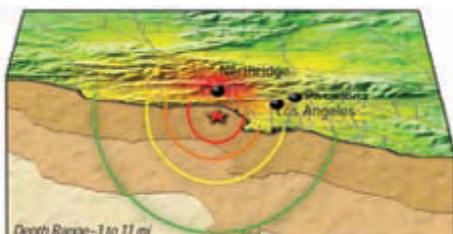


## EARTHQUAKE SHAKING

Magnitude is a measurement of the energy produced by an earthquake and is not a measure of the shaking you feel. What you feel is very complex—hard or gentle, long or short, jerky or rolling—and is not describable with one number. What you feel in an earthquake is controlled by three main factors: magnitude, distance, and local soil conditions.



**2001**  
M6.8 Nisqually Earthquake



**1994**  
M6.7 Northridge Earthquake

▲ The 2001 Nisqually (M6.8) and 1994 Northridge (M6.7) earthquakes shown above provide an interesting example of how distance from an earthquake affects the level of shaking experienced. Even though the Nisqually earthquake was slightly larger than the Northridge earthquake on the magnitude scale, the resulting damage was far less. One reason is that the section of fault that moved was much deeper than the fault that moved in the Northridge earthquake. Therefore every house was at least 50 kilometers (30 miles) away from the fault.

### Magnitude

Typically you will feel more intense shaking from a higher magnitude earthquake than from a small one. Bigger earthquakes also release their energy over a larger area and for a longer period of time.

An earthquake begins at the hypocenter, and from there the rupture front travels along the fault, producing waves all the time it is moving. Every point crossed by the rupture front gives off shaking, so longer faults produce bigger earthquakes that have longer durations. The actual durations of 15 earthquakes are shown on the previous page. For a magnitude 5 event, the actual process of rupturing the fault is over in a few seconds, although you might continue to feel shaking for longer because some waves reach you after they bounce and echo within the earth.

The magnitude 7.8 earthquake on the San Andreas fault in 1857 ruptured almost 360 kilometers (220 miles) of the fault. At 3 kilometers (2 miles) per second, it took two minutes for that length of fault to rupture, so you would have felt shaking for several minutes.

### Distance

Earthquake waves diminish in intensity as they travel through the ground, so earthquake shaking is less intense farther from the fault.

Low-frequency waves diminish less rapidly with distance than do high-frequency waves. If you are near an earthquake, you will experience all the shaking produced by the earthquake and feel “jolted.” Farther away, the higher frequencies will have died away and you will feel a rolling motion.

The amount of damage to a building does not depend solely on how hard it is shaken. In

general, smaller buildings such as houses are damaged more by higher frequencies, so they must be close to the hypocenter to be severely damaged. Larger structures such as high-rises and bridges are damaged more by lower frequencies and will be affected by the largest earthquakes, even at considerable distances.

### Local soil conditions

Soils can greatly amplify the shaking in an earthquake. Passing from rock to soil, seismic waves slow down but get bigger. Hence a soft, loose soil may shake more intensely than hard rock at the same distance from the same earthquake. An extreme example for this type of amplification was in the Marina district of San Francisco during the 1989 Loma Prieta earthquake. That earthquake was 100 kilometers (60 miles) from San Francisco, and most of the Bay Area escaped serious damage. However, some sites on landfill or soft soils experienced significant shaking.

The same factors also apply to areas covered by thick sediment—such as the Los Angeles basin where sediments can be as much as 10 kilometers (6 miles) thick. Shaking from an earthquake in the region can be 5 or more times greater at a site in the basin than the level of shaking in the nearby mountains.

