Putting Down Roots in EARTHQUAKE COUNTRY

Your Handbook for Earthquakes in Utah

2nd Edition

Developed by the:
Utah Seismic Safety Commission
Utah Division of Emergency Management

Utah Geological Survey
University of Utah Seismograph Stations
Structural Engineers Association of Utah

In cooperation with the:
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For additional copies, contact:
The Natural Resources Map & Bookstore
1594 W. North Temple
Salt Lake City, Utah 84116
Phone (801) 537-3320, toll-free (888) UTAH MAP
Email: geostore@utah.gov
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Prepared by the Utah Seismic Safety Commission (USSC), Utah Geological Survey (UGS), Utah Division of Emergency Management (UDEM), University of Utah Seismograph Stations (UUSS), and Structural Engineers Association of Utah (SEAU).

Contributors: UGS—Steve Bowman, Gary Christenson, Jim Davis, Sandra Eldredge, Adam Hiscock, Michael Hylland, Emily Kleber, Mark Milligan; USGS—Christopher DuRoss; UDEM—Robert Carey, John Crofts, Wade Matthews; UUSS—Walter Arabasz, Kristine Pankow, Paul Roberson, Rebecca Sumsion; SEAU—Jessica Chappell, Barry Welliver; Envision Utah—Ryan Beck, Jason Brown, Ari Bruening, Leota Coyne, Robert Grow, Cody Lutz, Lisa Sun

Reviewed by: University of Utah—Kristine Pankow, Keith Koper; USGS—Christopher DuRoss; FEMA—Sean McGowan; SCEC—Mark Benthien.

Production, design, and illustration by: First edition: Liz Paton and Stevie Emerson (UGS) based on template for the San Francisco Bay Region version of this handbook by Susan Mayfield (USGS).

Second edition: improved on original template and additional design by John B. Good, Jessie Pierson and Jennifer Miller (UGS).

Other illustrators: Pat Bagley (pages 1, 25, 28); from San Francisco Bay Region version of this handbook (USGS), Todd Connor (pages 28, 35).

Front Cover: Damage to the Sears Mansion in Salt Lake City from the 2020 M 5.7 Magna, Utah, earthquake. Photo courtesy of the Utah Geological Survey.

Contents

Introduction

Utah is Earthquake Country 1

Utah and the Intermountain West are Seismically Active. 2
Most of Utah's Populated Area Lies Within an Active Earthquake Belt 4
Utah Faces a Dual Earthquake Threat—and Earthquakes in Utah Are Not Just a Wasatch Front Problem. 5
The Wasatch Fault. 6
March 18, 2020, Magna Earthquake 8
Southern Utah Faults 10
Cache Valley Faults 11
Most Earthquake Damage is Caused by Shaking. 12
Utah's People, Economy, and Infrastructure Are Increasingly Vulnerable to a Wasatch Fault Earthquake 13
Earthquakes Can Cause Damange in Different Ways 14

Response of Buildings to Earthquakes. 16
Building Codes Save Lives, but Not All Buildings 17
Unreinforced Masonry Buildings and Homes. 18
What Would Happen if There Was a Magnitude 7.0 Earthquake on the Wasatch Fault?. 20
Earthquake Early Warning Systems: Preparation not Prediction 21
Your Life Could Change Unexpectedly in the Next Quake. 22
Your Financial Situation Could Be Affected by a Quake. 24

The Seven Steps to Earthquake Safety. 26
STEP 1—Learn How to Protect Yourself During an Earthquake 27
STEP 2—Conduct a Home Hazard Hunt 28
STEP 3—Assemble Disaster Kits and Other Supplies 31
STEP 4—Identify Potential Weaknesses In Your Home 33
STEP 5—Drop, Cover, and Hold On 34
STEP 6—Assure Life Safety, Hazards, and Damage 35
STEP 7—Put Your Plan into Action 35

Earthquake Information on the Web. 36
Glossary 37

Information about earthquakes in Utah can be found at: https://earthquakes.utah.gov/

Utah is Earthquake Country

It's not a question of if a major earthquake will strike the Beehive State, but a question of when. However, a major earthquake doesn't have to ruin life as we know it—we can take steps as individuals, families, and entire communities to be ready.

This handbook will help you understand earthquake risks in Utah and find actions you can take to survive earthquakes and improve your ability to successfully recover. Knowledge is power, and with this information you will have the power to become less vulnerable to a major earthquake.

There is more than a 50 percent chance that a major earthquake will happen along the Wasatch Front in the next 50 years (page 13).

Scientists forecast a major earthquake on the Wasatch Front could be one of the deadliest and most costly natural disasters in U.S. history (page 20). It's not just a Wasatch Front problem. Other populated areas, including Washington County (page 10) and Cache County (page 11), are also at risk of a major quake.

You can take steps to be ready during earthquakes and the immediate aftermath.

Learn how to protect yourself during the quake and reduce hazards at home by following the Seven Steps to Earthquake Safety (pages 26–35). Assemble emergency supplies like a 72-hour kit , or even better, a 96 hour kit. Create a response plan for you and your family or loved ones.

Beware of Utah's dangerous buildings! Older buildings made of clay bricks, concrete masonry units, hollow clay masonry units, or stacked stone with few or no steel reinforcing bars (called Unreinforced Masonry Buildings or URMs) are at risk of collapse or significant damage from earthquake shaking and will be responsible for the majority of deaths, injuries, and displacements (pages 16–20). If you live, work, or frequently visit a URM, a few targeted structural improvements can increase your chances of survival (page 33). People in all types of housing can reduce the likelihood of heavy objects such as furniture and appliances from falling on them by conducting a home hazard hunt (page 28).

Full recovery can take months or even years, but there are actions we can take to prepare for an accelerated recovery.

It will take many months for even basic utilities like water and sewer to be restored for many residents after a major quake. Even when power and telecommunications are restored, many homes and buildings will be unsafe to enter. When communities are unprepared for a disaster of this scale, the damage can be so extensive that many residents leave and start over somewhere else.

The fewer URM homes and buildings we have, the better off we will be. Between now and whenever the earthquake hits, we can take steps as individuals or communities to upgrade or replace these buildings.

Keep in mind that all homes and buildings are potentially vulnerable to earthquakes—even if they are not URMs. Modern building codes are designed to prevent building collapse and loss of life, but your home may still be rendered uninhabitable (page 17). Obtaining an active earthquake insurance policy can help you to afford structural and other repairs (page 24). Additionally, by becoming informed and involved in public processes, you can help Utah to prepare for long-term community and economic recovery.

Illustration by Pat Bagley, The Salt Lake Tribune.

AS UTAHNS, We face a very real risk of a major earthquake.

AS INDIVIDUALS, We need to take steps to prepare for large earthquakes and aftershocks. And of course, know how to DROP, COVER, and HOLD ON when shaking begins!

AS A COMMUNITY, We need to prepare to survive earthquakes and then get back to normal by reducing the number of dangerous buildings and upgrading our infrastructure.

Utah and the Intermountain West are Seismically Active

Geologic evidence shows that the Wasatch fault and other faults in Utah have caused earthquakes of magnitude 6.5 to 7.0+. This section (pages 2–15) describes where earthquakes occur in Utah and explains how earthquakes will shake the ground and cause damage in other ways, such as liquefaction and landslides (pages 14–15). Technical terms used throughout this pamphlet are explained in the Glossary (page 39).

Horizontal Extension Created Normal Faults

Stretching, or horizontal extension, of Earth's crust produces a type of dipping (or inclined) fault called a "normal" fault. During an earthquake on a normal fault, the crust above the fault plane moves down relative to the crust below the fault plane. This up/down movement differs from movement on strike-slip faults like the San Andreas in California, where the crust on one side of the fault moves horizontally against the crust on the other side. In Utah, the faults that are considered capable of generating large surface-faulting earthquakes are primarily normal faults in and near the edge of the Basin and Range Province in western and central Utah.

Earthquakes Occur in Earth's Crust

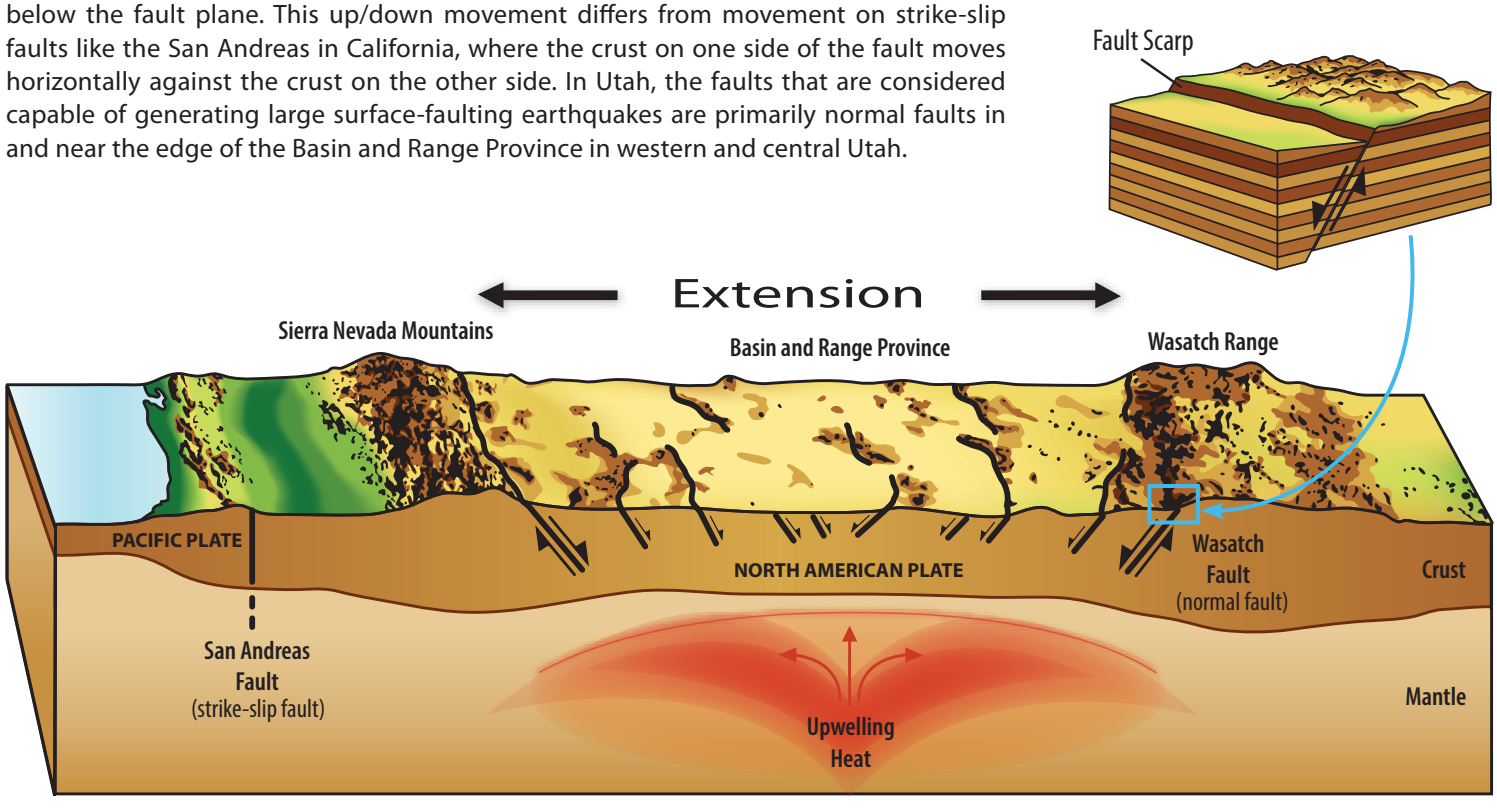
Earthquakes happen when geologic forces that distort and fracture Earth's crust release suddenly. These geologic forces are concentrated on tectonic plate boundaries, like on the West Coast of North America. Utah is not on a plate boundary, but these tectonic forces are a key reason we have earthquakes in the Beehive state.

Basin and Range Province

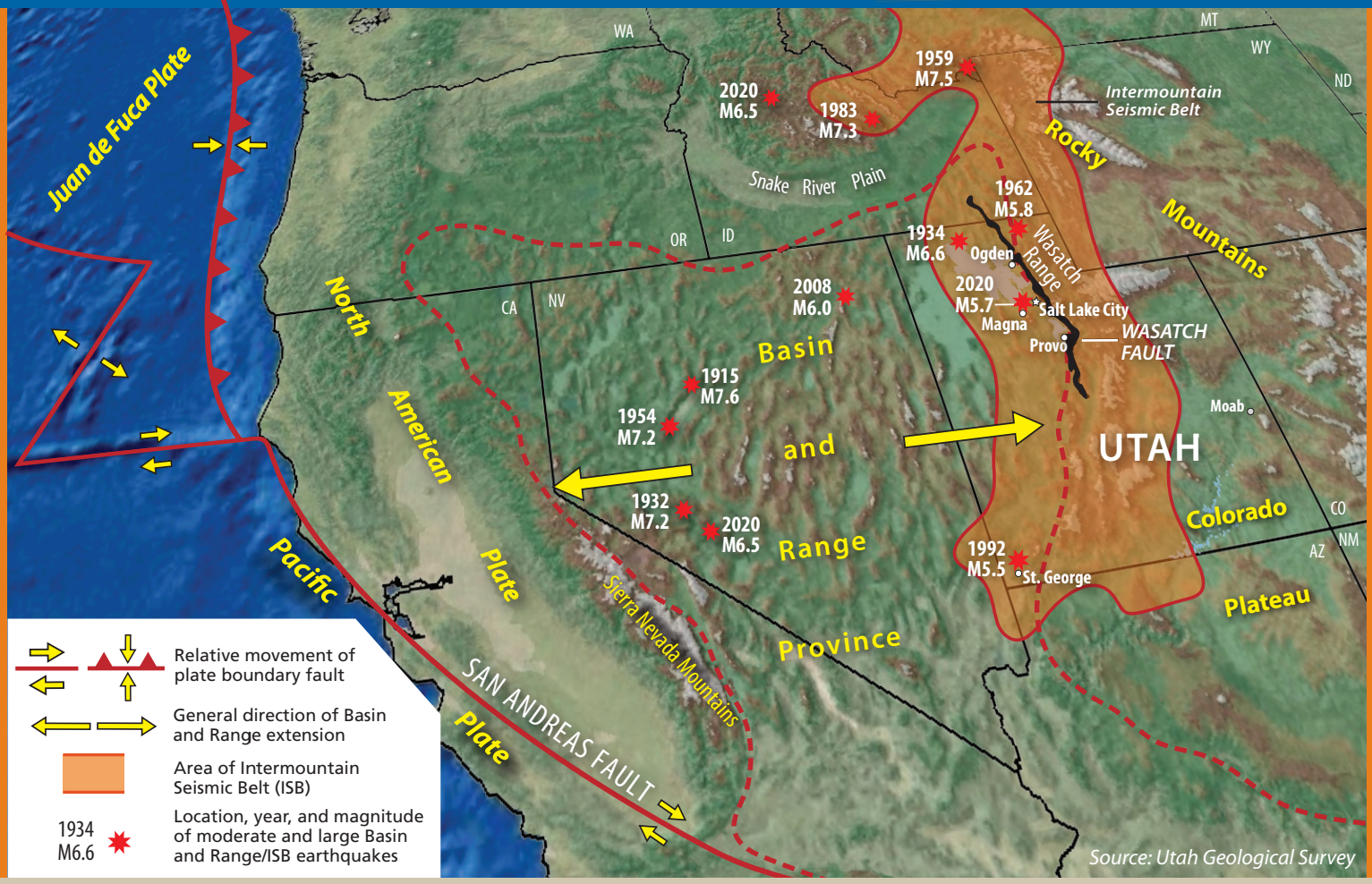
In the figure to the right, notice the mountain ranges and flat basins between Utah's Wasatch Range and California's Sierra Nevada Mountains. This region is called the Basin and Range Province, where tectonic forces have extended the western part of the North American plate for the past 17 million years. Earth's crust is being stretched in an east-west direction at the rate of about one-half inch per year. In response to this stretching, the rigid crust breaks and shifts along faults, raising the mountain ranges and lowering the basins, and producing earthquakes in the process.

Intermountain Seismic Belt

Utah straddles the boundary between the extending Basin and Range Province to the west and the relatively more stable Rocky Mountains and Colorado Plateau to the east. This boundary coincides with an area of earthquake activity called the Intermountain Seismic Belt (ISB). Utah's longest and most active fault, the Wasatch fault, lies within the ISB. The heavily populated Wasatch Front (Ogden – Salt Lake City – Provo urban corridor) and the rapidly growing Cache Valley, St. George, and Cedar City areas are also within the ISB, putting most of Utah's residents at risk.



Source: Utah Geological Survey



Fault Scarp Formation

In a large normal-faulting earthquake, the amount of vertical movement on the fault deep in Earth's crust is sufficient to rupture and offset the ground surface, producing a steep break or fault scarp (see diagram to the left). Geologic evidence shows that individual prehistoric earthquakes on the Wasatch fault produced scarps 6 to 12 feet high. Similar-sized scarps have formed during historical surface-faulting earthquakes in the region, such as the scarp shown below, which formed during the 1954 magnitude 7.2 and 6.9 Fairview Peak and Dixie Valley earthquakes in central Nevada. Surface faulting from large earthquakes and aftershocks ruptured the surface near a small cabin (see photo). Over time, repeated movement on a normal fault eventually produces a mountain range on the uplifted crustal block (for example, the Wasatch Range) and a valley or basin on the down-dropped block (for example, Salt Lake Valley). Photo courtesy of Karl Steinbrugge.

Surface Faulting in Utah

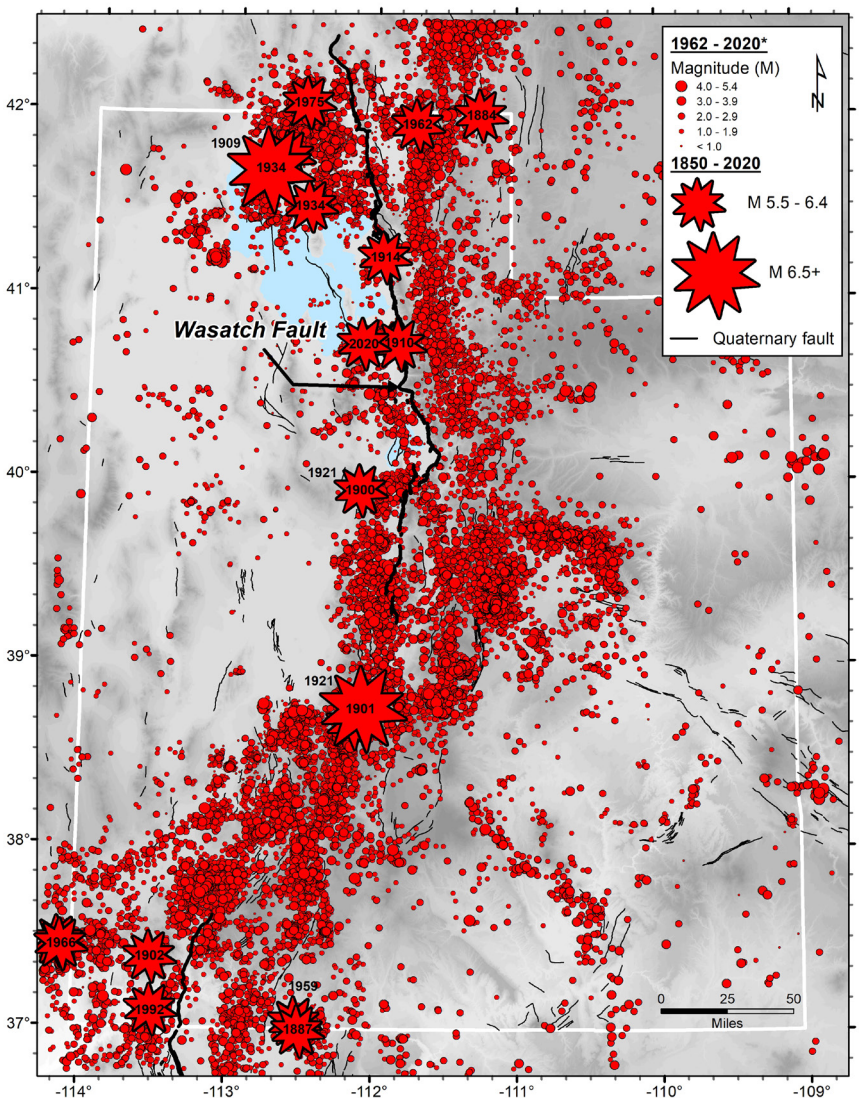
Since 1854, Utah has had only one earthquake large enough to rupture the surface and create a fault scarp. The 1934 magnitude 6.6 Hansel Valley earthquake was near the threshold magnitude for earthquakes that cause surface rupture, and produced small scarps in an unpopulated area north of Great Salt Lake. In Salt Lake City, 80 miles away, ground shaking from this earthquake was strong enough to cause adjacent 6- and 10-story buildings to sway and batter against each other as well as clock equipment to shake loose from the City and County Building's 12-story clock tower and crash down through the building. Photo courtesy of the F.J. Pack Collection, Special Collections Department, University of Utah Libraries.

Most of Utah's Population Lives Within an Active Earthquake Belt

Historical Earthquakes of Moment Magnitude (M) 5.0 and Larger in the Utah Region*		
1884	M 5.6	Paris, Idaho
1901	M 6.6	Tushar Mountains
1902	M 6.3	Pine Valley
1909	M 5.6	Hansel Valley
1910	M 5.3	Salt Lake City
1921	M 5.5	Elsinore
1934	**M 6.6**	Hansel Valley
1937	M 5.4	Idaho-Nevada-Utah border
1950	M 5.3	Northwestern Uinta Basin
1959	M 5.6	Arizona-Utah border
1962	**M 5.8**	Richmond (Cache Valley)
1963	**M 5.1**	Juab Valley
1966	M 5.2	Nevada-Utah border
1967	**M 5.1**	Marysvale
1975	**M 6.0**	Pocatello Valley, Idaho
1988	M 5.0	San Rafael Swell
1989	**M 5.2**	Southern Wasatch Plateau
1992	**M 5.5**	St. George
2020	**M 5.7**	Magna

*Bolded moment magnitudes directly determined; other values estimated from other size measurements.

Earthquakes in the Utah Region



Earthquakes in the Utah region 1850–2020. Starbursts show mainshock earthquakes. Source: University of Utah Seismograph Stations earthquake catalogs.

About Moment Magnitude

Moment magnitude (M_w or **M**) is the best indicator of an earthquake's true relative size and is preferred over Richter local magnitude (M_L). Values of **M** shown on this page for quakes prior to 2017 are from an in-depth study and revision of Utah's historical earthquake catalog. Indicated earthquake sizes supersede those in earlier versions of *Putting Down Roots*.

What is UUSS?

UNIVERSITY OF UTAH SEISMOGRAPH STATIONS

The University of Utah Seismograph Stations (UUSS) is a research, educational, and public service entity that operates a monitoring network of more than 200 regional and urban seismic stations in Utah and neighboring areas, including the Yellowstone National Park region. For more information about UUSS, recent earthquakes, and other earthquake information, see https://quake.utah.edu.

Utah Faces a Dual Earthquake Threat

Threat 1
(time scale of 100s to 1000s of years):

Infrequent, large surface-faulting earth quakes (**M** 6.5 to 7.5) on mapped hazardous faults, such as the Wasatch fault.

Threat 2
(time scale of 10s of years):

More frequent, moderate-size (**M** 5 to 6.5) earthquakes that do not cause surface faulting. If they occur under an urban area, as happened in the 2020 Magna earthquake (see photo below), considerable damage can result.

Average Frequency of Earthquake Mainshocks*

	Wasatch Front Region	Entire Utah Region
Magnitude	**Frequency**	**Frequency**
≥ 3.0	5 per year	13 per year
≥ 4.0	1 every 2 years	1 per year
≥ 5.0	1 every 25 years	1 every 11 years
≥ 6.0	1 every 60 years	1 every 35 years
≥ 7.0	*[Average inter-event times of more than a 100 years]*	

* Excludes foreshocks, aftershocks, and human-triggered seismic events.

Magnitudes are moment magnitude (**M**), the size measure now preferred by seismologists. The symbol ≥ signifies sizes "greater than or equal to."

Rates in the first three rows based on instrumental seismic monitoring (WGUEP, 2016, Tables E-20 and E-21).

Rates for **M** ≥ 6.0 based on Utah's long-term earthquake record. For the Wasatch Front Region, rate is from figure 7-1.2 in WGUEP (2016); for the Utah Region, rate is based on four historical mainshocks of **M** ≥ 6.0 since 1880, the period of complete reporting (WGUEP, 2016, Appendix E).

Source: University of Utah Seismograph Stations

*Damage in downtown Magna caused by the **M** 5.7 Magna earthquake of 2020. Photo courtesy of the Utah Geological Survey.*

Earthquakes Occur Throughout Utah

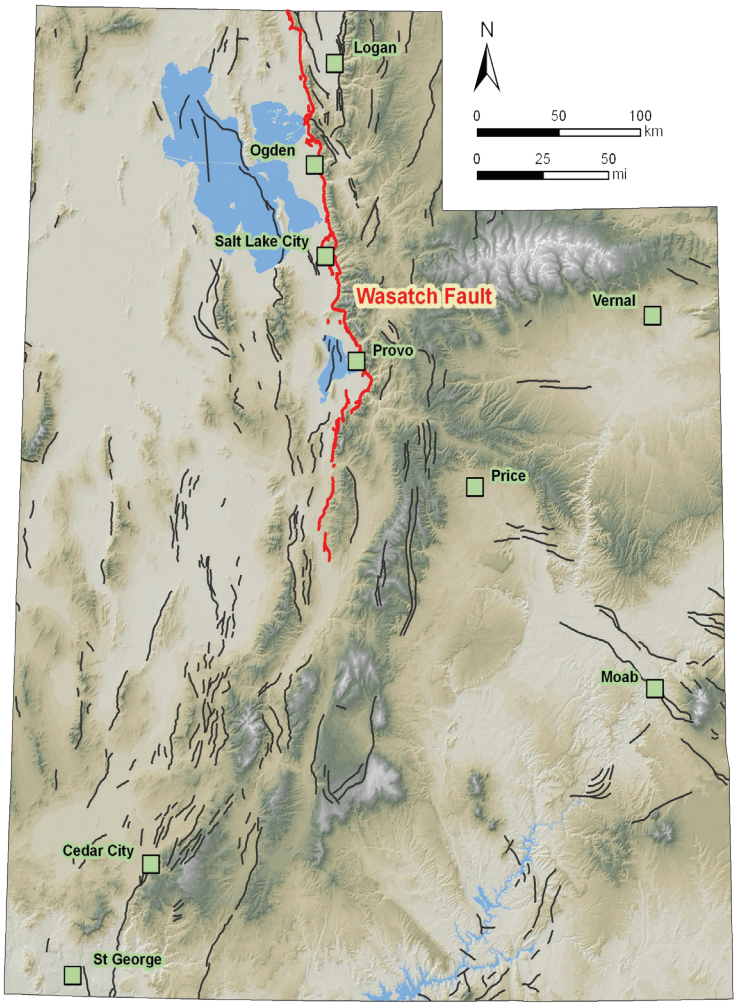
- More than 36,000 earthquakes have occurred in the Utah region since 1962. The Wasatch Front is part of a regional Intermountain Seismic Belt (map on page 3).
- One-half of the 17 damaging earthquakes in Utah of magnitude 5.5 and larger since 1850 have occurred outside the Wasatch Front.
- One of the largest historical earthquakes in Utah was a damaging shock of magnitude 6.6 near Richfield in 1901. The Sevier Valley area between Richfield and Marysvale has had eight earthquakes of magnitude 5 and larger.
- Thousands of mining-induced earthquakes (as large as magnitude 4.2), caused by underground coal mining, have occurred in Carbon, Emery, and eastern Sevier Counties.
- In the Uinta Basin, an earthquake of magnitude 4.5 in 1977 caused minor damage north of Duchesne. Earthquakes as large as magnitude 4.9 have been induced by oil and gas production and other activities in the Colorado-Utah border region. The December 19, 2020 **M** 4.3 earthquake that was felt in Moab and surrounding areas is an example of an induced earthquake.

*Damage caused by the **M** 5.5 Elsinore, Utah, earthquake of 1921 (above) and by the **M** 5.8 Richmond (Cache Valley) earthquake of 1962 (right). (Photos courtesy of, respectively, the F. J. Pack Collection, Special Collections Department, University of Utah Libraries, and Ariel D. Benson, Richmond, Utah)*

The Wasatch Fault

One of the longest and most active normal faults in the world, the 240-mile-long Wasatch fault extends from Malad City, Idaho, south to Fayette, Utah. The fault is subdivided into 10 segments, averaging 25 miles in length; each segment is generally thought to rupture independently and is a separate source of large earthquakes.

Although scientists are unsure about how many small- to moderate-size historical earthquakes can be attributed to slip on the Wasatch fault at depth, the geologic record shows that numerous large (magnitude 6.5–7.5) surface-faulting earthquakes have taken place on the Wasatch fault over the past 10,000 years.



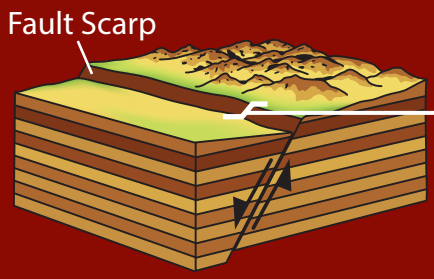
The Wasatch fault (red line) and other faults (black lines) in Utah that have been sources of large earthquakes. Map source from the Utah Geological Survey.

How Do We Know When There Have Been Large Earthquakes on the Wasatch Fault?

Timing information for Wasatch fault earthquakes comes largely from trenches excavated across fault scarps. The trenches expose soil and sediments that were faulted, or displaced, by prehistoric earthquakes. Soils can be measured, sampled, and analyzed to determine when earthquakes occurred in the past, how large those earthquakes were, and how often they happened. With this information, scientists can show when, where, and how large (greater than **M** 6.5) prehistoric earthquakes have been on the Wasatch fault and other faults.

The Wasatch fault typically extends along the base of the Wasatch Range, and forms triangular "facets" as seen in this view of the Wasatch fault to the east near Mapleton, Utah. Image from Google Earth.

Fault scarps formed by surface-rupturing earthquakes are visible along the Wasatch fault (white arrows), and are especially prominent near the mouth of Bells Canyon in Salt Lake County shown here. Photo courtesy of the Utah Geological Survey.



Source: Utah Geological Survey

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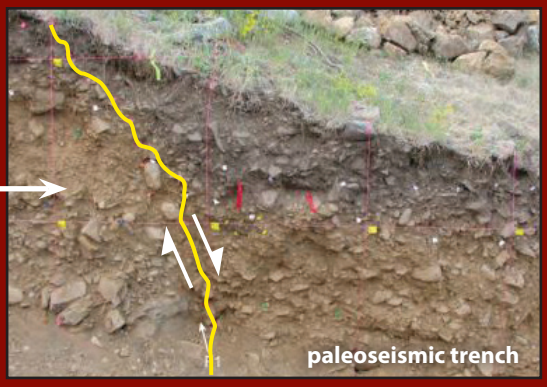
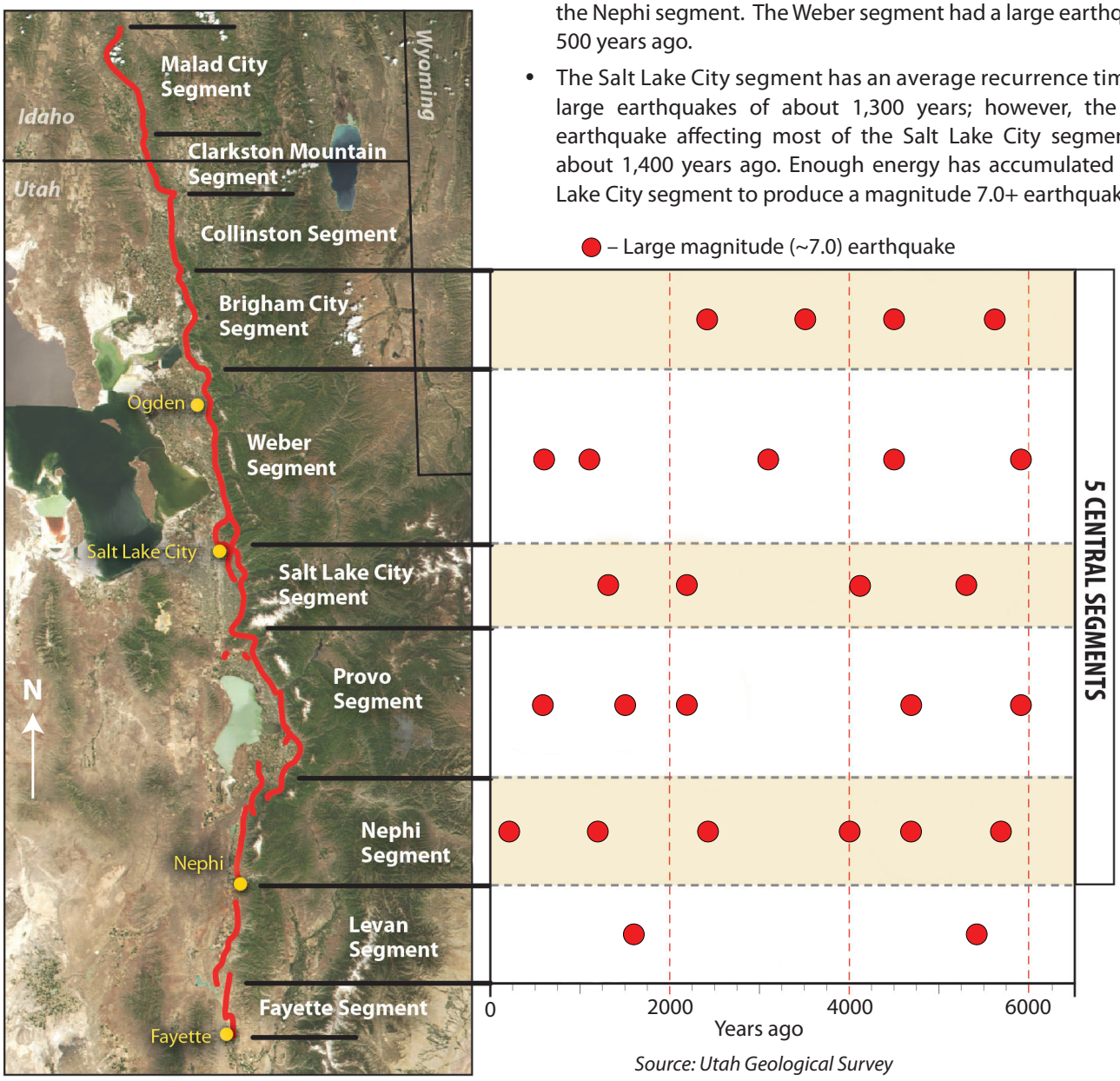


Source: Utah Geological Survey

On the five central segments of the Wasatch fault...

- At least 26 large-magnitude (~6.5 or greater), surface-rupturing earthquakes have occured in the past 6,500 years.
- On average, a large earthquake occurs every 300 years.
- The most recent large earthquake took place about 300 years ago on the Nephi segment. The Weber segment had a large earthquake about 500 years ago.
- The Salt Lake City segment has an average recurrence time between large earthquakes of about 1,300 years; however, the last major earthquake affecting most of the Salt Lake City segment occurred about 1,400 years ago. Enough energy has accumulated on the Salt Lake City segment to produce a magnitude 7.0+ earthquake.



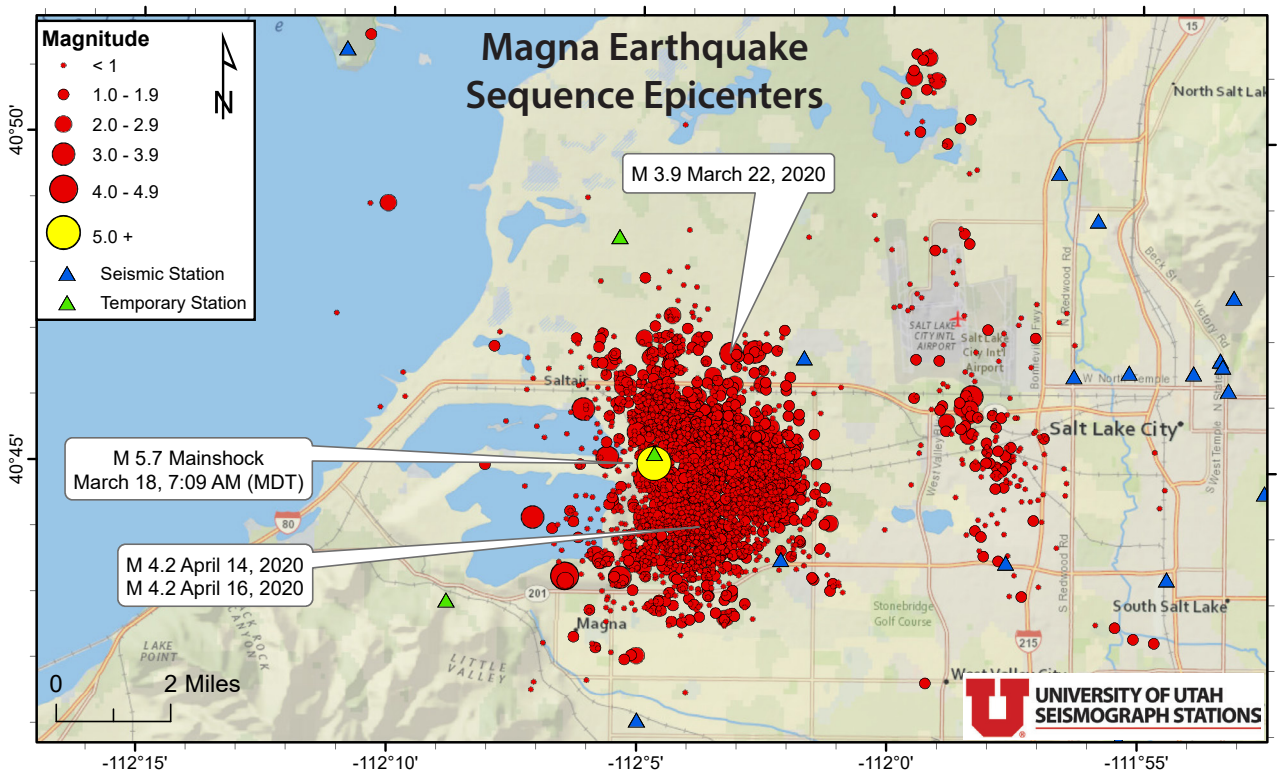
Source: Utah Geological Survey

March 18, 2020, Magna Earthquake

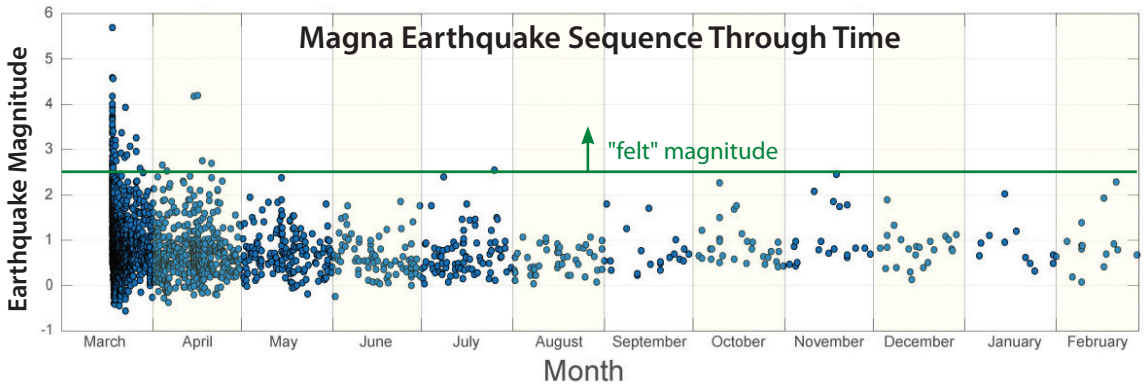
On the morning of Wednesday, March 18, 2020, the Wasatch Front experienced a magnitude 5.7 earthquake with an epicenter north of Magna, Utah. The mainshock was widely felt with over 25,000 felt reports received by the U.S. Geological Survey.

2020 Magna Earthquake Facts

- This was considered a moderate-sized earthquake—the Wasatch fault is capable of generating up to a magnitude 7.5 earthquake.
- This earthquake occurred at a depth of about 7 miles along the Wasatch fault plane underneath the Salt Lake Valley.
- This earthquake did not change the long-term probabilities of a large-magnitude earthquake along the Wasatch Front (see page 20).
- Shaking felt from this earthquake varied based on location. In downtown Salt Lake City, the shaking lasted about 20 seconds, with the strongest shaking lasting 4–6 seconds.



The UUSS has located 2,589 earthquakes as part of the Magna earthquake aftershock sequence from March 18, 2020, through March 18, 2022. The Magna earthquake shows that strong shaking from aftershocks can continue for months to years following the earthquake. Map courtesy of the University of Utah Seismograph Stations.



*Distribution of aftershocks over time from the Magna earthquake sequence. Generally, earthquakes larger than about **M** 2.5 can be felt, depending on location. Data from University of Utah Seismograph Stations.*

Damage:

- No major injuries were reported from the mainshock or aftershock sequence.
- The Magna earthquake caused home, building, and infrastructure damage throughout the Salt Lake Valley.
- The Utah State Office of Historical Preservation reported nearly 150 historic buildings were damaged, the majority of which were unreinforced masonry (URM, or brick) construction.
- State estimates show that there could be upwards of $100 million in total building-related damages, contributing to $629 million in total economic losses related to buildings. This does not include damage to public infrastructure.
- On July 9, 2020, Utah received a major disaster declaration from the President, opening the door for federal assistance money to come to Utah. More than $3.3 million in loans and grants has been provided by the Federal Emergency Management Agency (FEMA) to help businesses and individuals recover from the earthquake.

Structural damage from ground shaking to the historical Sears Mansion in Salt Lake City. This home was subsequently demolished due to the extensive damage. Photo courtesy of the Utah Geological Survey.

Geologic Effects:

- The magnitude 5.7 Magna earthquake was not large enough to create surface fault rupture, or a fault scarp. In the Intermountain West region, surface rupture generally only occurs with earthquakes larger than about magnitude 6.5.
- Ground shaking generated by the earthquake created liquefaction-related ground deformation features (see page 15), including sand boils and lateral-spread-related ground cracking. These features were especially abundant near the shoreline of Great Salt Lake.

Structural damage to an unreinforced masonry building in downtown Magna caused by strong ground shaking from the Magna earthquake. Photo courtesy of the Utah Geological Survey.

MYTH: The 2020 Magna earthquake was the "Big One."

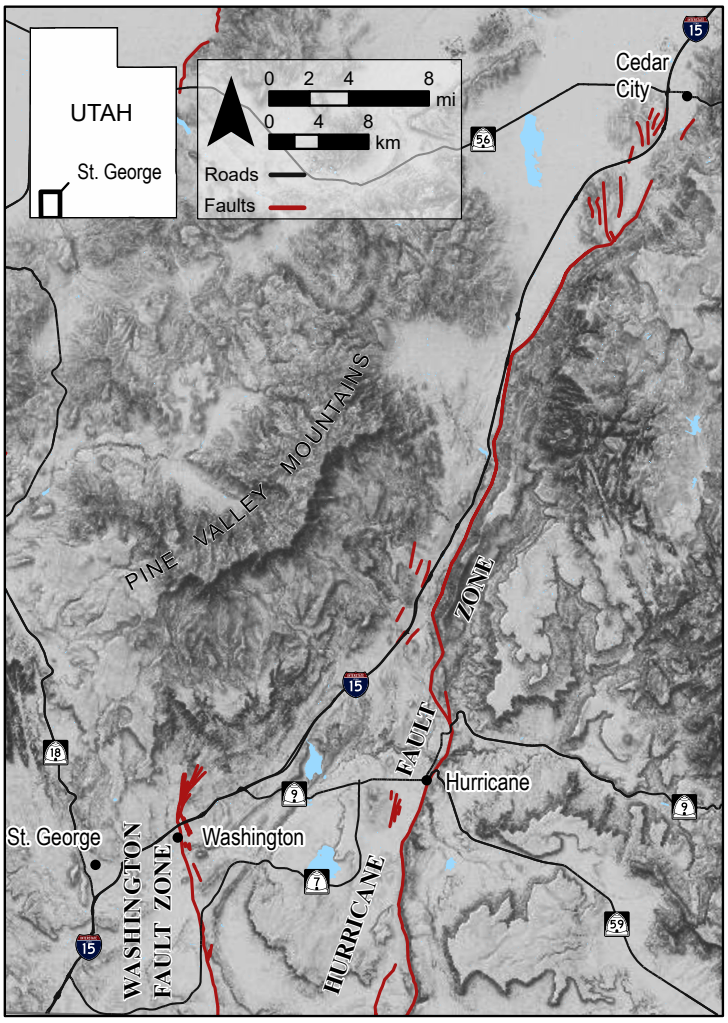
This is false. Although the magnitude 5.7 Magna earthquake produced a lot of shaking and damage, this size earthquake is considered moderate. An expected magnitude of 7.2 for the "Big One" would generate ground shaking about 32 times more violent than the Magna earthquake. Additionally, in the "Big One," we would expect shaking to be felt over a much broader region, and to be accompanied by the ground surface breaking and separating along one or more mapped fault traces, extensive liquefaction features, and potentially rockfall and seiche waves in Great Salt Lake.

Lateral-spread ground cracking along the Great Salt Lake Marina access road from the Magna earthquake. Photo courtesy of the Utah Geological Survey.

Sand boils near the Great Saltair event center caused by ground-shaking-induced liquefaction from the Magna earthquake. Photo courtesy of the Utah Geological Survey.

Southern Utah Faults

- Southern Utah is also home to several active normal faults, including the Washington, Hurricane, and Sevier/Toroweap fault zones.
- The 160-mile-long Hurricane fault zone is one of the longest and most active faults in the Intermountain Seismic Belt (see page 3).
- The Washington and Hurricane faults trend directly through the rapidly growing St. George metropolitan area—the largest population center in Utah outside of the Wasatch Front, and one of the fastest growing metropolitan areas in the United States.
- Faults in southern Utah have lower slip rates and longer recurrence intervals than faults in northern Utah (like the Wasatch fault) but are still capable of generating moderate to large earthquakes as demonstrated by the 1992 **M** 5.5 St. George earthquake.



Faults in southern Utah (red lines) that may be sources of large earthquakes. Source: Utah Geological Survey

The Hurricane fault (white arrows) cutting across an alluvial fan south of Cedar City, Utah. Photo courtesy of the Utah Geological Survey.

1992 M5.5 St. George Earthquake

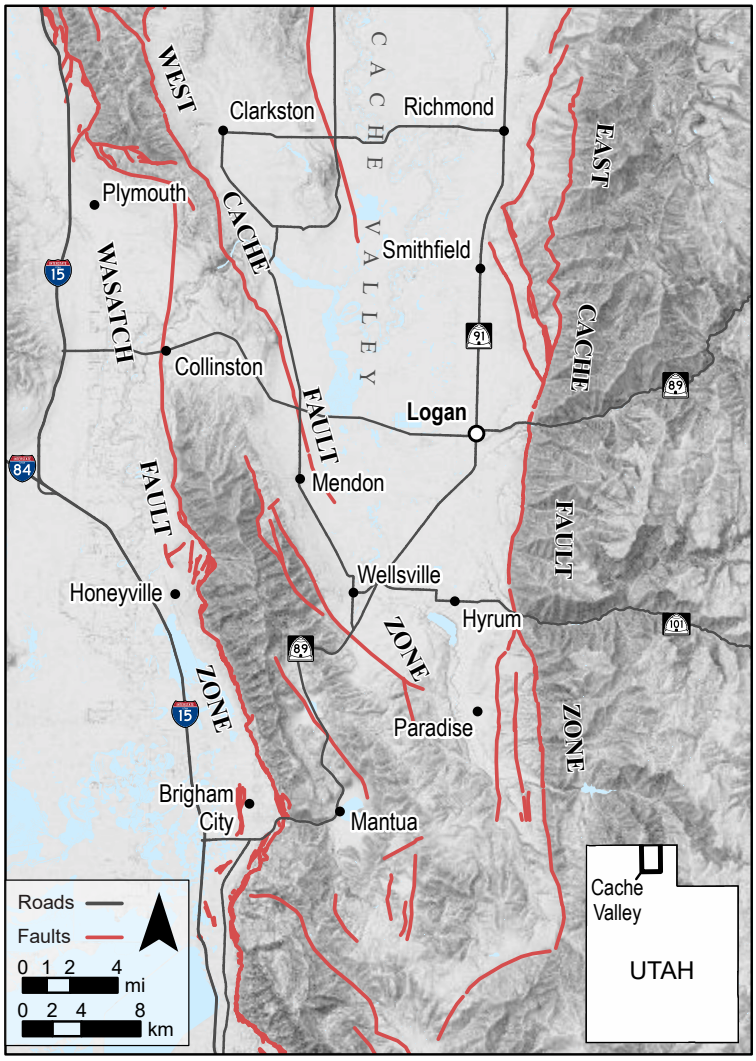
- The September 2, 1992, **M** 5.5 St. George earthquake occurred on the Hurricane fault zone, and was the largest earthquake in the area since the 1902 **M** 6.3 Pine Valley earthquake.
- Minor damage occurred in St. George, mostly non-structural damage from ground shaking and some minor liquefaction along the Virgin River.
- The earthquake triggered a large destructive landslide in Springdale, Utah, near the main entrance to Zion National Park.

*Home destroyed by the Springdale landslide, triggered by the September 2, 1992, **M** 5.5 St. George earthquake. Photo courtesy of the Utah Geological Survey.*

*Aerial view of the Springdale landslide, triggered by the September 2, 1992, **M** 5.5 St. George earthquake. The top of the landslide is denoted by black arrows. Photo courtesy of the Utah Geological Survey.*

Cache Valley Faults

- Cache Valley is home to two major valley-bounding faults: the 38-mile-long East Cache fault zone and the 50-mile-long West Cache fault zone.
- Both faults show geologic evidence of large surface-faulting earthquakes occurring in the region.
- Cache Valley has experienced rapid population growth in recent years, with development infringing closer and closer to hazardous faults.
- Evidence from geologic studies on the East and West Cache fault zones shows fewer recent surface-rupturing earthquakes (magnitude 6.5 or greater) than the Wasatch fault zone. However, numerous large fault scarps from past earthquakes foreshadow the risk of future large earthquakes.



Faults in the Cache Valley region (red lines) that may be sources of large earthquakes. Source: Utah Geological Survey

Scarps (white arrows) along the East Cache fault zone, Cache Valley, Utah. Photo courtesy of the Utah Geological Survey.

Exposure of the East Cache fault visible in a road construction cut-bank near Logan. Photo courtesy of the Utah Geological Survey.

1962 M 5.8 Richmond, Utah, Earthquake

- The August 30, 1962, **M** 5.8 Richmond earthquake caused severe property damage throughout the Cache Valley region, including Logan.
- One report noted that approximately 75 percent of homes in Richmond received some kind of damage from the earthquake.

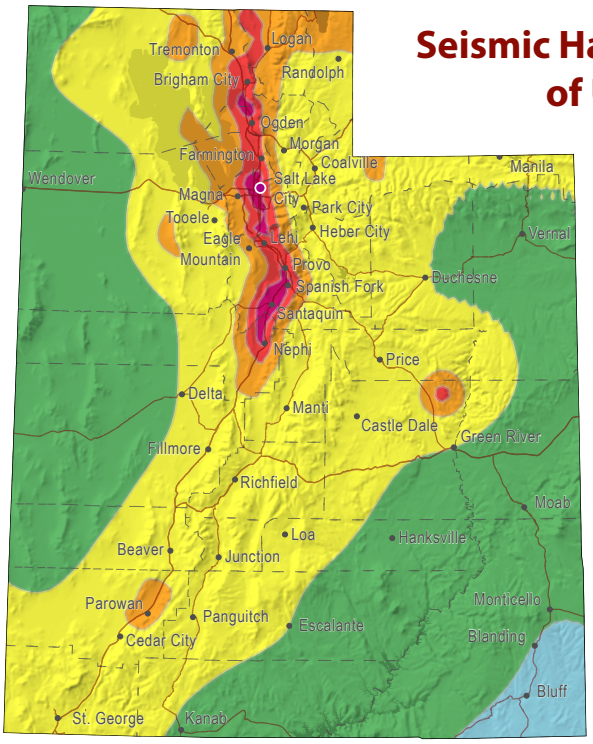
*Ground shaking from the 1962 **M** 5.8 Richmond earthquake caused this brick garage to collapse onto a car. Photo courtesy of* The Ogden Standard Examiner.

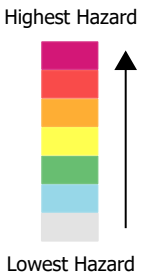
Most Earthquake Damage is Caused by Shaking

The intensity of shaking that a building will experience during an earthquake is variable, but generally depends on three main factors:

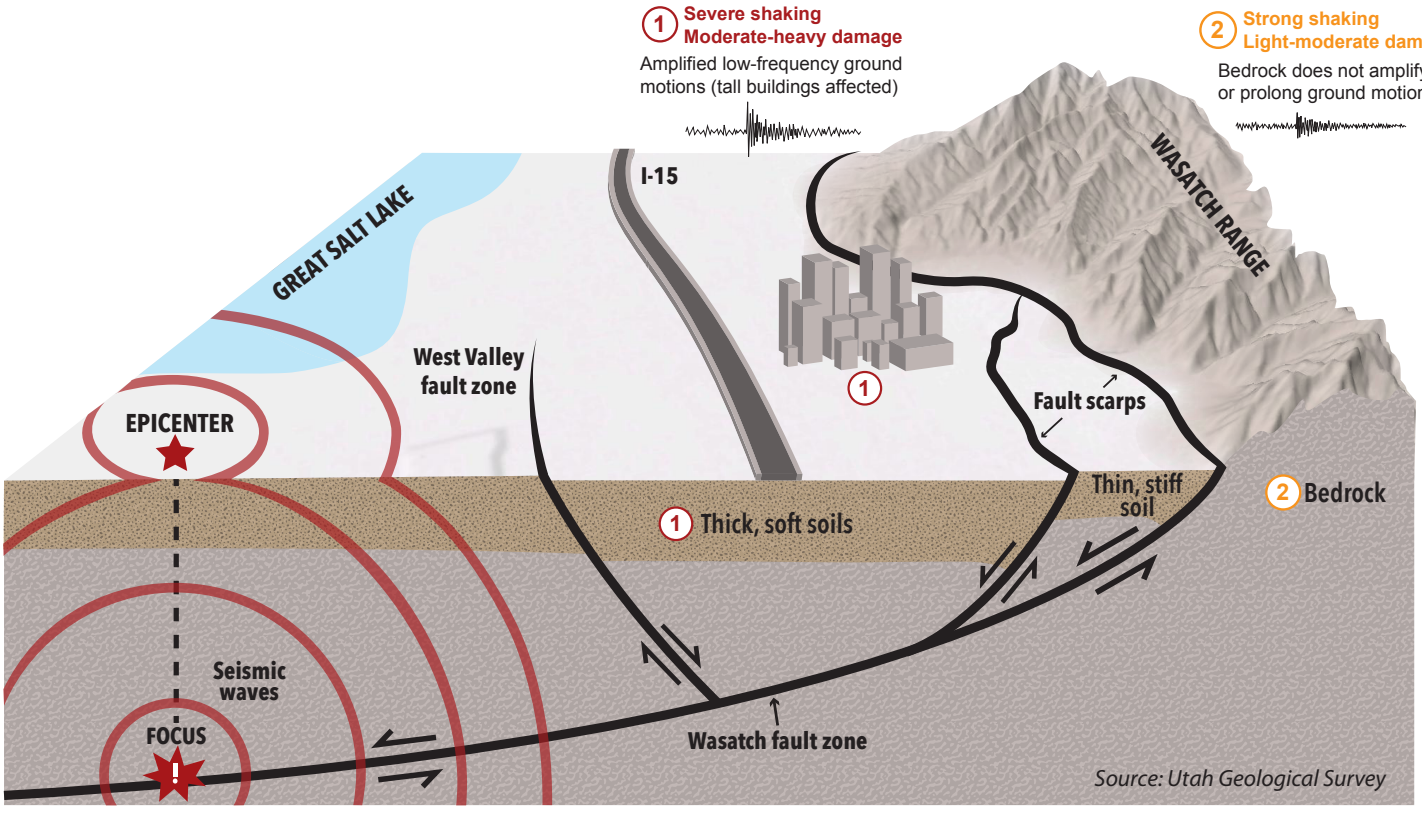
- **The magnitude of the earthquake**—in general, the larger the earthquake, the stronger the shaking and the larger the area affected.
- **The distance from the earthquake epicenter**—the closer to the source of the earthquake, the greater the shaking.
- **The type of ground beneath the structure**—soils may amplify or deamplify the shaking relative to hard bedrock.

Seismic Hazard Model of Utah





This map shows the expected shaking near major faults, such as the Wasatch fault, and in areas of greatest historical seismicity such as the Intermountain Seismic Belt. Much of Utah has a moderate to high likelihood of future intense shaking. Data source: U.S. Geological Survey



Generalized east-west cross section through the eastern part of the Salt Lake Valley, showing the response to seismic waves generated during a Wasatch fault earthquake. Earthquakes generate seismic waves at a wide variety of frequencies, and certain frequency waves may be amplified by local soil conditions.

(1) In the Salt Lake Valley, areas of thick, soft, clayey soil amplify low-frequency seismic waves, yielding slow rolling-type shaking that can damage tall buildings and long-span overpasses. (2) Bedrock does not amplify or prolong ground motions.

Utah's People, Economy, and Infrastructure are Increasingly Vulnerable to a Wasatch Fault Earthquake

- Over 85 percent of Utah's population lives within 15 miles of the Wasatch fault in the Wasatch Front area.
- More than 75 percent of Utah's economy is concentrated in Salt Lake, Utah, Davis, and Weber counties—above the Wasatch fault, which projects beneath the developed Wasatch Front valleys.
- Most of Utah's state government facilities are located within 15 miles of the Wasatch fault.
- Major interstate transportation corridors and the Salt Lake City International Airport are located within 15 miles of the Wasatch fault.
- By 2030 the population in the Wasatch Front area is projected to grow to 2.8 million, a 50 percent increase over 2005.
- To meet the needs of the dramatically growing population along the Wasatch Front, $14.4 billion of new transit and highway infrastructure is planned over the next three decades.

Earthquake Forecast for the Wasatch Front Region

- In 2016, the Working Group on Utah Earthquake Probabilities (WGUEP) assessed the probability of large earthquakes in the Wasatch Front region, highlighting the seismic threat in the region.
- The resulting forecast, shown on this page, conveys the probability of one or more earthquakes of a specified magnitude range in the region for 2016–2066 (50 years), similar to how a meteorologist might describe a chance of rain within a region during the next few hours.
- There is a 43 percent probability of one or more magnitude (**M**) 6.75 or greater earthquakes and a 57 percent probability of one or more **M** 6.0 or greater earthquakes in the region in the next 50 years. This is similar to the odds of flipping a coin, or a 1 in 2 chance of a large-magnitude earthquake impacting the Wasatch Front region.

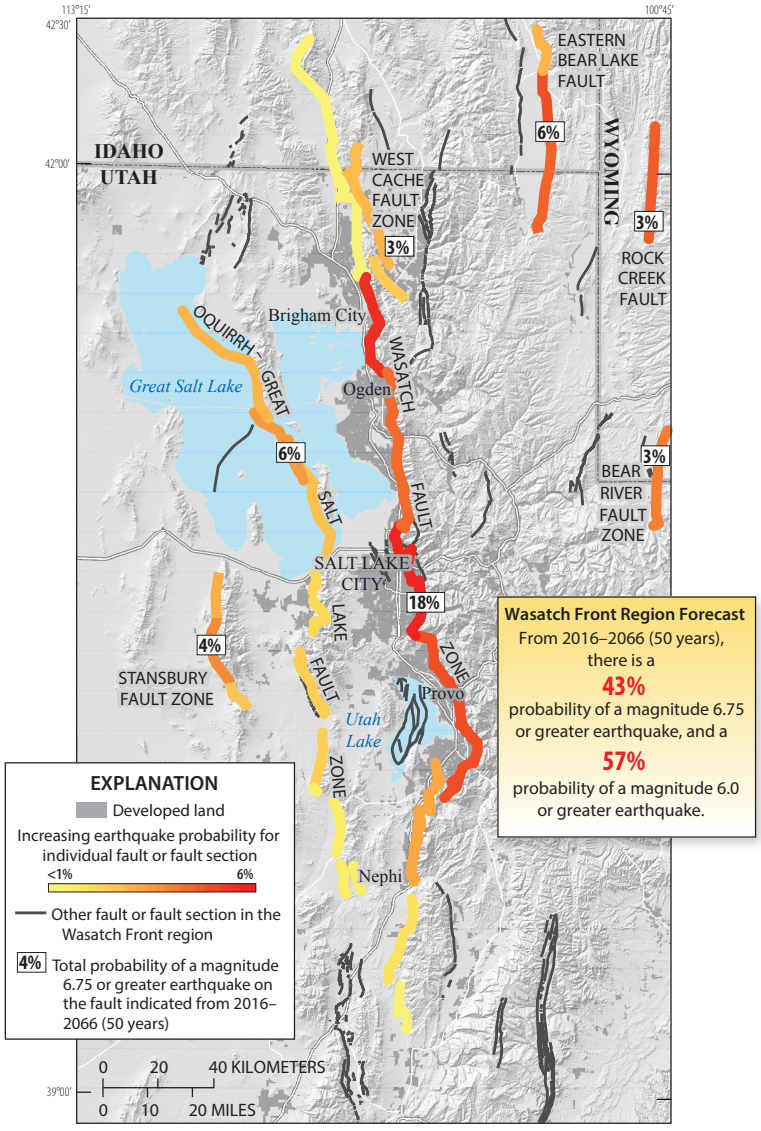
	M6.0 or greater	M6.75 or greater
Wasatch fault zone	18%	18%
Oquirrh-Great Salt Lake fault zone	7%	6%
Other faults in the region[1]	34%	25%
Background earthquakes	14%	NA[2]
Wasatch Front region total	**57%**	**43%**

Probabilities are for one or more earthquakes between 2016–2066 (50 years)(WGUEP, 2016).

[1]Combined probability for the 45 other faults or fault sections in the region.

[2]Probability not calculated for background earthquakes.

Earthquake risk (the probability of loss or damage) is increasing with population growth and development.



Magnitude 6.75 or greater earthquake probabilities may vary along faults (yellow to red fault colors). For example, the total probability for the entire Wasatch fault zone is 18 percent. Modified from the Working Group on Utah Earthquake Probabilities (2016).

For more information, scan QR code to see *Earthquake Probabilities for the Wasatch Front Region in Utah, Idaho, and Wyoming* report.

Full Report

Summary Fact Sheet

Earthquakes Can Cause Damage in Other Ways

Although most earthquake damage is caused by shaking, other effects can be just as devastating. For example, in the 1992 magnitude 5.5 St. George earthquake, the greatest damage to homes was caused by a massive landslide in Springdale (see page 10).

Human Constructed Hazards

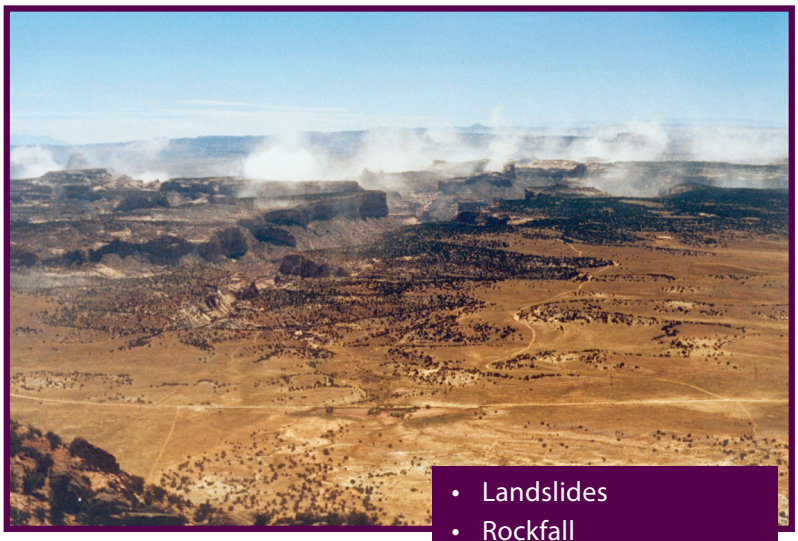
Earthquakes often damage roads and bridges, hindering rescue and recovery efforts and causing accidents. Water and sewer pipeline breaks can result in contamination of surface and groundwater. Damage to natural gas and electrical lines can cause fires and major service outages. Damage to petroleum pipelines can cause oil spills. Earthquakes in urban areas are often followed by destructive fires because gas lines break, electrical shorts ignite fires, damaged water tanks and broken pipes limit water for firefighting, and clogged roads and collapsed bridges hinder access for firefighters. Earthquake damage can cause spilling of hazardous materials from refineries and other chemical storage and distribution systems, research and industrial laboratories, manufacturing plants, and railroad tank cars. There was a chemical spill at a refinery near the epicenter of the 2020 **M** 5.7 Magna earthquake.

- Damaged infrastructure
- Fires
- Dam failures
- Hazardous materials spills

*Cracks and road damage along the Great Salt Lake Marina access road likely from the 2020 **M** 5.7 Magna, Utah earthquake. Photo courtesy of the Utah Geological Survey.*

Geologic Hazards

Earthquakes may generate waves of water in lakes and reservoirs (seiches) many feet high that may flood shorelines and damage dams. One of the most common types of landslides caused by earthquakes are rockfalls, triggered by ground shaking in areas of rock outcrops or loose rocks on hillsides. Surface faulting on normal faults causes subsidence and tilting on the down-dropped side of the fault. Flooding may occur along the east shores of Great Salt Lake and Utah Lake due to subsidence from earthquakes on the Wasatch fault.



*Numerous rockfalls caused dust clouds in the epicentral region of the 1988 **M** 5.8 San Rafael Swell earthquake. Photo by Terry Humphrey, Bureau of Land Management.*

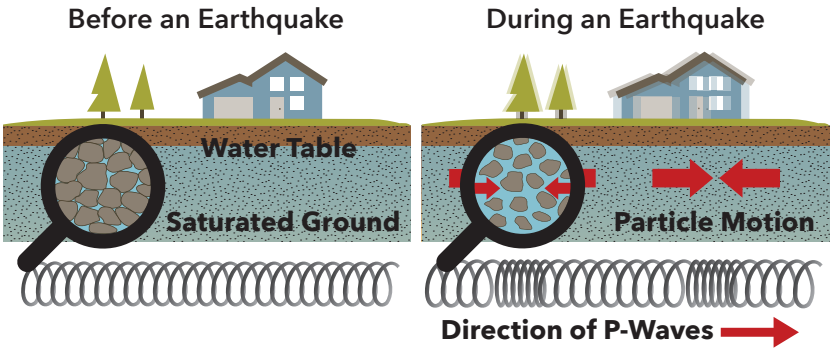
- Landslides
- Rockfall
- Tectonic subsidence
- Surface fault rupture
- Seiches
- Liquefaction (see below and right)

Liquefaction Hazards in Utah

Material in this section is modified from the Utah Geological Survey public information flyer *Liquefaction Hazards in Utah* (PI-100). Please refer to that publication for more information about liquefaction.

What is liquefaction?

Earthquakes larger than about magnitude 5 can induce liquefaction, a process by which strong ground shaking causes the ground to temporarily lose its strength and behave like a viscous liquid. Liquefaction is caused by seismic waves traveling through water-saturated, loose, sandy or silty soils within about 30 to 50 feet of the surface. Specifically, waves alternately compress and expand the materials they travel through, intermittently increasing water pressure between soil grains, which forces the grains apart, causing the soil to lose its strength. Clays and gravels, compacted soils, and dry or unsaturated soils are not prone to liquefaction.



P waves are compressional waves that alternately expand and compress soil and rock. Such waves can be seen in an expanding and contracting spring.

Types of Liquefaction Damage:

1. Loss of bearing strength can cause buildings to settle, tilt, topple, or collapse. However, liquefaction does not cause buildings to sink like ships at sea, a common misconception.

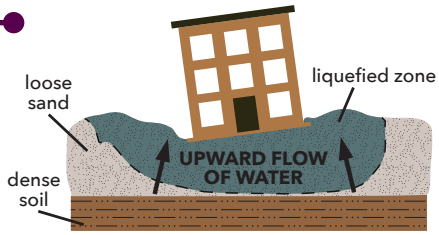


Photo courtesy of the Earthquake Engineering Research Institute

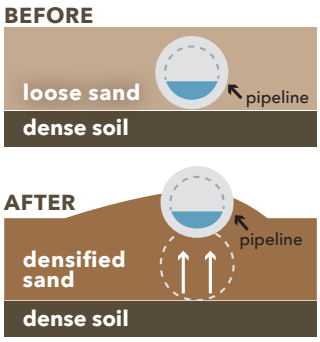


Photo courtesy of Jim Harding

2. Buried objects such as tanks and large pipes can float towards the surface and be damaged.

3. Lateral spreads form when gentle slopes (less than 3 degrees) move sideways over a liquefied layer, causing ground deformation and cracking. Lateral spreading is expected to cause major damage during a large Wasatch Front earthquake.

4. Flow failures take place on slopes steeper than about 3 degrees and can produce fast-moving debris flows that can travel for miles.

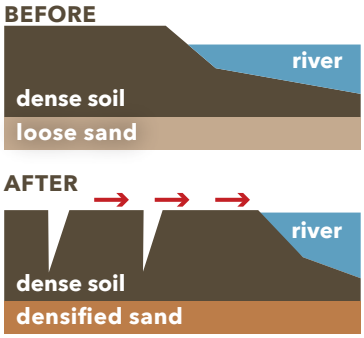


Photo courtesy of Schwede66, via Wikimedia Commons

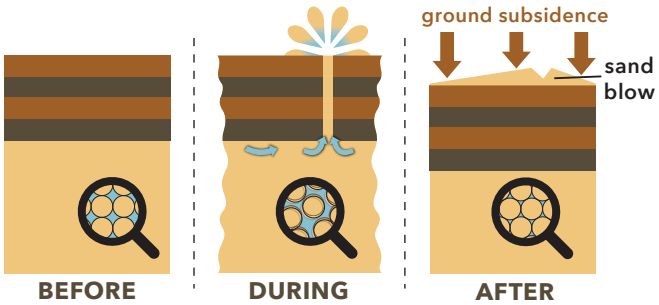


Image courtesy of Mark Lincoln

5. Ground subsidence occurs when soil grains rearrange to denser packing and decreased volume. Subsidence may cause sand blows, and ground deformation and cracks that cause building and infrastructure damage.

Response of Buildings to Earthquakes

What earthquakes do to the ground…

Earthquake energy waves travel through the ground, affecting what is underground, as well as what is built in and on the ground (see diagram on page 12).

- Soft soils with lots of clay tend to increase the motion at the ground surface and thereby amplify the effects on buildings and structures.
- Rock does not change the motion nearly as much as soil, so shaking is more predictable.

What earthquakes do to buildings…

From the bottom up, foundations connect buildings to the ground, and are critical to determining the forces a building can resist. Engineers may choose to "cushion" the effect by using special foundation designs. The soil underlying buildings is an important factor in determining the effects of earthquakes on structures.

A building's configuration and height also play an important role in determining the effects an earthquake will have on its performance.

- Square or rectangular buildings typically perform better than irregular-shaped buildings.
- Tall buildings respond by swaying back and forth.
- Short structures are jarred from side to side as the earthquake releases its force at the ground surface.

Earthquakes shake buildings from the ground up, and an important consideration for performance is the length of time the ground shakes. The longer the ground shakes, the more likely the structure will be unable to resist the effects. Building materials can resist temporary "overstress," but when stretched beyond their limits, will break, much like a paper clip bent back and forth will eventually break.

The materials from which a building is constructed help determine how it performs during an earthquake.

- Steel and wood are considered flexible or "ductile" and tend to absorb the energy.
- Concrete and masonry are more "rigid" and can transfer the ground motion directly into the structure, causing failure.

Contents of a building can also cause injury or death. "Nonstructural" elements such as bookcases, shelves, ceiling tiles, sprinklers, air systems, and light fixtures can fall to the floor or tip over during earthquakes. You can safeguard building occupants by addressing these risks before an earthquake. For more info see pages 26–35.

The State of Utah renovated the Capitol Building to preserve a historic building and to ensure public safety and continuity of government in the event of a large earthquake. The Capitol Building rests on a system of 265 seismic base isolators, separating the building from the foundation and lessening the effects of earthquake shaking. Photo taken September 24, 2006, courtesy of the Utah Geological Survey.

Bracing of an unreinforced masonry home damaged by the 1992 St. George earthquake. Cracks can be seen between the first and second story windows. Photo courtesy of the Utah Geological Survey.

Building Codes Save Lives, but Not All Buildings

Seismic building codes are intended to allow people to exit a building safely. Structures built according to the current code should resist minor earthquakes, resist moderate earthquakes without significant structural damage, and resist severe earthquakes without collapse. Code design does not ensure buildings are undamaged or usable after an earthquake. For example, a building built to code may not cause casualties, but it may not be liveable or usable for months.

Seismic Performance Levels

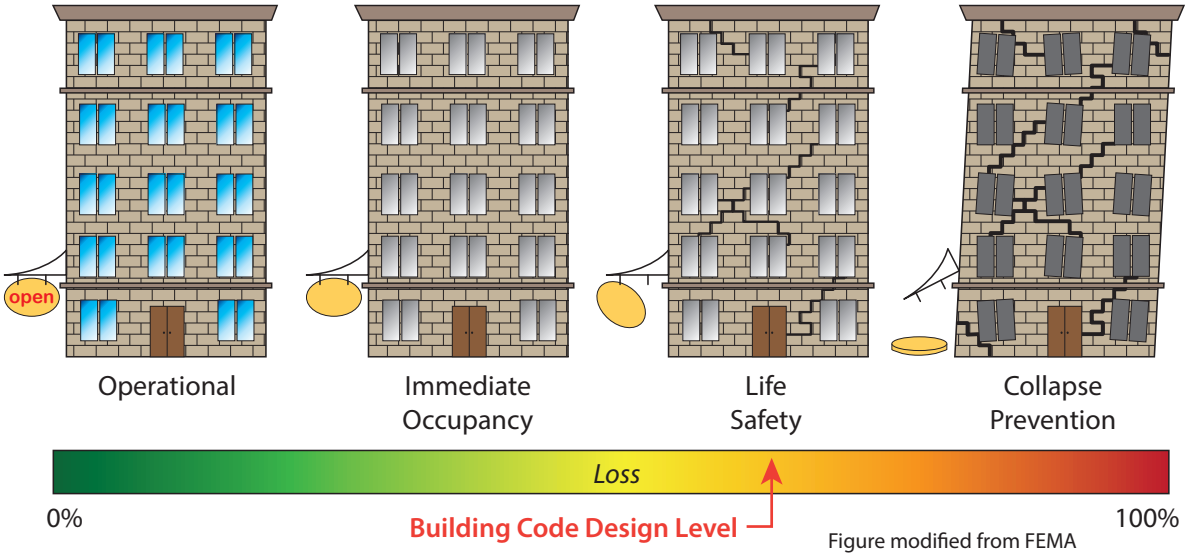


Figure modified from FEMA

Building Codes in Utah

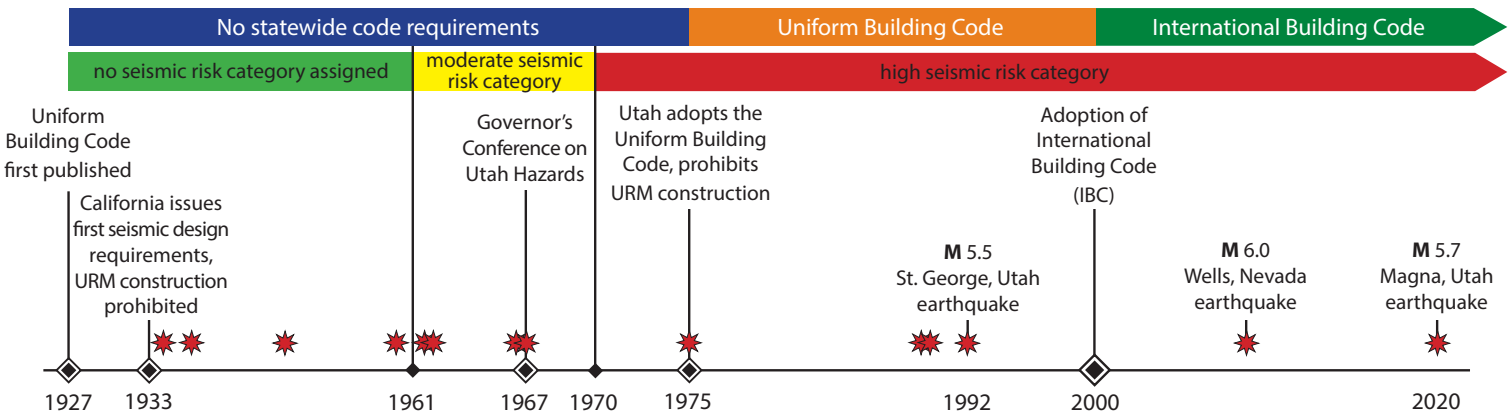
In Utah, seismic building codes made substantial improvements in construction as early as the mid-1970s. Buildings constructed prior to this time may be seismically unsafe. However, buildings constructed in the 1980s would also not be as seismically safe as buildings constructed under today's seismic codes.

The Uniform Building Code (UBC) standardized and improved building safety in some parts of the United States beginning in 1927. It was updated and expanded approximately every three years. Although UBC standards may have been applied in Utah buildings prior to 1975, they were not required.

Three periods in Utah building code status:

1. No statewide code requirements (until 1975)—some buildings may have been designed to UBC standards due to local jurisdiction requirements, design engineer's decisions, and/or building owner's request.
2. Uniform Building Code adoption (1975–2000)—URM construction is prohibited, all buildings must be designed for seismic forces.
3. International Building Code adoption (2001–present)—significant changes to seismic design basis and code implementation.

Building Codes Timeline in Utah



= Earthquakes of M 5.0 and larger in the Utah region (see page 4)

Unreinforced Masonry Buildings and Homes

When it comes to earthquakes, unreinforced masonry buildings are dangerous. There are an estimated 140,000+ unreinforced masonry buildings, roughly 20 percent of occupied buildings, in Utah today. These include single family homes, apartment buildings, schools, and offices, and while Utah's adopted building codes have not allowed this kind of construction since 1975, we still live, work, and learn in these buildings every day. Most injuries and deaths expected in a large-magnitude Wasatch fault earthquake are linked to these buildings.

An unreinforced masonry, or URM, building has walls constructed of clay bricks, concrete masonry units, hollow clay masonry units, or stacked stone with few or no steel reinforcing bars. When URM buildings are shaken in an earthquake they are prone to collapse. These buildings crumble on top of people, cars, sidewalks, or other structures in and around them. Damage to unreinforced brick buildings is dangerous. If the URM walls support floor or roof framing, significant structural collapse can occur. When masonry debris falls, it is potentially lethal. Particularly vulnerable to collapse outside of a building are parapets—short walls that often extend around the perimeter of a roof. Other building elements such as chimneys and decorative architectural elements such as cornices are also vulnerable to collapse. Past earthquakes have shown that expensive repairs are needed to rehabilitate damaged URM buildings. Not only are buildings of this type more likely to become damaged in an earthquake, but they require costly repairs, during which the building is unsafe to occupy. Often, a damaged URM building will be irreparable and need to be demolished. In the 2020 Magna earthquake, a moderate-sized event, the Sears Mansion in Salt Lake City was determined to be damaged beyond repair and was ultimately demolished (see front cover).

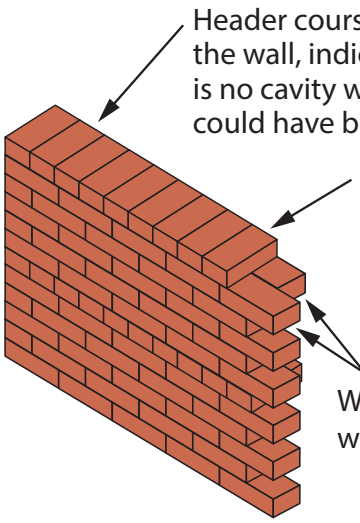
Examples of Unreinforced Masonry (URM) Construction

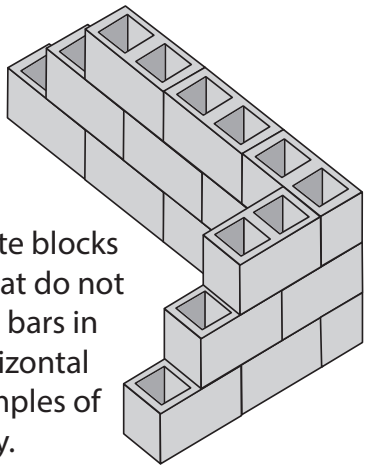
Photo courtesy of Jessica Chappell

Row of Brick Ends (Header Course)

Photo courtesy of Jessica Chappell

Arched Windows





Walls made of concrete blocks (or "cinder blocks") that do not have reinforcing steel bars in grouted cells and horizontal bond beams are examples of unreinforced masonry.

If you are in doubt whether your home or building is a URM, contact a licensed structural engineer.

Damage to a URM building in downtown Salt Lake City from the 2020 Magna earthquake. The "X" pattern between the arched windows is a telltale sign of URM construction. This is an example of "in-plane" failure. Photo courtesy of Reaveley Engineers.

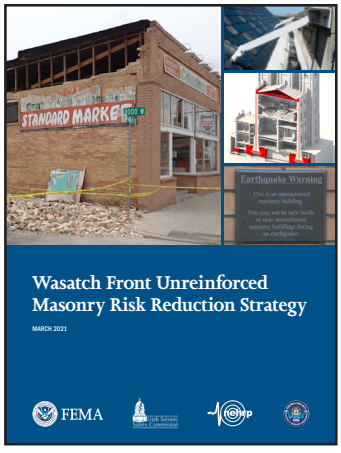
Utah URM Facts

Utah has a long "transitional period" for masonry building construction—from the 1950s to 1970s. Reinforcement begins to be used more frequently in masonry for some buildings beginning in the 1950s.

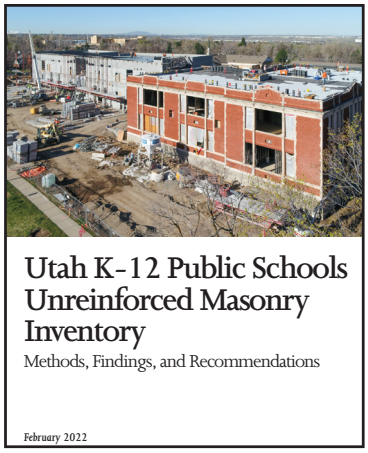
Record drawings, investigation, and testing can determine the status of a masonry building.

URM is not the only vulnerable building type in Utah. Non-ductile concrete frames are older concrete buildings that do not have sufficient reinforcement to perform to modern standards in seismic events.

Damage to a URM building in downtown Salt Lake City from the 2020 Magna earthquake. The image shows unreinforced brick with header courses (red lines). The wall has out-of-plane masonry damage. The diagonal brace (white arrow) was strong enough to support the roof beam preventing collapse of the roof framing. Photo courtesy of Reavley Engineers.



This report provides Utah with a strategy for significantly reducing the risks posed by URM buildings across the Wasatch Front.



This inventory study identified 119 school campuses statewide with URM construction.

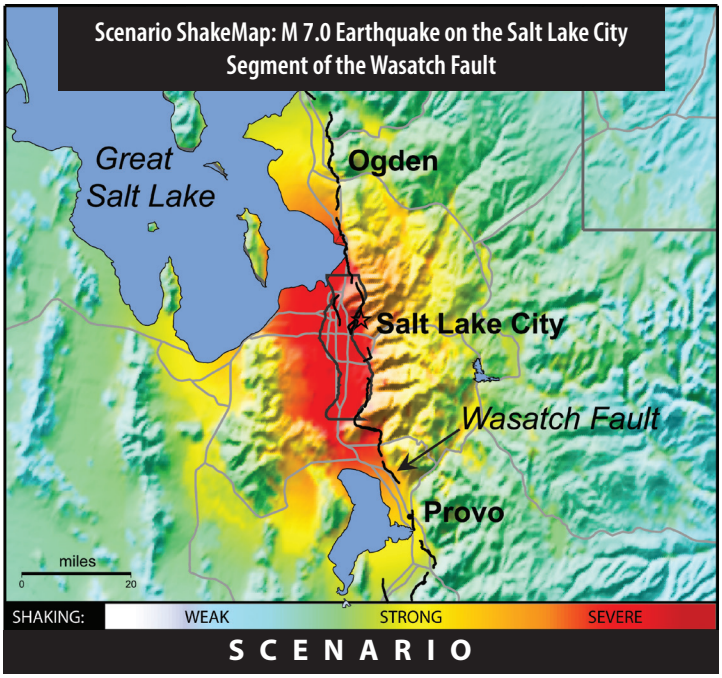
What Would Happen if There Was a Magnitude 7.0 Earthquake on the Wasatch fault?

Strong ground shaking from a magnitude 7 or greater earthquake along one of the five central segments of the Wasatch fault will cause major losses. However, we do not need to wait for these earthquakes to occur to estimate what they could do to Wasatch Front communities. In 2015, a report developed by the Utah Chapter of the Earthquake Engineering Research Institute presented a realistic picture of the effects of a scenario Wasatch fault earthquake on the Salt Lake City segment, as well as other neighboring segments. In particular, this report addresses how long it may take the state of Utah and its residents to fully recover and the potential long-term impacts on Utah's economy. Using the Federal Emergency Management Agency's Hazards U.S. loss-estimation model, experts can estimate the extent of future damage and take actions now to reduce potential losses and plan for recovery.

Loss Estimates for the Central Segments of the Wasatch Fault

Wasatch Fault Segment	Building Losses	Displaced Households	Life threatening Injuries and Fatalities
Brigham City	$3 billion	14,000	500
Weber	$16 billion	57,000	3,000
Salt Lake City	$42 billion	150,000	9,000
Provo	$14 billion	48,000	3,000
Nephi	$1 billion	4,000	200

Estimated losses from a magnitude 7.0 earthquake on each of the central segments of the Wasatch fault. Although the cost of building losses will increase over time, displaced households and injuries will will not decrease unless major action is taken.



PLANNNG SCENARIO ONLY—Map Version 7 Processed Thu Jul 6, 2006 04:52:11 PM MDT

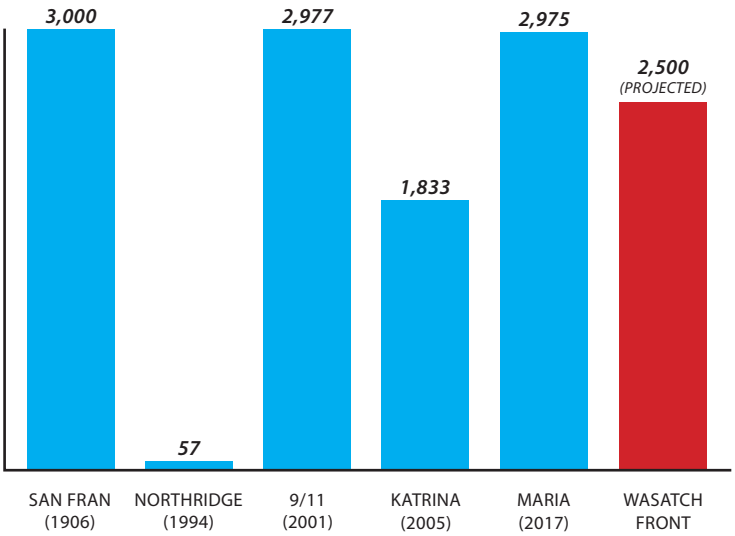
*A scenario ShakeMap for a magnitude 7.0 earthquake on the Salt Lake City segment of the Wasatch fault. The severe shaking from a **M** 7.0 earthquake would cause considerable damage in new and well-designed structures. Damage in brick and older buildings would be substantial, with partial collapse. Buildings would be shifted off foundations, liquefaction would occur, and underground pipes would break.*

How would a M 7.0 earthquake affect life on the Wasatch Front?

- A **M** 7.0 earthquake on the Wasatch Front would be among the deadliest disasters in U.S. history largely because of the number of unreinforced masonry homes (see bar chart).
- Water and sewer service across the Wasatch Front is projected to be disrupted for more than a million people for many months, leaving Utahns without shelter and critical lifeline services.
- Short-term economic losses for the state were estimated at $33.2 billion in 2015, and would be significantly higher if estimated today.
- Long-term losses would undoubtedly be much larger as people leave, many never to return. Businesses that close may never reopen.

FATALITIES IN MAJOR U.S. DISASTERS

SINCE 1900



Graphic courtesy of Envision Utah.

For more information, scan QR code to see 2015 EERI Scenario Report.

Earthquake Early Warning Systems: Preparation, not Prediction

Although earthquakes cannot be predicted, technology exists that can detect earthquakes quickly and broadcast a warning of the predicted arrival times of ground motion (shaking), and the severity (intensity) of shaking, in the general region of the earthquake epicenter. Alerts, even if seconds before strong shaking arrives, can prompt critical actions to protect life and property before strong shaking arrives. The technology has recently been implemented in California, Oregon, and Washington, and earthquake early warning could come to Utah soon.

How does earthquake early warning work?

Earthquake early warning systems use seismic networks and software that can perform real-time data communication and analysis to issue alert messages within seconds from the origin of an earthquake. Electronic warning signals can be transmitted almost instantaneously, while destructive S waves generated by the earthquake travel through Earth's shallow crust at speeds of around 0.5 to 3 miles per second.

1. When a fault ruptures and creates an earthquake, the fault sends out different types of seismic waves. The fast-moving, but less damaging, P-wave is the first to arrive. This wave is used to issue a warning before the slower but more damaging waves (S-wave and surface) arrive.
2. Sensors detect P-waves and immediately transmit data to an earthquake alert center.
3. The location, size, and estimated shaking of the earthquake are determined at the earthquake alert center.
4. A message is sent to partners, such as transportation agencies, emergency facilities, and hospitals, to alert people to Drop, Cover, and Hold On as well as trigger automated actions, such as shutting down a train or halting industrial processes.

Possible scenario for implementing an earthquake early warning system in Utah. An earthquake on the Brigham City segment of the Wasatch fault may give populated areas to the south 10 or more seconds to prepare.

Your Life Could Change Unexpectedly in the Next Quake

Where will your family be?

- Your children may be at school, day care, or other activities.
- Family members may be at work or commuting.
- Pets may run away or be injured.

Debris in the entryway to West Lake Junior High School in Saratoga Springs after the 2020 Magna, Utah, earthquake. Photo courtesy of Francisco Kjolseth, The Salt Lake Tribune.

Pets may not be allowed in some emergency shelters. Do you have a plan to feed and care for your animals after an earthquake?

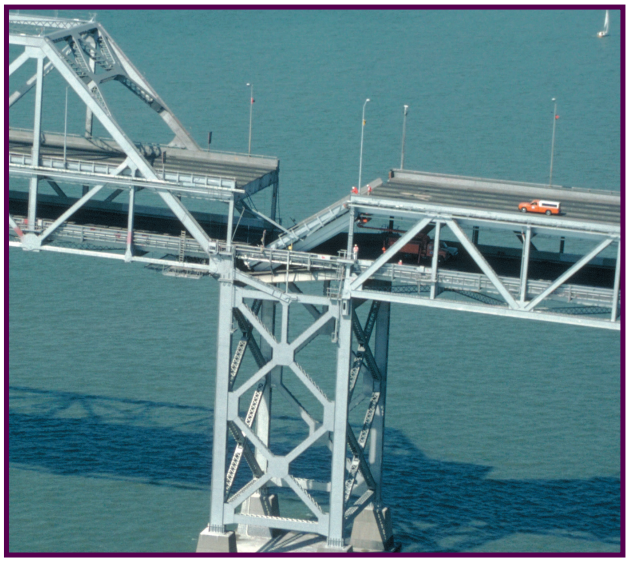
Will you have medical services?

- The 911 emergency system will likely be overloaded.
- Hospitals and other medical facilities may be damaged.
- Emergency rooms and trauma centers may be overwhelmed.
- Assisted living, critical care, and other health services such as dialysis may not be operational.

This hospital in Sylmar, California, had to be demolished after the 1971 ***M*** *6.7 San Fernando earthquake. Photo courtesy of the U.S. Geological Survey.*

Will you be able to get home?

- Road damage and closures may restrict your ability to travel by car.
- Public transportation, including buses, light rail, commuter trains, and airports may experi ence closures or interruptions in service.
- Commute times may be dramatically increased.



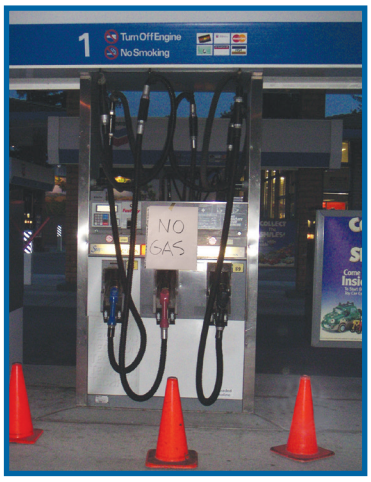
The 1989 ***M*** *6.9 Loma Prieta earthquake caused this section of the San Francisco-Oakland Bay Bridge to collapse. Photo courtesy of the U.S. Geological Survey.*

Will you be able to stay in your home?

*This mobile home in Magna, Utah, was thrown off its foundation due to the shaking of the 2020 **M** 5.7 Magna, Utah earthquake. Photo courtesy of Francisco Kjolseth,* The Salt Lake Tribune.

- Your home may be damaged and unsafe to live in.
- Your personal property may be damaged or destroyed.
- Construction materials and labor for repairs will be in limited supply and costs will increase.
- Rebuilding scams may be common.
- Availability of rental housing may be limited due to damage and high demand.

Can you live without the services you rely on?



Where will you get your water, food, medicines, and gasoline after an earthquake? Photo courtesy of the U.S. Geological Survey.

- Water may be in short supply.
- Natural gas and electric power may be out for days or weeks.
- Garbage and sewage services may be interrupted.
- Telephone, internet, cell phone, and wireless communications may be overloaded or unavailable.
- Mail service may be disrupted or delayed.
- Gasoline may be in short supply, and rationing may be necessary.
- Bank operations may be disrupted, limiting access to cash, ATMs, or online banking.
- Grocery, drug, and other retail stores may be closed or unable to restock shelves.

How will your job be affected?

- Businesses may sustain damage and disruption—many small businesses require a long time to reopen or do not survive disasters.
- Your income may be affected—payroll checks or direct deposits may be delayed.
- Your workplace may become a temporary shelter for you or others.
- Supplies and deliveries will be interrupted.

*Businesses were closed in downtown Magna following the 2020 **M** 5.7 earthquake. Photo credit: Francisco Kjolseth,* The Salt Lake Tribune.

How will the American Red Cross Help?

After a damaging earthquake, the American Red Cross will help in the following ways:

- Opening and operating emergency shelters.
- Providing food at shelters and feeding locations and through mobile distribution.
- Obtaining and delivering other needed items such as water, baby supplies, and blankets.
- Assisting with the immediate mental-health needs of those affected.
- Providing for basic health needs at shelters and other locations.
- Helping with initial recovery through casework and referrals to other agencies and partners.
- Providing blood and blood products.

For more information go to: https://www.utahredcross.org

American Red Cross

Your Financial Situation Could Be Affected by a Quake

Aid may not be available immediately following a major disaster. Without proper planning, the financial impact of an earthquake on you and your family could be devastating. Although many things are out of your control after a quake, your ability to recover financially depends on a number of factors that you can control. Prepare and follow a financial disaster recovery plan and you will be more likely to recover successfully. Consider the following:

Will you have money, food, and medicine?

- Bank operations may be disrupted, limiting access to cash, ATMs, and online banking.
- Food, drug, and other retail stores where you shop may be closed or unable to restock shelves.

Will you be able to recover financially?

- You are still responsible for your existing debts, such as mortgage, lease, car, and credit-card payments.
- You may not have access to important financial records.
- Your assets are at risk without sufficient earthquake insurance.
- If you have earthquake insurance and experience loss, begin working with your insurer to file a claim as quickly as possible.

This bank was damaged in the Nisqually, Washington, earthquake, requiring customers to seek services elsewhere. Photo courtesy of The Olympian*, Olympia, Washington.*

Your Financial Disaster Recovery Kit

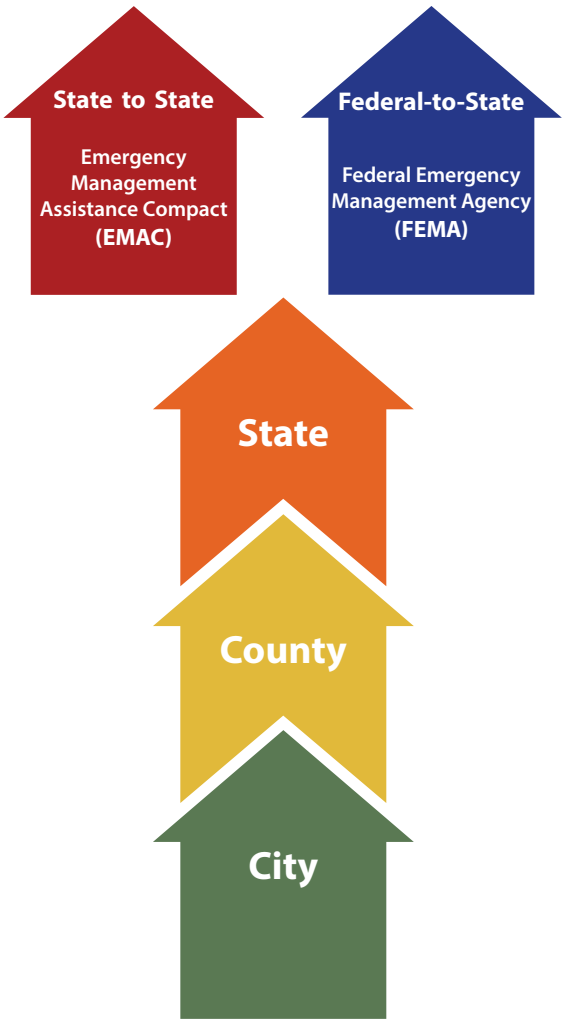
Following a quake, disaster aid may not be immediately available, so you should plan ahead. If you have prepared a financial disaster recovery plan, you are more likely to recover successfully after a quake.

After a damaging earthquake, you will need copies of essential financial documents, as well as emergency cash. Keep these items together, current, and stored in a fire-proof document safe. Consider purchasing a home safe or renting a safe deposit box. Some essential items in your financial disaster recovery kit are:

- ☐ Birth certificates.
- ☐ Marriage license/divorce papers and child custody papers.
- ☐ Passports and driver's licenses.
- ☐ Social security cards.
- ☐ Naturalization papers and residency documents.
- ☐ Military/veteran's papers.
- ☐ Critical medical information.
- ☐ Cash, in the event ATM or bank services are disrupted.
- ☐ Documentation for stocks, bonds, and other investments.
- ☐ Bank statements.
- ☐ Credit card numbers.
- ☐ Insurance policies.
- ☐ A list of phone numbers for financial institutions and credit card companies where you have accounts.
- ☐ An inventory of your household possessions.
- ☐ Appraisals of valuable jewelry, art, antiques, and heirlooms.
- ☐ Home improvement records.
- ☐ A backup of critical files on your computer (also keep a copy at work).
- ☐ A list of names, phone numbers, and e-mail addresses of critical personal and business contacts.
- ☐ Deeds, titles, and other ownership records for property such as homes, autos, RVs, and boats.
- ☐ Powers of attorney, including health-care powers of attorney.
- ☐ Wills or trust documents.

How does the government respond to an earthquake?

Every disaster is unique. The general framework for assistance and types of assistance may vary depending on the type of disaster, but it tends to start at the local level. When a city has exhausted all of its resources, they request assistance from the county Emergency Operations Center (EOC). When the county has exhausted all of its resources, they request assistance from the State of Utah EOC. When the State of Utah has exhausted all of its resources, they can request assistance through the Emergency Management Assistance Compact (EMAC). This compact is a state-to-state compact providing quick access to select needed resources. The state can also request help from the federal government through the Federal Emergency Management Agency (FEMA). Disaster assistance to individuals from the government is typically limited to covering immediate basic needs; insurance is necessary to cover home repairs.



All disasters start at the local level. Through the disaster declaration process, lower level jurisdictions can request disaster assistance from the next higher level of government.

Will your insurance cover your losses?

- Homeowner's and renter's insurance policies do not cover losses related to earthquakes. Businesses also need insurance, since they are generally only eligible for post-disaster loans, not grants.
- There is uncertainty attached to insuring against earthquakes.
- A separate earthquake insurance policy is one way to help protect your home, in addition to seismic retrofitting.
- Earthquake insurance may help with additional living expenses in the days and weeks after earthquakes.

- Relatively few (< 20%) Utah homeowners have earthquake insurance.
- Most insurers do not provide new earthquake coverage after there has been a recent earthquake. When there has been recent seismic activity, people rush to add earthquake coverage, then after the panic dies down, they may cancel their coverage. The exposure to risk and the expense to insurers are usually greater than the premium earned, so insurers choose not to issue coverage in these circumstances.

The State of Utah Emergency Operations Center (EOC). Photo courtesy of the Utah Division of Emergency Management.

For more information about insurance, scan the QR code to visit the Utah Insurance Department's website.

Preparing for Earthquakes is Up to You, but Be Ready Utah is Here to Help with these Seven Steps

How well you and your family survive and recover from a major earthquake depends on the effort you put into planning and preparing before an earthquake happens. It's important to remember that you alone are ultimately responsible for your own safety, not the government, your church, or the National Guard. However, many resources are available to help you, including Be Ready Utah.

Your planning and preparedness for earthquakes should cover three phases of an earthquake disaster: Before, During, and After the earthquake.

Before an earthquake, take time to prepare for and reduce the impact from earthquakes. This is the time for you and your family to learn how to survive an earthquake, to take action to make your home safer during an earthquake, and to gather necessary emergency items to get you through the disaster.

During an earthquake, don't hesitate to take the right protective actions: Drop, Cover, and Hold On. Learn what that means in the various situations you may face when an earthquake hits.

After an earthquake, plan to check on your loved ones and neighbors, providing necessary aid. Be prepared to Drop, Cover, and Hold on for additional earthquakes, called aftershocks, which occur after moderate to large earthquakes.

In the following pages, you will learn more about the Seven Steps to Earthquake Preparedness, helping you to prepare for all three phases of an earthquake disaster. More information is also available at beready.utah.gov.

STEP 1

Learn How to Protect Yourself During an Earthquake

Learn to Drop, Cover, and Hold On

The most important part of any hazard emergency plan is learning and practicing the appropriate protective actions. If you do not know how to survive the disaster then the rest of your plans do not really matter. Some of those protective actions are in the form of a memorable phrase. For earthquakes that protective action phrase is "Drop, Cover, and Hold On."

- **DROP**: Immediately drop to the floor
- **COVER**: Crawl to a location providing cover over head, such as a desk, table, or chair
- **HOLD ON**: Hold on to a leg of the furniture until the shaking stops

People in wheelchairs or using walkers should stay seated and lock the wheels, then cover their head with their arms and hands.

Practice Drop, Cover, and Hold On during the Great Utah ShakeOut or another earthquake drill.

Great earthquake drill tips can be found at https://www.shakeout.org/Utah.

A Special Note About Children

Before the next earthquake, spend time with your kids to discuss what might occur. Involve them in developing your disaster plan, preparing disaster kits (ask them what game or toy they want to include), and practicing "DROP, COVER, AND HOLD ON."

In the days after a quake, kids need extra contact and support. They may be frightened and under great stress, and aftershocks won't let them forget the experience. Parents may have to leave children with others in order to deal with the emergency, and this can be scary. Whenever possible, include your children in the earthquake recovery process.

Resources for kids to learn about disaster preparedness:
http://www.fema.gov/kids/
http://earthquake.usgs.gov/4kids/

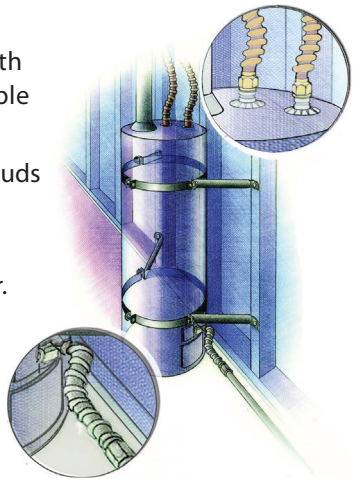
The Great Utah ShakeOut™

The Great Utah ShakeOut

STEP 2 Conduct a Home Hazard Hunt

Your "Before" planning should also include conducting a Home Hazard Hunt to find and fix the potential dangers that could occur in your home during an earthquake. Be Ready Utah has made this easier for you by creating a list of things to check and mitigate in your home. One of the first things to check is the water heater.

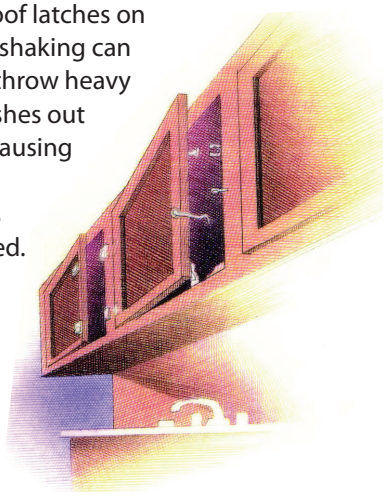
- Fasten securely to the wall with water heater strap kit (available at hardware stores).
- Use long screws directly into studs or concrete.
- Install flexible gas line from supply line to the water heater.



Next, secure tall furniture including bookcases, curio cabinets, and china cupboards to the wall.

- Use L-brackets or nylon furniture straps, again using long screws directly into the studs.
- Relocate heavy objects from high shelves down to lower shelves.
- Use museum putty or contact paper to better hold them in place.
- Remove shelves, picture frames, and other heavy and sharp items from over beds.

- Consider installing child-proof latches on kitchen cupboards. Violent shaking can open cupboard doors and throw heavy canned goods and glass dishes out into the room, potentially causing serious injury. Child-proof latches may keep the doors closed and the items secured.
- Lining cupboards with contact paper can help prevent things from slipping as easily.



Check out the Be Ready Utah Home Hazard Hunt, on the next two pages, for many more helpful things to do at home to make it more earthquake and hazard safe. Nothing can be completely earthquake-proof, but taking these steps will help keep you and your family safer during an earthquake.

Download copies of the comprehensive Home Hazard Hunt to share with others at http://ow.ly/5nva30rRduV.

Be Ready Utah Home Hazard Hunt Checklist

MYTH: Quake injuries are all from collapsing buildings.

Many people think that all injuries in earthquakes are caused by collapsing buildings. Actually, most injuries in quakes are from objects that break or fall on people. For example, in the 1994 magnitude 6.7 Northridge earthquake, 55 percent of quake-related injuries were caused by falling objects, such as televisions, pictures and mirrors, and heavy light fixtures.

Home Hazard Hunt

CHECK YOUR HOME AND PROTECT YOUR FAMILY FROM HAZARDS *BEFORE* THEY BECOME AN EMERGENCY

GENERAL HOME HAZARDS

- ❑ Have emergency numbers next to every phone.
- ❑ Install smoke detectors on every floor and inside or near every bedroom. Test monthly.
- ❑ Install carbon monoxide (CO) detectors on every floor. Test monthly.
- ❑ Replace batteries in smoke and carbon monoxide detectors every six months.

- ❑ Make sure dangerous products and cleaners are labeled and stored separately from food, beverages, and medicine.
- ❑ Secure rugs and carpets to the stairs or remove them.
- ❑ Be sure stairways, porches, and walkways are lit.
- ❑ Be sure house number is clearly visible from the street, day and night.
- ❑ Make sure automatic garage door opener has an auto-reverse feature to prevent injuries.

EARTHQUAKE HAZARDS

- ❑ Secure entertainment centers, cabinets, book cases, refrigerators, freezers, free standing flat screen TV's, and tall bookshelves to wall studs with "L" shaped brackets or furniture safety straps.
- ❑ Secure items on shelves to prevent toppling.
- ❑ Use earthquake picture wall hangers for large, heavy, hanging pictures.
- ❑ Remove objects from above beds.
- ❑ Place heavier items on lower shelves and lighter items above.
- ❑ Secure food storage, glass canning jars, books, paint, cleaning supplies, etc. with rope, boards or other bracing in front of shelves to prevent falling.
- ❑ Install cupboard locks to prevent doors from swinging open and contents falling out.
- ❑ If necessary, consult a trusted contractor regarding structural reinforcement.

FIRE HAZARDS

- ❑ Keep fire extinguishers in or near utility room, kitchen, laundry room, garage, and any other room that contains a major heat source. Know how to operate properly.
- ❑ Have all HVAC systems, flue pipes, vents, and chimneys inspected and cleaned yearly.
- ❑ Keep curtains, potholders or other combustibles away from cooking ranges or other heat sources.
- ❑ Keep the stove, oven, and broiler clean of grease.
- ❑ Only store fuels like gasoline, kerosene, and propane in an outbuilding away from the home.

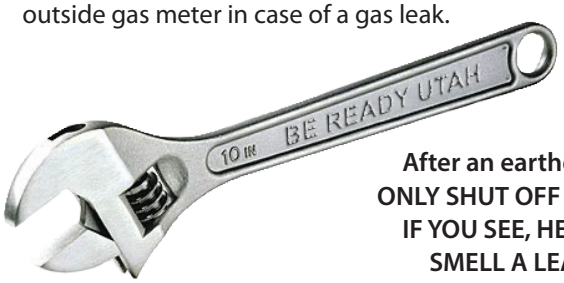
- ❑ Clear brush, leaves, debris, and other combustibles from around your home. Use fire-resistant landscaping, and fire-safe construction.
- ❑ If the garage is attached, make sure a tight fitting, self-closing fire door is used in the doorway between the garage and the house.

EVACUATION and ESCAPE HAZARDS

- ❑ Make sure there are at least two escape routes from every room.
- ❑ Make sure upper floor rooms have an emergency ladder or other means of escape.
- ❑ Make sure all exterior doors and windows have locks that unlock and open easily from the inside.
- ❑ Make sure all deadbolt locks have an inside thumb turn lock, not a key lock. A missing key could trap you inside.
- ❑ Make sure security bars have an inside release latch.
- ❑ Install night-lights and emergency lights in hallways and along emergency escape routes.

UTILITIES HAZARDS

- ❑ Keep a shut-off tool or adjustable wrench attached to the outside gas meter in case of a gas leak.



After an earthquake, ONLY SHUT OFF THE GAS IF YOU SEE, HEAR OR SMELL A LEAK!!!

- ❑ Keep flashlights and spare batteries easily accessible and in working order in the event of a power outage. Flashlights are safer than candles.
- ❑ Only allow qualified electricians to install or repair your wiring.
- ❑ Have enough electrical outlets in every room to avoid the need for multiple plug attachments or long extension cords.
- ❑ Know how to safely reset breakers or replace fuses.
- ❑ Do not run extension cords under rugs, furniture, over hooks, or through doorways.
- ❑ Make sure all outlets and switches have properly fitting face plates.
- ❑ Make sure bulbs are the correct wattage for the lamps or light fixtures in which they are used.
- ❑ Too many appliances using the same outlet can cause a fire. Use outlets properly and use surge protectors as needed.
- ❑ Set water heater to 120º F to prevent scalding.
- ❑ Secure the water heater and any other gas appliance to wall studs with sturdy earthquake straps and make sure it is connected to the gas main with a flexible gas line.
- ❑ Teach all responsible people how, when and where to turn off main water, gas, and electricity.
- ❑ Make sure all appliances have an Underwriters Laboratories (UL) mark or stamp.
- ❑ Make sure all electrical outlets in bathrooms and near water use a Ground Fault Circuit Interrupter (GFCI) to prevent shock.

HAZARDS THAT AFFECT CHILDREN

- ❑ Keep children away from the range when cooking.
- ❑ Use product safety caps and cupboard locks.
- ❑ Properly install toilet seat locks.
- ❑ Keep medicines, cosmetics, and cleaners locked up.
- ❑ Keep window blind cords up out of reach and cut the cord loop in two pieces to prevent strangling.
- ❑ Install window guards in upper windows to prevent falling out.
- ❑ Install gates at the top and bottom of stair cases.
- ❑ Install safety caps over electrical outlets.
- ❑ Store large buckets upside down to prevent collecting water and making a drowning hazard.

Rubber grip shelf liner is a great tool to keep items from sliding off a shelf in an earthquake. It has many other uses throughout your home as well.

- Jar gripper
- Pot holder
- Liner for tool box
- Prevent breaks between glass dishes
- Hold mobile phones in place
- Under throw rugs
- Under cutting boards
- Keep seat cushions in place
- Behind frames to prevent crooked pictures
- Etc.

STEP 3

Assemble Disaster Kits and Other Supplies

Disaster supply kits are intended to provide you with basic life-saving and comfort items needed to survive during and in the immediate aftermath of an emergency situation. Your kit and the information contained in it should also help in the recovery phase after a disaster.

Disaster supply kits (also called 72-hour kits, bug-out bags, go kits, etc.) should contain supplies to last a minimum of three days, but depending on the scale of the earthquake or other disaster, it could be days, weeks, or even longer before help is able to arrive.

You should have a disaster supply kit for every member of your family.

Let family members choose the food and personal items to put in their individual kits. Do not forget special needs for the elderly, young children, infants, and those with access and functional needs. Also assemble an emergency kit for your pets.

There are lists everywhere for assembling disaster supply kits, but the thing to remember is no matter which list you use, personalize your kit. That means if there is anything that you need to be healthy, happy, and comfortable then include it in your kit. Download a copy of this list from Be Ready Utah (http://ow.ly/Sv4730rRdKL) to share with family and friends.

Be Ready Utah Disaster Supply Kit List

The supplies in your kit need to cover the twelve areas of emergency preparedness including:

- Shelter, clothing, and fire
- Water
- Food
- Hygiene and sanitation
- Light and power
- First aid
- Communication
- Safety and security
- Tools and personal items
- Cooking
- Important documents and money
- Transportation

Disaster Supply Kit

REMEMBER:

- Store in a backpack, wheeled suitcase, or other portable container in an easy-access location, as near as possible to an exit
- Have a separate kit for each family member
- Items susceptible to water damage should be in plastic bags
- Check kit twice a year and replace items that have expired or don t work

Cover all 12 Areas of Emergency Preparedness in your disaster supply kits.

ADD ADDITIONAL ITEMS TO KITS TO FIT INDIVIDUAL NEEDS

1) Shelter, Clothing, & Fire
- ❑ Waterproof poncho
- ❑ Emergency reflective blanket
- ❑ Wool or fleece blanket or sleeping bag
- ❑ Tent or tarp
- ❑ Clothing for warm/cold weather
- ❑ Extra socks and underwear
- ❑ Hat with brim and/or bandanna
- ❑ Windproof/waterproof matches
- ❑ Alternate fire-starter
- ❑ Hand and body warmer packets

2) Water
- ❑ 1-2 gallons of water
- ❑ Refillable water container
- ❑ Water tablets and/or filter

3) Food
- ❑ 3 day supply of ready-to-eat, nonperishable food
- ❑ Hard candies

4) Hygiene & Sanitation
- ❑ Personal hygiene kit: soap, toothbrush, toothpaste, comb, toilet tissue, feminine items, razor, lip balm, wash cloth, etc.
- ❑ Garbage bags
- ❑ Hand sanitizer
- ❑ Baby wipes

5) Light & Power
- ❑ Flashlight
- ❑ Batteries
- ❑ Light sticks

6) First Aid
- ❑ First aid kit: Adhesive bandages, rolled gauze and pads, antibiotic cream, disposable gloves, burn gel, antiseptic towelettes, tweezers, triangle bandage, etc.
- ❑ First aid instruction booklet
- ❑ Personal medications
- ❑ Scissors and sewing kit
- ❑ Insect repellent
- ❑ Sunblock

7) Communication
- ❑ Multi-power AM/FM radio
- ❑ Notepad and pencil
- ❑ Plastic whistle with neck cord
- ❑ Extra mobile phone charger

8) Safety & Security
- ❑ Work gloves
- ❑ Dust mask
- ❑ Mace/pepper spray
- ❑ Spare house/car keys

9) Tools & Personal Items
- ❑ Extra glasses or contacts
- ❑ Compass
- ❑ Multifunction pocket knife
- ❑ Duct tape and 50-ft nylon rope
- ❑ Stress relief item: book, toy, etc.

10) Cooking
- ❑ Camp cup, plate, and utensils
- ❑ Lightweight stove and fuel
- ❑ Paper towels
- ❑ Can opener (may be on knife)

11) Important Documents & Money
- ❑ Copies of: emergency plan, birth certificates, marriage license, will, insurance info, financial info, vehicle title, family photos, ID, emergency contact list, etc.
- ❑ At least $200 in small bills

12) Transportation
- ❑ Sturdy walking shoes or boots
- ❑ Wagon, stroller, cane, or wheelchair as needed

Keep a flashlight and a sturdy pair of shoes near your beds. If an earthquake strikes at night and knocks the power or lights out you will want to have another light source to help you see your way through your home to gather family and move them to safety after the shaking stops.

You will also want family members to put on a sturdy pair of shoes to protect their feet from potential hazards such as broken glass, nails, splinters, and other fallen objects.

You don't want to add to the trauma of an earthquake by sustaining preventable injuries after the shaking stops.

STEP 4 Identify Potential Weaknesses In Your Home

Is your residence strong enough to withstand an earthquake?

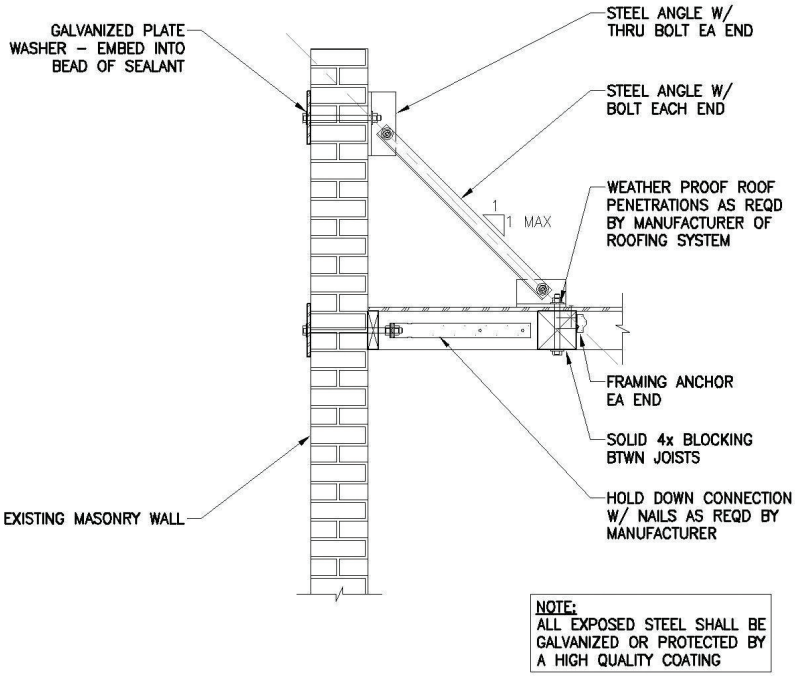
Most earthquake damage to buildings is from the ground shaking back and forth. Many houses, particularly older ones made with brick, were not built to withstand this shaking caused by earthquakes. Some houses are more resilient than others in an earthquake, depending on the shape, height, materials, and construction techniques. If planning to tackle a home project like re-roofing or remodeling, investigate the variety of options available for retrofitting, as some can be very cost effective if built into plans. Local building departments and the Structural Engineers Association of Utah (seau.org) are excellent resources. You may start by asking yourself some questions about your home:

- Is your house properly connected to the foundation?
- Is there plywood on the exterior walls of your house?
- Are there anchors attaching the roof and floor systems to the walls?
- Is your house constructed out of unreinforced masonry?
- Do you have large openings like a garage door that may require better bracing?

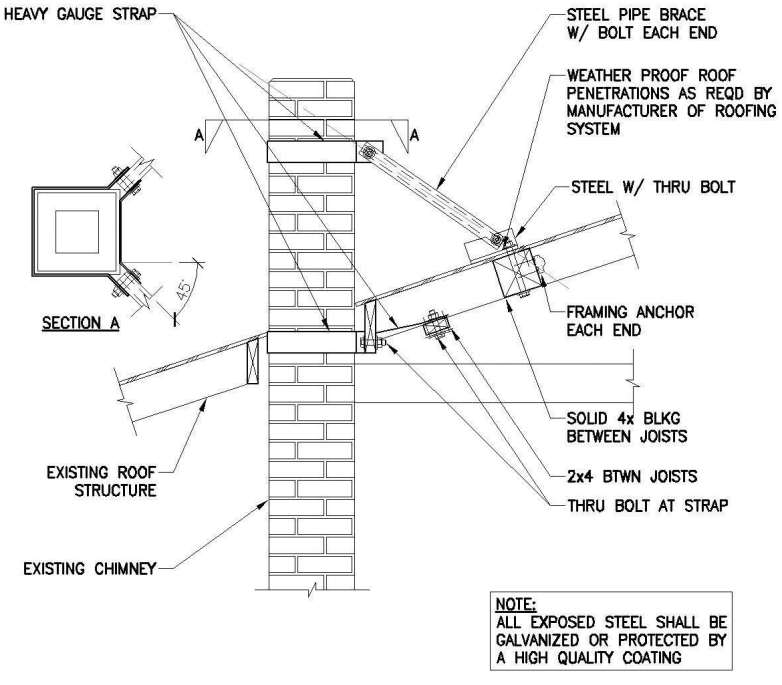
MYTH: We have good building codes, so we must have safe buildings.

The best building code in the world does nothing for buildings built before the code was enacted. Although building codes used in Utah have strict seismic provisions, many older buildings, particularly unreinforced masonry buildings, have not been "retrofitted" to meet updated codes. Retrofitting—fixing problems in older buildings—is the responsibility of a building's owner. See page 17 for more information.

The Utah Guide for the Seismic Improvement of Unreinforced Masonry Buildings



PARAPET BRACING



CHIMNEY BRACING

The figures above show how to brace parapets and chimneys. These figures are based on The Utah Guide for the Seismic Improvement of Unreinforced Masonry Buildings *and may be viewed via the QR code to the left.*

STEP 5

Drop, Cover, and Hold On

As mentioned earlier, the proven and endorsed protective action for earthquakes is Drop, Cover, and Hold On.

It does not matter what type of building you are in. Drop, Cover, and Hold On wherever you are.

The biggest cause of injury and death in an earthquake is falling objects, not collapsing buildings. So getting cover over head is the best way to prevent that injury and death. Holding on to a leg of a desk or table will help keep that cover over head instead of allowing it to slide away from you.

Drop, Cover, and Hold On has some other meanings, too.

If there is not any sturdy furniture to take cover under then try to kneel down against an interior wall without any glass overhead like windows, mirrors, and picture frames.

If you're in bed stay in bed and cover your head with your pillow or blankets.

If you are in the bathroom try to curl up in the tub.

People in wheelchairs or using walkers should stay seated and lock the wheels, then cover their head with arms and hands.

Do NOT try to run or move during the shaking. It could just knock you down or expose you to falling objects.

Do NOT run into or out of a building. Just Drop, Cover, and Hold On wherever you are.

If outdoors, try to move to an open area away from buildings, power lines, tall trees, and fences.

If driving, try to pull over and stay in the car. Try not to stop near buildings or under power lines, trees, and overpasses or bridges.

MYTH: The Triangle of Life survival method is the best method to use inside a building to survive an earthquake

The best survival method inside a building is to Drop, Cover, and Hold On under a table, desk, or chair, rather than trying to get into a survivable void next to a large, bulky object as advocated by the Triangle of Life method. The Drop, Cover, and Hold On survival method protects individuals from objects falling from walls and shelves. It also provides a level of protection from structural failures. If a table or desk is not available, sit down with your back against an interior wall, using your hands and arms to protect your head and neck.

STEP 6

Assure Life Safety, Hazards, and Damage

Life Safety First

After the shaking stops, you can exit your Drop, Cover, and Hold On location.

- Gather your family members or meet them at your family meeting place outside your home.
- Check for injuries and administer first aid if necessary.
- Check on nearby neighbors, especially those with functional and access needs, to see if they need assistance.

Prepare for aftershocks, which are just similar or smaller sized earthquakes. Remember the protective action is still Drop, Cover, and Hold On.

Check for Hazards

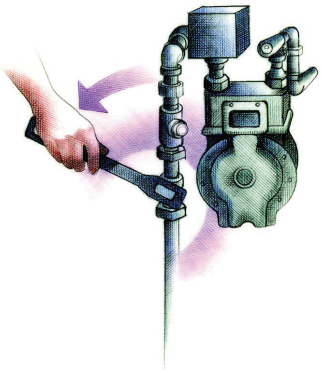
Look for potential life-threatening hazards.

- Immediately put out small fires if you have the means to do so safely.
- Check for gas leaks, downed power lines, and rising water.
- If you suspect a gas leak (smell, hear, or see leaking gas) then you should shut off the gas at the meter.
- If you have broken water lines that are flooding your lower level then you should shut off the water where it comes into the house or at the water meter.

Assess the Damage

Next, do a visual inspection of your home to assess the damage. You should look for various types of damage:

- The home leaning, twisted, or shifted off its foundation.
- The roof separated from the walls.
- Large cracks running through the concrete, bricks, cinder blocks, or other building material.
- Parts of the building separated such as chimneys and porches.
- Collapsed areas of the home.



If you find any of that type of damage it is probably not safe to stay in the residence. If you find only minimal damage such as cracked windows or shingles shaken loose then it is probably still safe to occupy. But you will have to make that determination.

Damaged or disrupted utilities, by themselves, would not require you to evacuate the home, unless they are associated with the damage listed above. Otherwise, you will just have to prepare to live without those utilities until they are restored.

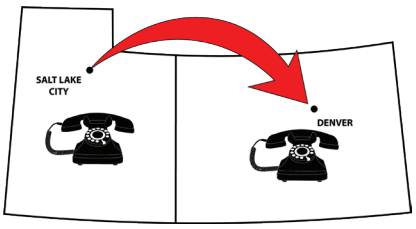
STEP 7

Put Your Plan into Action

Depending on your circumstances, you should implement your family disaster plan to take care of yourself and your family at home. If necessary, activate your evacuation plan and prepare to leave the area. You may go to an available community shelter or to a relative or friend's house outside of the danger area.

Listen for and heed emergency instructions from officials. They may tell you where shelters, triage and treatment areas, and supply distribution centers are located.

Contact your out-of-state contact to let them know of your status. They can relay information to other concerned family members and friends. Texting may be the most reliable form of communication during a disaster.



Additional earthquake science and preparedness information can be found at earthquakes.utah.gov and at ussc.utah.gov.

Earthquake Information on the Web

Where can I find information immediately after an earthquake?

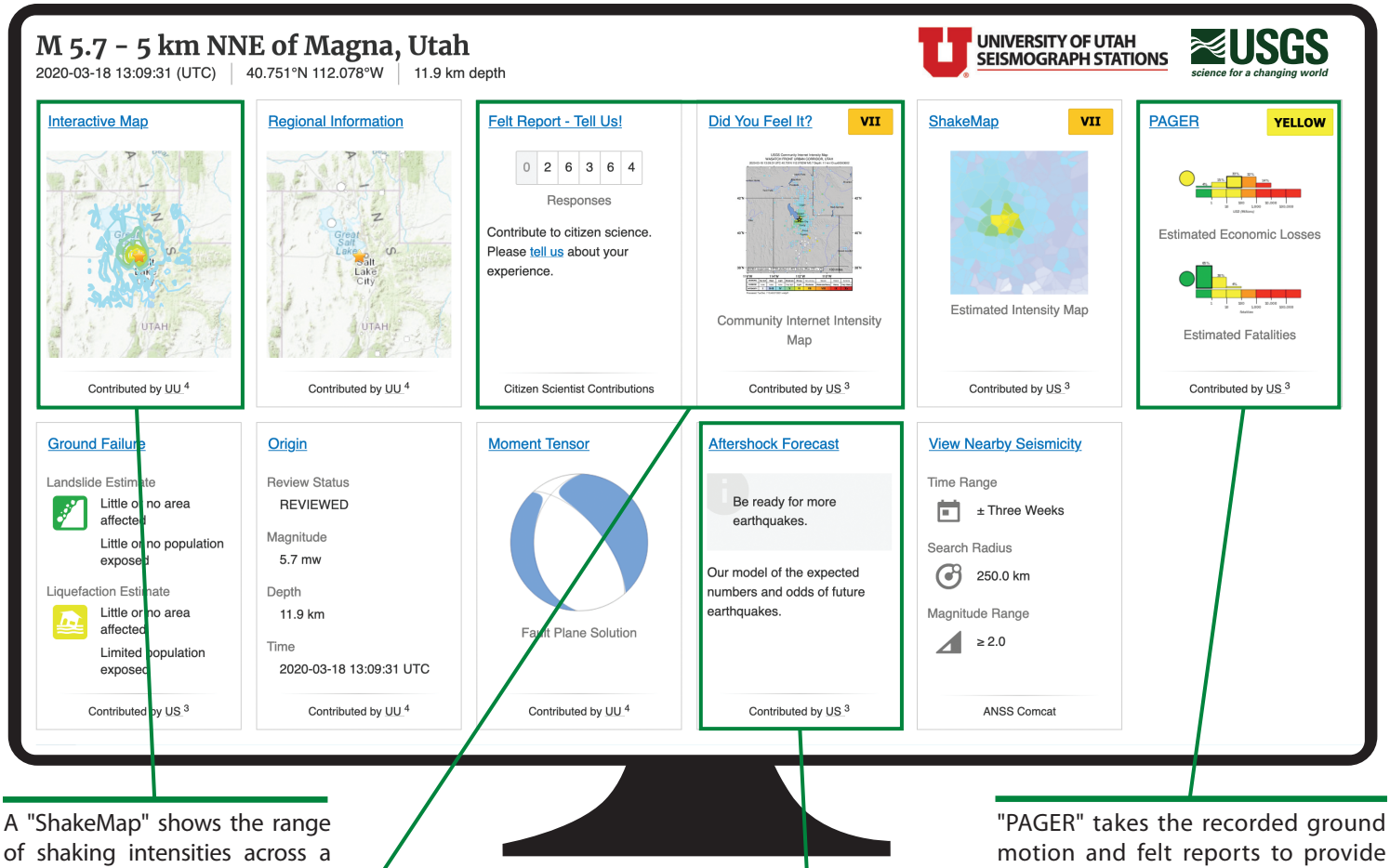
Within 1 to 2 minutes of an earthquake, its location and magnitude are available online. For each earthquake a separate event webpage is generated. This webpage contains magnitude, location, and regional information for recent earthquakes, like the 2020 Magna, Utah, earthquake shown below. For most felt earthquakes (magnitude 3.0 and greater in the Wasatch Front area), a "ShakeMap," a "Did You Feel It?" map, and a "PAGER" report are available.

Websites

U of U Seismograph Stations: https://quake.utah.edu
earthquakes.utah.gov: https://earthquakes.utah.gov
U.S. Geological Survey: https://earthquake.usgs.gov

Social Media

U of U Seismograph Stations: @UUSSquake
Utah Seismic Safety Commission: @UtahSeismic



A "ShakeMap" shows the range of shaking intensities across a region using data recorded on seismic instruments.

"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?" website at https://earthquake.usgs.gov/dyfi/.

Following a significant earthquake, this aftershock forecast provides situational awareness of the expected number of aftershocks, as well as the probability of subsequent larger earthquakes.

"PAGER" takes the recorded ground motion and felt reports to provide an estimates of economic losses and the number of fatalities. Additional products that may be available on the Event Page include maps showing regions of potential ground failure and aftershock forecast, which shows the chance for aftershocks (magnitudes and numbers).

Glossary

Aftershocks. Earthquakes that follow the largest shock of an earthquake sequence. They are smaller than the "mainshock" and can occur over a period of weeks, months, or years. In general, the larger the mainshock, the larger and more numerous the aftershocks and the longer they will continue.

Crust. Earth's outermost layer consisting of rigid rock that is 4 miles (oceanic crust) to 25 miles thick (continental crust).

Epicenter. The point on Earth's surface above where an earthquake begins at depth in the crust.

Fault. A fracture or crack along which the two sides slide past one another.

Fault rupture. The area of the earth through which fault movement occurs during an earthquake. For large quakes, the section of the fault that ruptures may be several hundred miles in length. Ruptures may or may not extend to the ground surface.

Fault scarp. A steep, linear break or slope formed where a fault ruptures the ground surface.

Fault segment. A part of a fault that is thought to rupture independently of other parts of the fault. One or more segments may rupture in a single earthquake.

Foreshock. An earthquake that precedes the largest quake ("mainshock") of an earthquake sequence. Foreshocks may occur seconds to weeks before the mainshock. Not all mainshocks are preceded by foreshocks.

Intensity. A measure of ground shaking describing the local severity of an earthquake in terms of its effects on Earth's surface and on humans and their structures. The Modified Mercalli Intensity scale, which uses Roman numerals, is one way scientists measure intensity.

Landslide. A mass movement of soil, mud, and (or) rock down a slope.

Liquefaction. The process that occurs when an earthquake shakes wet sandy soil until it behaves like a liquid, allowing sand to "boil up" to the surface, buildings to sink, or sloping ground to move.

Magnitude (M). A number that represents the size of an earthquake, as determined from seismic instruments that record ground shaking. An increase of one unit of magnitude (for example, from 4.6 to 5.6) corresponds approximately to a thirty-fold increase in energy released (by definition, a two-unit increase in magnitude —for example, from 4.7 to 6.7—represents a thousand-fold increase in energy). Quakes smaller than magnitude 2.5 generally are not felt by humans.

Mainshock. The largest quake of an earthquake sequence, possibly preceded by smaller foreshocks and commonly followed by aftershocks.

Mantle. The layer of heated viscous rock between Earth's crust and core.

Normal fault. An inclined fault along which the upper side moves downward relative to the lower side. Utah's Wasatch fault is a good example.

Parapet. A wall-like barrier at the edge of a roof.

Retrofit. Strengthening an existing structure to improve its resistance to the effects of earthquakes.

Seiche. Waves "sloshing" in a lake as a result of earthquake ground shaking. Waves caused by landsliding into water or displacement of the lake bed are termed a surge. Waves caused by a displacement of the lake or ocean floor is called a tsunami.

Seismic hazard. The potential for damaging effects caused by earthquakes. The level of hazard depends on the magnitude and frequency of likely quakes, the distance from the fault that could cause quakes, and geologic conditions at a site.

Seismic risk. The chance of injury, damage, or loss resulting from seismic hazards. There is no risk, even in a region of high seismic hazard, if there are no people or property that could be injured or damaged by a quake.

Seismometer. A sensitive instrument that detects and records seismic waves generated by an earthquake.

Strike-slip fault. A generally near-vertical fault along which the two sides move horizontally past each other. The most famous example is California's San Andreas fault.

Surface faulting (surface fault rupture). Propagation of an earthquake-generating fault rupture to the surface, displacing the surface and forming a fault scarp.

Tectonic plate. Earth's outer layers are composed of large, relatively strong "plates" that move relative to one another. However, faulting and earthquakes can also occur within a plate, such as along the Wasatch Front.

Tectonic subsidence. Lowering and tilting of a basin floor on the down-dropped side of a fault during an earthquake.

AS UTAHNS, We face a very real risk of a major earthquake.

AS INDIVIDUALS, We need to take steps to prepare for large earthquakes and aftershocks. And of course, know how to **DROP, COVER,** and **HOLD ON** when shaking begins!

AS A COMMUNITY, We need to prepare to survive earthquakes and then get back to normal by reducing the number of dangerous buildings and upgrading our infrastructure.

This handbook will help you understand earthquake risks in Utah and find actions you can take to survive the earthquake and improve your ability to recover quickly. Knowledge is power, and with this information you will have the power to become less vulnerable to a major earthquake.

Experience *Putting Down Roots in Earthquake Country* online at earthquakes.utah.gov/putting-down-roots

Department of Public Safety – Division of Emergency Management – Utah

Utah Seismic Safety Commission (USSC)

Structural Engineers Association of Utah

Utah DNR Geological Survey

University of Utah Seismograph Stations

Be Ready Utah – BeReadyUtah.gov

USGS science for a changing world

Envision Utah – How we grow matters.

U.S. Department of Homeland Security – FEMA