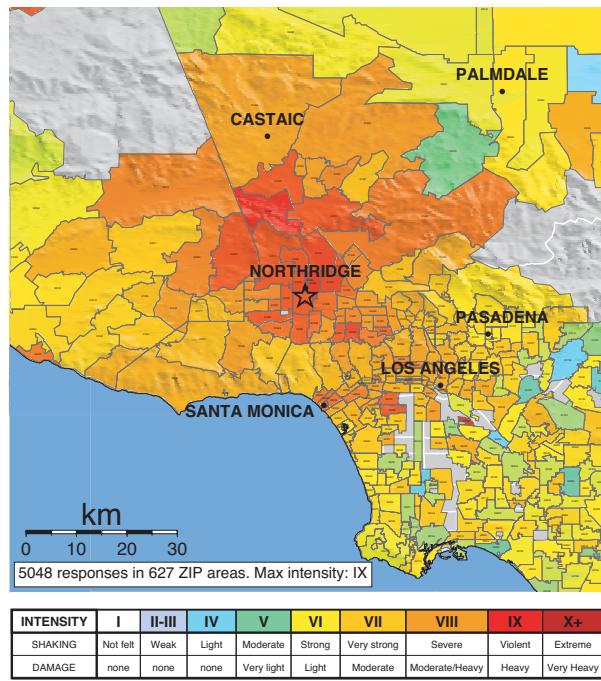
### P.S.

*Several other factors can affect shaking. Earthquake waves do not travel evenly in all directions from the rupture surface; the orientation of the fault and the direction of movement can change the characteristics of the waves in different directions. When the earthquake rupture moves along the fault, it focuses energy in the direction it is moving so that a location in that direction will receive more shaking than a site at the same distance from the fault but in the opposite direction. This is called directivity.*



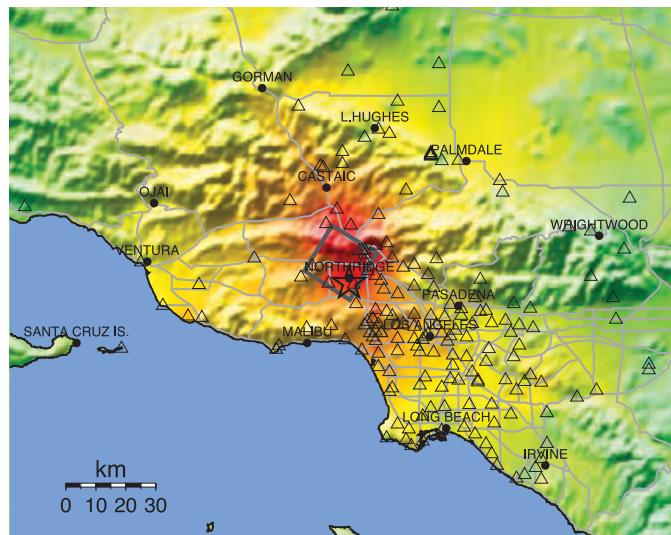
## Did You Feel It?

Community Internet Intensity Map — 1994 Northridge earthquake



## ShakeMap

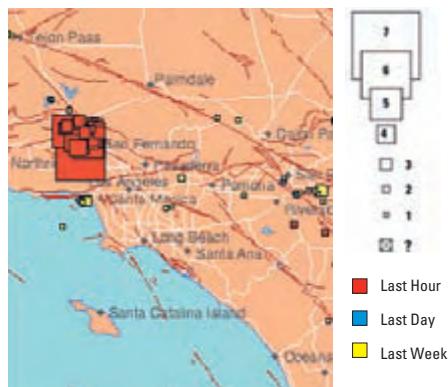
Instrumental Intensity Map — 1994 Northridge earthquake



## ONLINE EARTHQUAKE INFORMATION

After an earthquake, knowing more about what just happened can reduce fears and help you understand what to expect next. Online earthquake information products include:

**Recent earthquakes map** — Within 1 to 2 minutes of an earthquake, its location and magnitude are available at several Web sites, including [data.scec.org](http://data.scec.org) and [earthquakes.usgs.gov](http://earthquakes.usgs.gov).



### Recent Earthquake Map

5:30 am, January 17, 1994

(one hour after the Northridge earthquake)

**"Did You Feel It?"** — Tell us what you felt! Personal experiences of the effects of an earthquake are very valuable to scientists. When you have felt a quake, please report your observations by using a quick survey found on the U.S. Geological Survey "Did You Feel It?" Web site at [earthquake.usgs.gov/eqcenter/dyfi.php](http://earthquake.usgs.gov/eqcenter/dyfi.php).

When you fill out this online survey, your observations of actual damage and shaking are combined with those of thousands of other people. The quake's shaking intensities, derived from these observations, are displayed by ZIP code on a "Community Internet Intensity Map."

**"ShakeMap"** — Within 5 to 10 minutes of most felt earthquakes (magnitude 3.5 and greater) in Southern California, a "ShakeMap" is posted on the Web. This map shows the range of shaking intensities across a region. Every quake has only a single magnitude, but it produces a range of shaking intensity values over the area in which it is felt.

ShakeMaps use data from seismic instruments to provide a rapid picture of where the strongest shaking occurred. These maps help to identify areas where a quake's impact is greatest and are used by emergency managers to speed disaster response. ShakeMaps are available at [www.cisn.org/shakemap](http://www.cisn.org/shakemap) or [earthquake.usgs.gov/shakemap](http://earthquake.usgs.gov/shakemap).



Answers for many of your questions, online versions of this handbook in multiple languages, the *Seven Steps to an Earthquake Resilient Business* and other supplemental documents, are all available at:

**[www.earthquakecountry.org](http://www.earthquakecountry.org)**

**Why should I care?**



**Why should I care? (Page 4)**

California Earthquake Forecast: [www.scec.org/ucerf](http://www.scec.org/ucerf)

California Geological Survey

Seismic Shaking Hazard Maps: [www.consrv.ca.gov/CGS/rghm/psha/pqa.htm](http://www.consrv.ca.gov/CGS/rghm/psha/pqa.htm)

Tsunami Hazards: [tsunami.ca.gov](http://tsunami.ca.gov)

Landslide and Liquefaction Maps: [gmw.consrv.ca.gov/shmp](http://gmw.consrv.ca.gov/shmp)

The ShakeOut Earthquake Scenario: [urbanearth.usgs.gov/scenario08](http://urbanearth.usgs.gov/scenario08)

Historic Earthquakes in Southern California clickable map: [www.data.scec.org/clickmap.html](http://www.data.scec.org/clickmap.html)

Recent Earthquakes in Southern California: [www.data.scec.org/recenteqs.html](http://www.data.scec.org/recenteqs.html)

**What should I do?**



**What should I do? (Page 14)**

Earthquake Country Alliance: [www.earthquakecountry.org](http://www.earthquakecountry.org)

[www.ShakeOut.org](http://www.ShakeOut.org) [www.dropcoverholdon.org](http://www.dropcoverholdon.org) [www.terremotos.org](http://www.terremotos.org)

American Red Cross: [www.redcross.org](http://www.redcross.org)

California Emergency Management Agency: [www.calema.ca.gov](http://www.calema.ca.gov)

California Earthquake Authority: [www.earthquakeauthority.com](http://www.earthquakeauthority.com)

California Seismic Safety Commission: [www.seismic.ca.gov](http://www.seismic.ca.gov)

Emergency Survival Program (ESP): [www.espfocus.org](http://www.espfocus.org)

Federal Emergency Management Agency: [www.fema.gov](http://www.fema.gov)

"Step 1" in greater detail: [www.quakeinfo.org](http://www.quakeinfo.org)

**What should I know?**



**What should I know? (Page 26)**

United States Geological Survey Earthquake Hazards Program: [earthquake.usgs.gov](http://earthquake.usgs.gov)

California Geological Survey: [www.consrv.ca.gov/cgs](http://www.consrv.ca.gov/cgs)

Southern California Earthquake Center: [www.scec.org](http://www.scec.org)

Southern California Earthquake Data Center: [www.data.scec.org](http://www.data.scec.org)

Southern California clickable fault map: [www.data.scec.org/faults/faultmap.html](http://www.data.scec.org/faults/faultmap.html)

Southern California ShakeMaps: [www.cisn.org/shakemap](http://www.cisn.org/shakemap)

Did You Feel It? – report it!: [earthquake.usgs.gov/eqcenter/dyfi.php](http://earthquake.usgs.gov/eqcenter/dyfi.php)

Additional support provided by:

