2025

Utah Seismic Safety Commission Report and Recommendations

USSC

Table of Contents

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Cover image: Seismic retrofits underway at the Utah State Capitol, provided by Schooley Caldwell

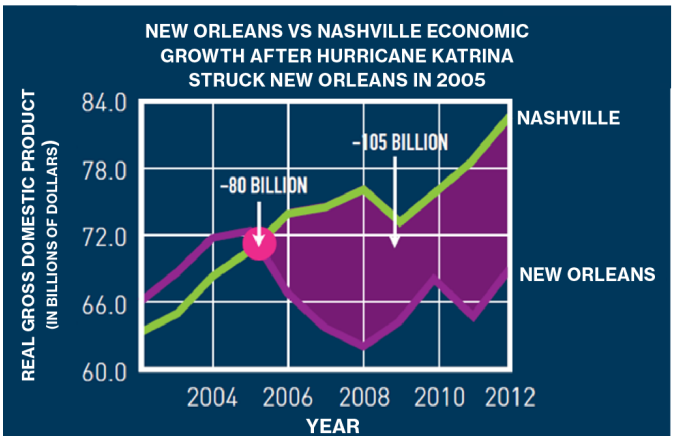
Introduction

The Utah Seismic Safety Commission (USSC) is a volunteer, multidisciplinary state commission focused on reducing vulnerabilities to an earthquake in Utah. The USSC is scheduled to sunset (to be terminated) at the end of 2024. This report summarizes USSC findings and recommendations for how Utah can continue to move toward robust seismic resilience. The first and most important of these recommendations is that the USSC be reauthorized, or that a similar group be created to carry forward this critical work in future years.

The Federal Emergency Management Agency (FEMA) has called the Wasatch fault "one of the most catastrophic natural threat scenarios in the U.S."[1] In 2016, it was estimated that the Wasatch Front region has a 43% chance of experiencing a magnitude 6.75 or greater earthquake in the next 50 years—a likelihood that has only increased in the intervening years.[2] In other words, the Wasatch Front's odds of experiencing a large earthquake in the next 50 years are essentially equivalent to a coin toss.

Without proactive measures, an expected magnitude (M) 7.0 earthquake (90 times stronger than the 2020 Magna M5.7 earthquake) on the Salt Lake City segment of the Wasatch fault (the "Big One") would be among the most devastating disasters ever to occur in the United States. There are two catastrophic impacts that need to be prevented.

First, **Utah's economy and way of life may never fully recover from the "Big One."** It would leave hundreds of thousands of Utahns without shelter and critical lifeline services (water, sewer, power, natural gas, communications, etc.), with some services not being restored for six months or more.[3] The damage to infrastructure and income would result in short-term economic losses estimated at $80 billion.[4] Long-term losses would undoubtedly be much larger as people leave, many never to return, and businesses close, many never to reopen. In fact, other places that have experienced this level of disaster, including New Orleans after Hurricane Katrina and Christchurch after an earthquake, have taken years, even decades, to recover—if they recover at all.



Data from the US Resilience Council shows the diverging economic fortunes of Nashville and New Orleans after Hurricane Katrina.

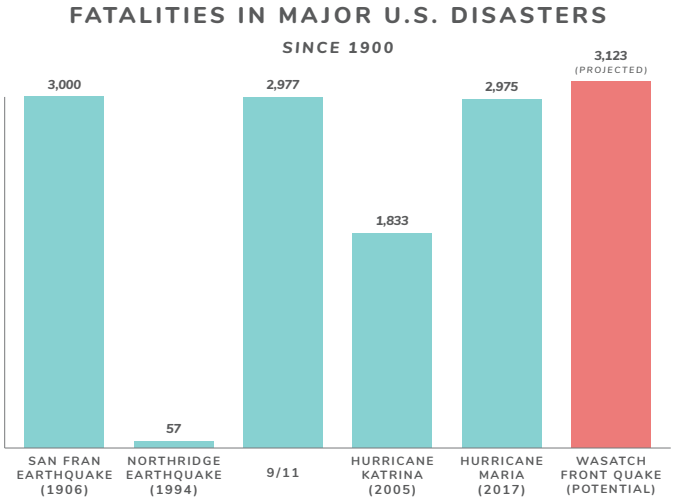
Second, the "Big One" would be one of the deadliest natural disasters in U.S. history. More than 3,000[5] Utahns could lose their lives—more than in Hurricanes Maria or Katrina or on 9/11. Another 40,000+ could be injured.

Because of this threat to the state, the Utah Legislature, ever interested in preparing Utah for the future, created the USSC in 1994 and tasked it with reviewing earthquake-related hazards and risks, preparing and prioritizing recommendations to mitigate those hazards and risks and presenting those recommendations to state and local governments.

The recommendations in this report have the potential to significantly reduce the devastation of an earthquake and enable the state to recover more quickly. These recommendations have been discussed and vetted with a variety of experts and key stakeholders and were coordinated with Envision Utah's disaster resilience working groups.

The awarding of the 2034 Olympics to Salt Lake City highlights and heightens the urgency of improving Utah's resilience to an earthquake. Without action, Utah's preparedness for the 2034 Games is under threat. Preparing for a seismic disaster can also help our communities be prepared for other disasters by examining our vulnerabilities.

Investing in Utah's disaster resilience now helps to decrease the risk of true catastrophe, and it also makes clear economic sense. Recent research by FEMA shows that, on average, **every dollar spent on disaster mitigation now avoids six dollars in future disaster costs.**[6] **Few other types of investments can boast that kind of economic payoff.**



1. Wasatch Front URM Risk Reduction Strategy Best Practices and Replicability, FEMA 2022.
2. Earthquake Probabilities for the Wasatch Front Region in Utah, Idaho, and Wyoming, UGS 2016.
3. Scenario for a Magnitude 7.0 Earthquake on the Wasatch Fault—Salt Lake City Segment, EERI 2015.
4. Lifeline Systems Analysis for Wasatch Fault Planning, Great Utah ShakeOut M7.0 Scenario, DEM 2021
5. Lifeline Systems Analysis for Wasatch Fault Planning, Great Utah ShakeOut M7.0 Scenario, DEM 2021.
6. Natural Hazard Mitigation Saves Interim Report Fact Sheet, FEMA 2018.

SUMMARY OF RECOMMENDATIONS:
What can we do to save lives and the economy?

The Utah Seismic Safety Commission recommends the following prioritized actions to protect Utahns' livelihoods and lives:

1. CONTINUE TO CONVENE EXPERTS AND STAKEHOLDERS

Reauthorize the USSC or convene a similar voluntary group that can continue to study, educate, and make recommendations.

Although the USSC is scheduled to sunset at the end of 2024, the need to prepare for and mitigate the potential impacts of a large earthquake will not go away. Reauthorizing the USSC or bringing together a voluntary body of experts and stakeholders who collectively understand earthquakes, buildings, infrastructure, economic impacts, and other issues is an effective way to identify and prioritize steps that state, local government, and the public can take to ensure Utah can bounce back quickly should the "Big One" occur.

2. KEEP WATER FLOWING

Invest an additional $125 million in aqueduct seismic upgrades to close the funding gap for the remaining two aqueducts that serve over two million residents.

If either of these major water pipelines rupture, many hundreds of thousands of Utahns would be left without water for six months or even longer. The total cost of improving the Salt Lake and Jordan Aqueducts is estimated at over $230 million. A state investment of $125 million would close the gap to significantly accelerate the projects.

3. KEEP INFRASTRUCTURE OPERABLE

Do a comprehensive analysis of Utah's infrastructure, looking at existing resilience, repair timelines, interdependence, design standards, and improvement funding sources.

Water, sewer, transportation, telecommunications, and energy systems are all at risk, and these lifelines are essential to protecting Utah's economy and way of life. If many residents and businesses are left without water, sewer, or energy, cannot cross the Jordan River, or are unable to connect to the Internet, Utah's economy will grind to halt. If these conditions persist, numerous residents will leave and many businesses will close.

4. KEEP UTAHNS INFORMED ABOUT SEISMIC RISKS AND MITIGATION MEASURES

Educate and inform Utahns about the state's seismic risk, as well as the individual and community steps that can be taken to improve resilience.

Becoming more resilient requires both individual action, as when a homeowner upgrades a home that is at risk, and collective action, as when a city upgrades its infrastructure. For both the individual and collective action to occur requires public officials the public to have a better understanding of long-term risk.

5. UPGRADE OUR HIGHLY VULNERABLE OLDER BUILDINGS

Analyze ways to accelerate building retrofits, upgrades, and replacements, particularly for public buildings.

Most deaths and injuries in a Wasatch Front earthquake will occur in and around buildings that were built before 1976. The state's most vulnerable structures are the 140,000 unreinforced masonry (URM) buildings that are scattered across the state and include single-family homes, multifamily structures, and offices—as well as government buildings and more than 119 schools. The damage to so many buildings could also have a devastating impact on the Utah economy.

6. ENSURE NEW BUILDINGS ARE RESILIENT

Develop and enforce building codes that adequately meet Utah's seismic risks.

Modern building codes have significantly improved building seismic resilience, but there are reasons for concern. First, the standard building code plans for significantly less ground shaking than is likely to occur on the Wasatch Front. Second, many buildings do not receive adequate structural plan reviews. Third, building codes do not present specific seismic design criteria for mitigating geological and geotechnical (e.g., liquefaction) hazards. As a result, many buildings built to "modern" codes will likely experience a significant level of damage causing not only loss of life and injury, but also devastating impact on the Utah economy.

Recent Accomplishments of the USSC

In 2023, Utah appropriated $50 million to bolster the seismic resilience of our aqueducts.

Due to the magnitude of the challenge, improving Utah's seismic resilience will require continual and incremental steps. In recent years, significant progress has occurred. Here are some examples:

- **Water**: To increase the likelihood that Utahns have running water in the months following an earthquake, the Utah Legislature allocated $50 million in 2023 to enhance the seismic resilience of our aqueducts. The Davis Aqueduct and Alpine Aqueduct received construction money, and upgrades are underway. This leaves a remaining gap of $125 million to upgrade the Salt Lake and Jordan Aqueducts. This funding leverages additional money from water conservancy districts and FEMA.
- **Public Awareness:** Efforts to raise awareness about seismic risks among Utahns and legislators have gained momentum. The USSC updated and re-released the public-facing Putting Down Roots in Earthquake Country following the Magna earthquake to better assist Utahns to understand how best to prepare their homes and families for the "Big One." In addition, the receipt of a FEMA grant for an outreach campaign represents a significant milestone. This initiative, now getting underway, promises to empower our communities with the knowledge needed to effectively prepare for seismic events.
- **Unreinforced Masonry:** The Utah Division of Emergency Management (UDEM) completed a Statewide Residential Seismic Retrofit Grant Program Feasibility Study that provides guidance for decision-makers as they consider creating a statewide grant program for retrofitting URM homes and other buildings.
- **Policymaker Awareness**: In September 2023, the Legislative Auditor General released a report identifying the seismic risk to aqueducts and unreinforced masonry buildings as among the most important critical vulnerabilities in Utah.
- **Research**: In 2023, the Utah Legislature allocated $2.5 million to establish an Earthquake Engineering Research Center at Utah State University. This center will help bridge the gap between what we know about the devastating effects of earthquakes and how to better design structures to withstand them.
- **Early Warning System:** In 2022, the Utah Legislature funded a feasibility study for an earthquake early warning system to provide critical seconds of warning that could reduce destruction and loss of life by triggering automated responses from a variety of key actors. The Utah Geological Survey has since completed the initial feasibility study in collaboration with the University of Utah Seismograph Stations and the Utah Division of Emergency Management.

- **Schools**: The USSC applauds the continuing effort of school districts to retrofit, replace, or close unreinforced masonry (URM) school buildings and other public structures. In 2022, UDEM and FEMA completed and released an inventory of the remaining unreinforced masonry buildings on school campuses. Local school districts continue to upgrade, replace, or remove from service these at-risk buildings. Examples include: (1) Following the recent Magna earthquake, the West Lake Junior High School was replaced, largely using FEMA grant money; (2) A recently passed Salt Lake School District bond will fund the replacement of its aging Highland and West High Schools; (3) Other districts are considering seismic risk as they determine which schools to close when school enrollment drops. A new Mitigation Endorsement Report[7] gives guidance to school districts that are considering retrofits.

While there is still much work to be done, all these accomplishments represent a collective commitment to Utah's safety and prosperity.

Seismic retrofits underway at the Salt Lake Temple to withstand the expected ground shaking of a 7.3 magnitude quake.

7. Mitigation Endorsement Report for Utah's Unreinforced Masonry K–12 Public Schools.

The Six Recommendations in Detail

1. Continue to Convene Experts and Stakeholders

Reauthorize the USSC or convene a similar voluntary group that can continue to study, educate, and make recommendations.

In the wake of the California Northridge Earthquake, the Utah legislature created the Utah Seismic Safety Commission (USSC) in 1994. The USSC is tasked with reviewing earthquake hazards, preparing and prioritizing recommendations to appropriate entities including state and local government, acting as a source of information, and conducting strategic seismic planning.[8] The commission includes representatives from scientific organizations, governmental organizations, and non-governmental organizations. Members collectively have expertise in seismology, engineering, construction, architecture, infrastructure, and risk management. Other than standard salaries of staff, members are not compensated for their participation—their participation is on a voluntary basis.

The USSC has published educational reports such as "Putting Down Roots in Earthquake Country," participated in strategic planning efforts resulting in documents such as the "Wasatch Front Unreinforced Masonry Risk Reduction Strategy," assisted entities, including school districts, in obtaining federal hazard mitigation funding, and identified and prioritized mitigation strategies that have led to significantly improved infrastructure resiliency.

No other group brings together such a diverse collection of experts and stakeholders. If the USSC sunsets at the end of 2024, there will be a vacuum in leadership on this topic. For Utah to continue to take meaningful steps toward improved resiliency, the USSC should be reauthorized, or alternatively, a similar group should be convened, whether under the auspices of a legislative mandate or through an executive branch action—or both. This new group, similar to the USSC, should be tasked with studying the hazard, educating key entities and Utahns more generally, prioritizing mitigation steps, and making recommendations to a variety of audiences including state and local government. Key areas of focus should include both infrastructure and buildings, both of which are critical for not only protecting life and property but for ensuring Utah is able to bounce back quickly from a large earthquake without long-term physical and economic devastation.

8. Utah Code 63C-6-102(2).

2. Keep Water Flowing

Invest an additional $125 million in aqueduct seismic upgrades to close the funding gap for the remaining two aqueducts that serve over two million residents.

In the event of a major earthquake on the Wasatch fault, water service across the Wasatch Front is projected to be disrupted for more than a million people for many months. Unlike freeway infrastructure, which is rebuilt far more often (at a much higher cost), much of Utah's major water infrastructure is over 50 years old. The Wasatch Front's most important aqueducts are located across and along major hazardous faults, landslide areas, high ground-shaking areas, and liquefaction areas, putting them at high risk for significant damage.

A plausible modeling scenario estimated that around 330,000 homes, or roughly one million people, will still be without water three months after a major Wasatch fault earthquake event.[9] Not only is water essential for life and for disaster response on the Wasatch Front, but it is essential for Utah's economy. Businesses along the Wasatch Front that are at risk of losing water contribute to more than 75% of Utah's economy.[10] Moreover, water is a critical aspect of other infrastructure and services, including power, medical care, and fire response. Without water, interdependent systems and infrastructure will remain offline.

PROPOSED WATER PROJECTS

Four critical aqueducts, or large pipelines, provide the majority of the water to the Wasatch Front. These aqueducts run across the Wasatch fault or through high ground-shaking and liquefaction areas. Without water from these four main aqueducts, other seismic upgrades to the water and sewer system will have negligible impact because there will be no water in the network. Additionally, if an aqueduct were to rupture, flooding would follow, although the specific impacts have yet to be modeled.

These massive aqueducts were built three generations ago, before the seismic risks of the Wasatch fault were understood, and it is unlikely that they will withstand the "Big One." Four projects have been identified by their respective water districts, which have estimated upgrade costs. The total cost of these projects is over $550 million.

Construction of the Salt Lake Aqueduct began in 1940 and was completed in 1951. Unlike our freeways, much of Utah's aqueduct infrastructure has not been updated for generations.

9. Community Resilience Planning Guide for Buildings and Infrastructure.

10. Utah Chapter of the Earthquake Engineering Research.

The water conservancy districts estimated that, after local and federal funds are applied, there is a shortfall of approximately $175 million that is needed to allow the projects to proceed in the near future rather than many years from now. In 2023, the Utah Legislature allocated $50 million, which, when combined with district and FEMA money, will fully fund the Davis Aqueduct and Alpine Aqueduct projects. The legislative money has also provided funding for engineering studies for the other two aqueducts. The gap to fund the remaining two projects is estimated at $125 million.

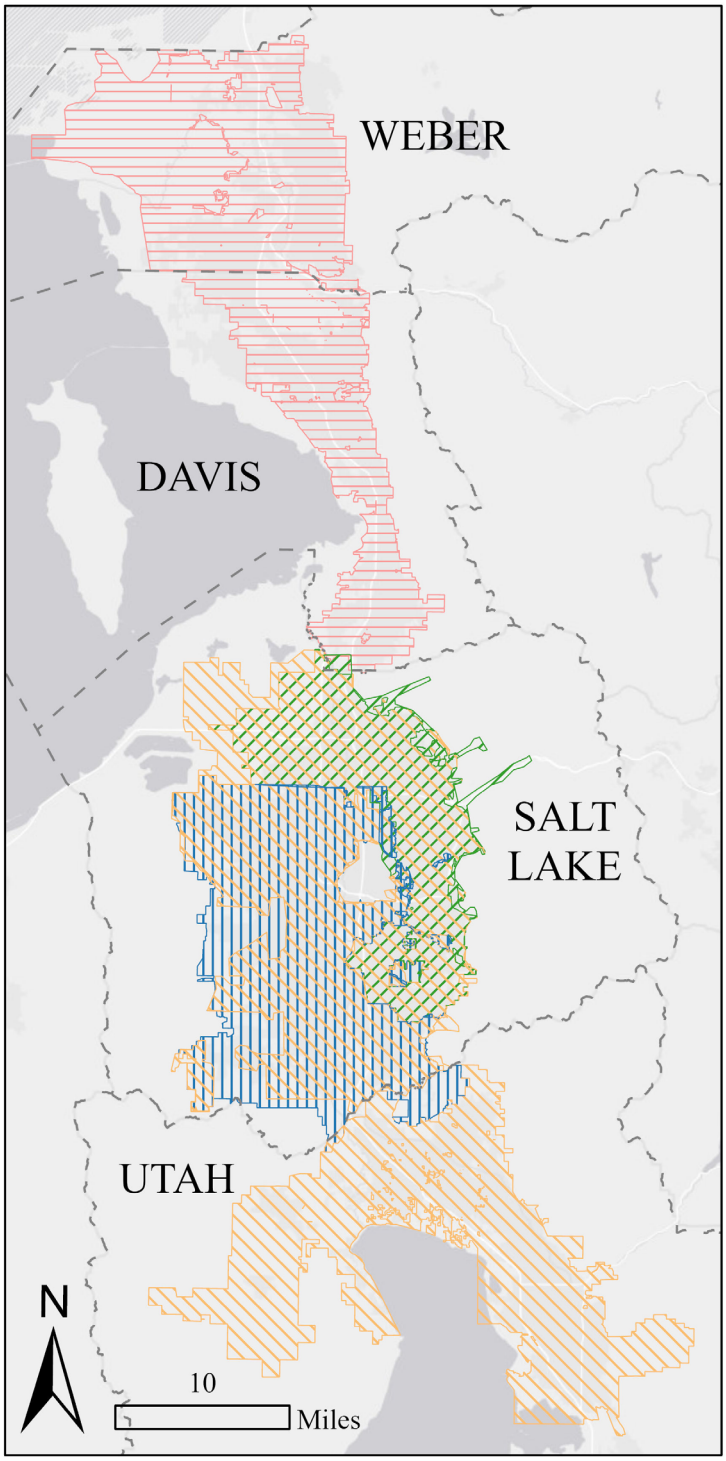
Funding upgrades now will greatly reduce the repair time and costs in the future. A barrier to recovery time is that spare parts cannot be kept on hand or in storage for these aqueduct projects and would have to be custom manufactured and brought in from outside the state after the earthquake. These aqueduct projects will reduce the chance that major repairs are needed, making them a key element of accelerating Utah's recovery.

SALT LAKE AQUEDUCT HARDENING | METROPOLITAN WATER DISTRICT OF SALT LAKE AND SANDY

The Salt Lake Aqueduct is a 42-mile, mostly reinforced concrete pipe that begins at the base of Deer Creek Dam in Wasatch County, runs through Utah County, and terminates in Salt Lake County near the mouth of Parleys Canyon. The pipeline, which **serves around 450,000 people**, was built in the 1940s and has several segments that are subject to earthquake damage where they cross the Wasatch fault. A recent risk assessment identified a high risk of joint failure during an earthquake due to ground deformation and ground shaking. Failed joints on an active aqueduct pose a secondary risk of landslides caused by saturated soils and flooding with the aqueduct location along the bench areas in Utah and Salt Lake Counties.

The risk assessment identified four segments in Pleasant Grove, Cedar Hills, Draper, and Cottonwood Heights as being the most critical. Mitigation for these four segments is expected to cost $160.4 million. The Metropolitan Water District of Salt Lake and Sandy is requesting $85.1 million to support this project. The economic benefit is approximately $203M per segment at a cost-benefit ratio of 5.5 to 10. Currently, construction for one segment is set to begin in 2041, and the other three are scheduled to begin construction in 2045.

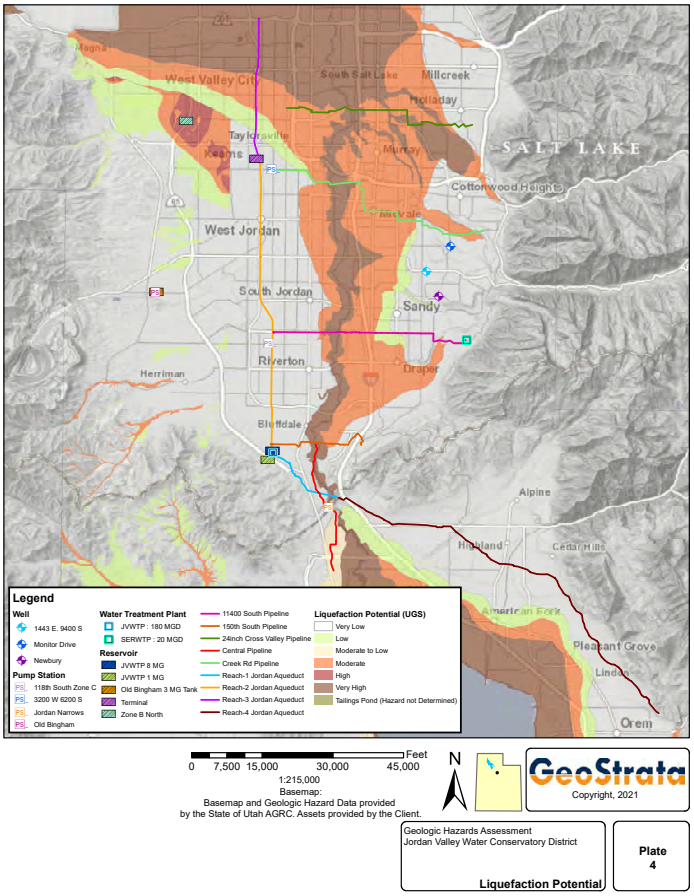
Areas Served by Aqueduct Projects



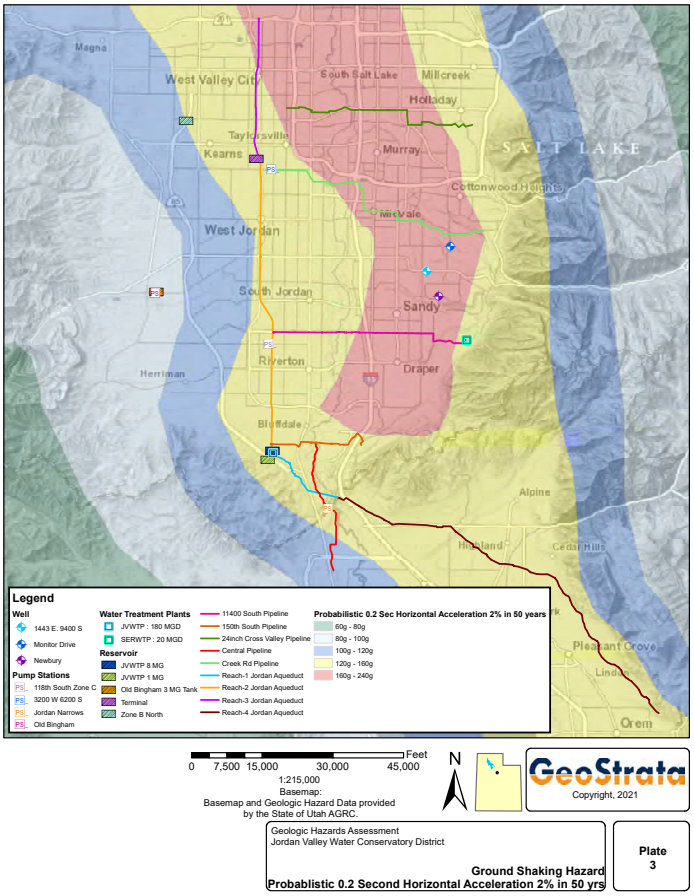
JORDAN AQUEDUCT REACHES 1–4 | JORDAN VALLEY WATER CONSERVANCY DISTRICT

The Jordan Aqueduct Reaches 1–4 are located in a predicted high ground-shaking and liquefaction potential area. **The aqueduct serves drinking water to over one million people**. Most of the Jordan Aqueduct Reaches 1–4 is steel pipe with unrestrained joints.

These unrestrained joints have a high potential to separate when subjected to high ground acceleration and/or liquefaction. Repair of a large number of separated joints would likely take at least two to three months. Welding or otherwise restraining the joints in high-vulnerability areas could prevent separation. Upgrades are estimated to cost approximately $75 million, of which about half needs outside funding.



The Jordan Aqueduct has multiple segments that pass through liquefaction zones, which will likely displace the pipeline.



The Jordan Aqueduct has multiple segments that pass through ground acceleration zones. A large earthquake could damage and separate the pipeline.

Improving the seismic resilience of these aqueducts will not guarantee that a Wasatch Front resident will have water service shortly after an earthquake. An earthquake could damage treatment or distribution infrastructure, the connection from a house to the distribution line in the street, and/or sewage transport and treatment facilities. However, these projects will substantially increase the likelihood that water is in the system and potentially available nearby for each resident. The projects will also significantly reduce the likely timeline for restoring full water service.

3. Keep Infrastructure Operable

Do a comprehensive analysis of Utah's infrastructure, looking at existing resilience, repair timelines, interdependence, design standards, and improvement funding sources.

Infrastructure resilience is one of Utah's most critical needs in the face of an expected large earthquake. Without access to water, sewer, transportation, telecommunications, and energy, life and the economy cannot go back to normal, and individual health and safety are at risk. Many of these systems are interdependent; for example, access to water treatment plants to perform repairs may depend on functioning road systems, as well as fuel availability. Modeling of a 7.0 earthquake on the Wasatch fault projects that essential lifelines such as water, electricity, gas, and sewer will be disrupted for days to months and, in some locations, perhaps longer. For example, more than 480,000 homes (about 1.5 million people) would be without water, and another 440,000+ homes (also about 1.5 million people) would be without electricity.[11] Those homes without water will not necessarily be the same as those without electricity. Restoration of service, particularly for water and sewer, could take many months.

The impacts will extend to the rest of Utah, as well as the greater Intermountain West, which is reliant on food, fuel, and other supplies sourced from or through the Wasatch Front. If Utah's communities are without functioning infrastructure for months, businesses will collapse and families will relocate. As a result, Utah's economy would take years, even decades, to recover.

While Utah's major aqueducts are the top priority, other infrastructure is also at risk, ranging from water treatment plants to major sewer lines and bridges. Additional research is needed to identify key priorities for this infrastructure. This research should look at the following:

- Existing infrastructure resilience and criticality. Which buildings, pipes, or other improvements are most at risk? How much of Utah's population and economy is affected by each? And how are different infrastructure elements dependent on other infrastructure?
- Upgrade costs, potential funding sources, and current upgrade plans and timelines.
- Design standards for new infrastructure. Are we building infrastructure to withstand the ground shaking and liquefaction that are likely to occur?

In October 2024, state and local officials toured the Davis County Aqueduct seismic resilience project, a critical $81 million effort aimed at securing the water supply for over 650,000 residents in the event of a major earthquake.

11. Scenario for a Magnitude 7.0 Earthquake on the Wasatch Fault—Salt Lake City Segment, EERI 2015.

4. Keep Utahns Informed about Seismic Risks and Mitigation Measures

Educate and inform Utahns about the state's seismic risk, as well as the individual and community steps that can be taken to improve resilience.

Keeping Utahns informed is essential for improving Utah's seismic resilience. Of the key steps that need to be taken, many depend on public action or public will.

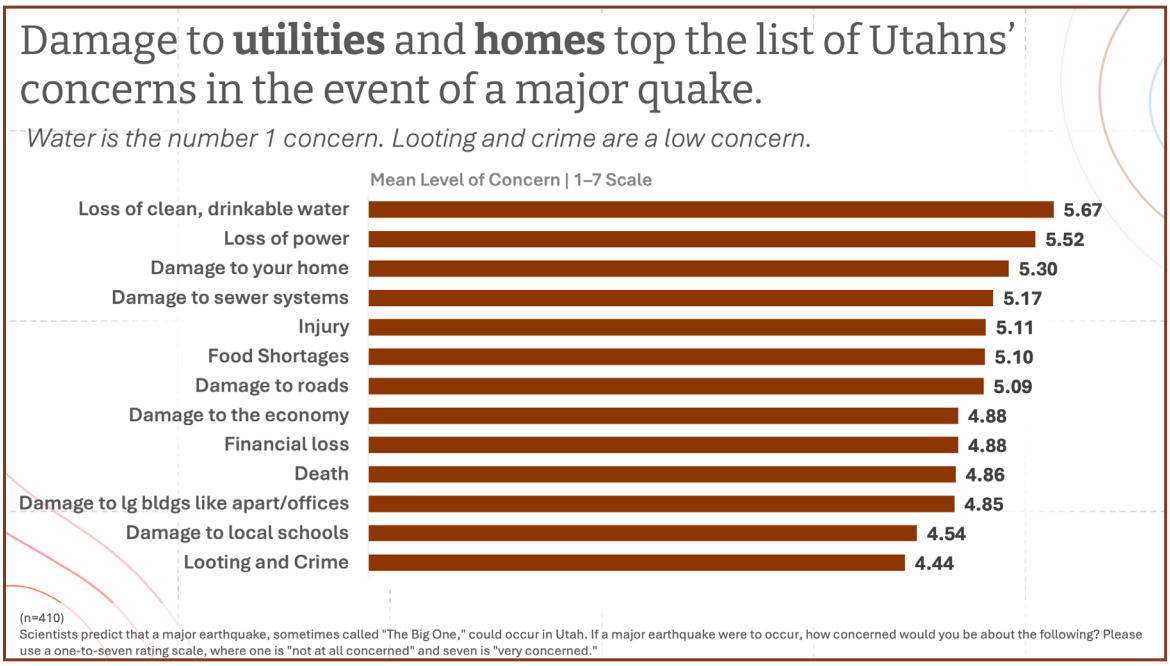
Some key steps involve individual action that is unlikely to occur without individual awareness. For example, upgrading or replacing Utah's 140,000+ seismically vulnerable privately owned buildings will require owners and purchasers to know that the buildings are dangerous and take steps to mitigate or avoid the risk. With increased awareness, more Utahns will voluntarily improve or rebuild their homes, ask realtors and sellers whether a home being sold is an earthquake-vulnerable URM, and have the opportunity to request upgrades to a building during a transaction or plan a future seismic upgrade. This information also helps renters make decisions about the type of properties they choose to inhabit.

Other key steps to improve seismic safety require public support. This need is most apparent when a public vote is required, such as when a school district bonds to finance the upgrade or replacement of a seismically vulnerable school. In other cases, an entity might only take action if it senses public support, as when a local government puts funding toward upgrading infrastructure.

The USSC and its partners recently updated and re-released *Putting Down Roots in Earthquake Country*, a public-facing handbook that is now available for the first time in Spanish. The guide outlines Utah's earthquake risks and actions Utahns can take to better prepare. Other publicly available materials and updates will be needed as earthquake science and knowledge continue to evolve.

Envision Utah has a grant to conduct an outreach campaign about disaster resilience. This campaign, which is close to launching, will increase public awareness about Utah's risk and the major steps that can be taken to improve resilience. While the grant funding is not sufficient to build strong ongoing public consciousness, it has funded "values research" into Utahns' correct and incorrect perceptions about Utah's earthquake risk and state of readiness and has created outreach assets that can be leveraged with ongoing funding.

Additional grants and other opportunities for public awareness should be pursued.



In preparation for an outreach campaign, Envision Utah conducted some research to see Utahns' current understanding and awareness of the risks posed by a major seismic event. The research shows Utahns would benefit from a greater understanding of the risks.

5. Upgrade Our Highly Vulnerable Older Buildings

Analyze ways to accelerate building retrofits, upgrades, and replacements, particularly for public buildings.

The projected casualties in a major Wasatch Front earthquake rival those in the largest natural disasters in US history. These high casualties are largely because of the numerous unreinforced masonry buildings (URMs).

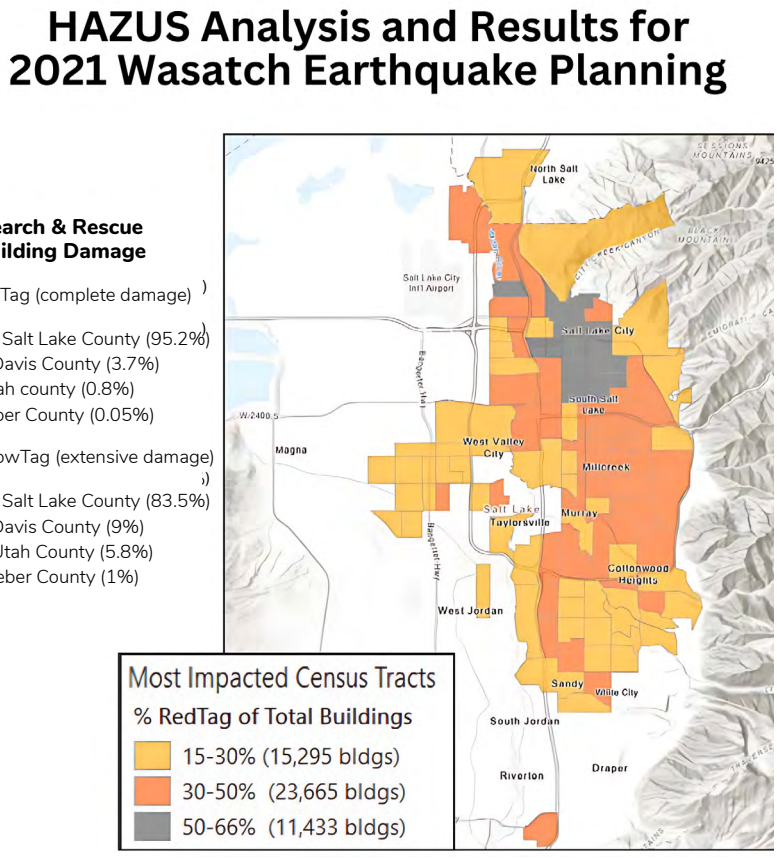
These are buildings constructed of fired clay brick or concrete block without reinforcing steel, which makes them extremely susceptible to damage from earthquake ground shaking.

While Utah's adopted building codes have not allowed this kind of construction since 1976, it has been estimated that more than 140,000 URMs are still standing today in the Wasatch Front region,[12] including single-family homes, apartment buildings, schools, and offices—far more than in the entire state of California, which has a population ten times larger than Utah.

URMs will be the primary source of deaths and injuries from a major earthquake. Further, these buildings will likely be uninhabitable and unusable after the earthquake, and many will require complete reconstruction or demolition. After the 2011 Christchurch earthquake and aftershocks, tens of thousands of buildings were unsafe to reenter, and many of them were eventually demolished, including a large percentage of the buildings in its city center. As shown in the map below, the "Big One" would similarly devastate the downtown business core of Salt Lake Valley.

Even though Utah's 140,000 URMs are scattered throughout our historic pioneer communities, public awareness of the risk is low. Many people live or work in these buildings but do not understand their vulnerability. As a result, few upgrades happen, and the market does not adequately take seismic soundness into account when setting prices or evaluating risk.

Salt Lake City's "Fix the Bricks" program is leveraging federal grant money to fund upgrades to single-family homes. There is currently a long waiting list for grants, and the program is seeking to improve 200 homes per year. Given the estimate that there are 140,000 URMs in Utah, at this rate, it will take 700 years to complete them all. Currently this popular program does not extend to the majority of the URM homes that are located outside Salt Lake City. For this reason, DEM sought and received federal funding to conduct a feasibility study for a statewide program. This study points to key considerations that could inform the creation of a statewide grant program.



Lifeline Systems Analysis for Wasatch Fault Planning, Great Utah ShakeOut M7.0 Scenario, DEM 2021.

PUBLIC AWARENESS

Beyond the potential for a statewide grant program, increasing public awareness of URMs can help. With increased awareness, more Utahns will voluntarily improve or rebuild their homes, ask realtors and sellers whether a home being sold is a URM, request upgrades during a remodel or purchase transaction, and encourage landlords to upgrade their rental units.

12.. Wasatch Front Unreinforced Masonry Risk Reduction Strategy.

GOVERNMENT BUILDINGS, INCLUDING SCHOOLS

FEMA, the State of Utah, and many other stakeholders collaborated to create the Wasatch Front Unreinforced Masonry Risk Reduction Strategy, which identifies mitigation strategies that would greatly reduce the URM risk in Utah. The strategy highlights five key recommendations to reduce URM seismic risk. The first two relate to mitigating government buildings and schools.

Many of Utah's schools are URMs. **The State of Utah published a statewide inventory of unreinforced masonry construction in public K–12 schools.**[13] Findings from the inventory suggest that at least 119 school campuses include URMs where more than 72,000 Utah children spend all or part of their school hours. In addition to protecting Utah's students, teachers, and staff, addressing URM school buildings is important for recovery from our disaster. For these schools to function as emergency shelters or gathering places during and after a disaster, they need to withstand the disaster itself. Moreover, disruption of this key education infrastructure could have extensive economic consequences; the sooner schools can reopen, the sooner parents can go back to work, the sooner our economy can recover, and the sooner society can go back to normal.

While some school districts have been very proactive at renovating or replacing URMs over the years, many still remain. It's essential to continue to retrofit or rebuild the remaining buildings. If a large-magnitude earthquake were to occur during school hours, tens of thousands of Utah school children would be at risk of death or serious injury in government-owned buildings. The moderate M5.7 Magna earthquake caused significant damage to Westlake Junior High School, a partial URM building. Students and staff would likely have been injured or killed if students had not been out of school due to a pandemic. An M7 earthquake would release approximately 90 times as much energy as the Magna event and be far more devastating to the many schools with similar vulnerabilities.

Local school districts continue to upgrade, replace, or remove URM buildings from service. A recently passed Salt Lake School District bond will fund the replacement of its aging Highland and West High Schools. Some other districts are considering seismic risk as they determine which schools to close when school enrollment drops because of the declining local school-aged population. In addition, recent legislative funding to assist with school capital needs adds to local efforts and federal grants.

Although an inventory has been completed for those schools owned and operated by school districts, there is no inventory of charter school buildings, some of which are older structures. Approximately 12% of Utah's public school students attend charter schools, so it is important to understand the risks of these structures.

Recent renovations at the Utah State Capitol serve as an example of the types of updates needed in URMs. An engineer explains the purpose of the base isolators, constructed predominantly from rubber, that enable buildings to slide up to 2 feet in any direction to counteract ground shaking.

A new Mitigation Endorsement Report[14] gives guidance to school districts that are considering retrofits. The report contains recommendations for seismic performance objectives and engineering retrofit criteria, as well as processes to confirm that a retrofit meets the minimum standard.

OTHER VULNERABLE BUILDINGS

While URMs are the most hazardous building type in Utah, there are many other building types that were not designed to withstand a major earthquake. Specifically, buildings constructed with non-ductile or pre-cast concrete are at risk. Tilt-up buildings were built with inadequate structural systems as late as 1996. And pre-Northridge Earthquake steel moment frame buildings are also of concern. After URMs, these buildings should be a focus of attention.

13. Utah K-12 Public Schools Unreinforced Masonry Inventory.

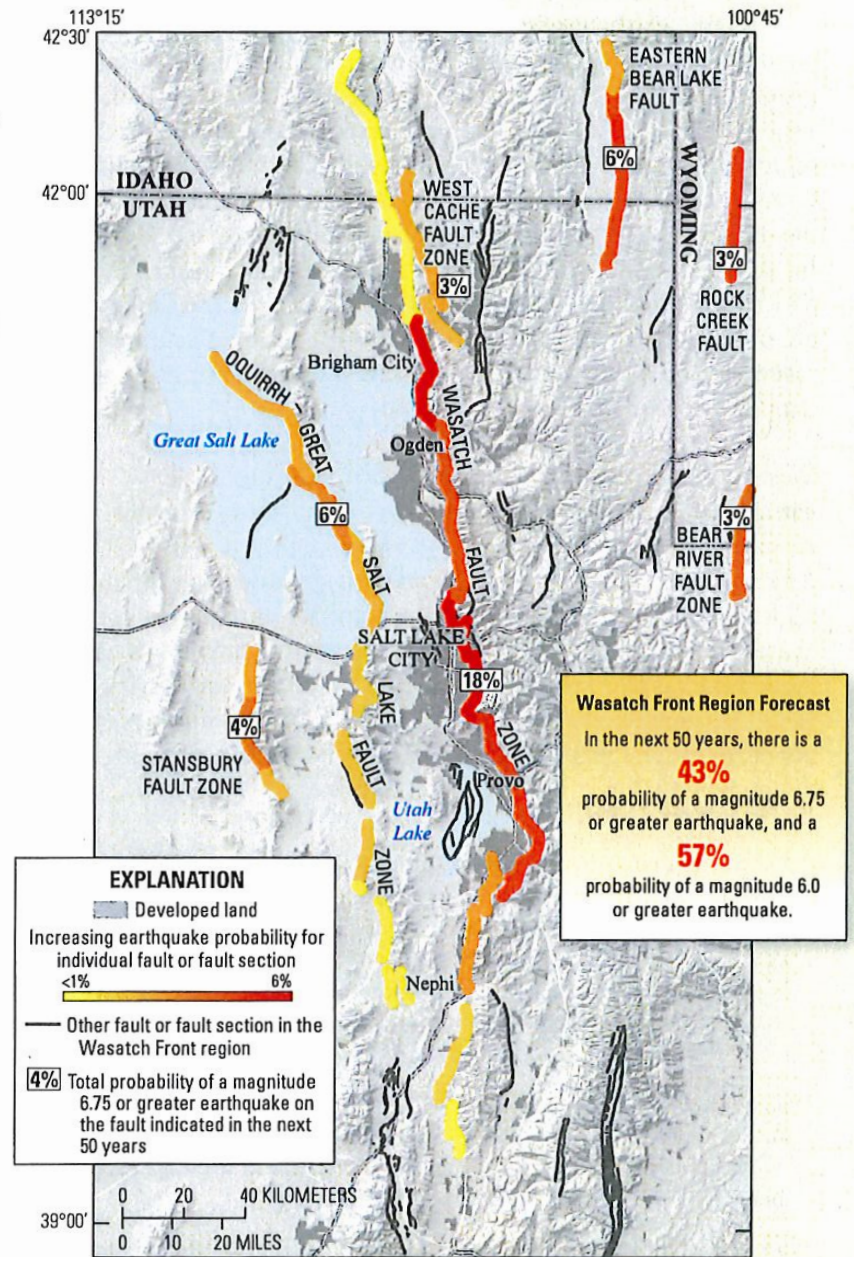
14. Mitigation Endorsement Report for Utah's Unreinforced Masonry K–12 Public Schools.

6. Ensure New Buildings Are Resilient

Develop and enforce building codes that adequately meet Utah's seismic risks.

Due to Utah's rapid population and economic growth, almost half of the buildings that will exist in 2060 have not yet been built,[15] and many of our existing buildings will be rebuilt in that same timeframe. Ensuring these new buildings quickly return to functionality following a large-magnitude earthquake is key to keeping Utahns in their homes and at their jobs so they can continue life as normal. Utah's building code is an important tool, requiring that seismic protection be incorporated into building design and construction.

The building code requires that new buildings be constructed to protect life safety at a certain level of ground shaking. A life safety standard means that, while the occupants will likely survive, the building may need major repairs before it is usable again. In addition, the level of ground shaking that must be considered is based not just on the projected strength of earthquakes that could happen in the area but also on the frequency of such earthquakes. In the Wasatch Front area, large earthquakes are not frequent, but they are due or overdue in some areas of the Wasatch fault. As a result, while the risk of a major earthquake in the coming decades is high, the code does not require design for the actual shaking from the anticipated earthquake—in fact, the building code design shaking level for new buildings is roughly one-half as strong as the shaking that could occur in some locations when a large Wasatch fault earthquake occurs.



Magnitude 6.75 or greater earthquake probabilities may vary along faults (yellow to red fault colors), but entire fault probabilities are labeled. For example, the total probability for the entire Wasatch fault is 18 percent. Only faults with a probability of 2 percent or greater are shown. Modified from Working Group on Utah Earthquake Probabilities, 2016.

SPECIAL SEISMIC ZONE FOR WASATCH REGION

Because of the lower levels of ground shaking that are required for structural design in Utah, many new buildings that are constructed to the modern code may collapse during a large Wasatch fault earthquake. New buildings constructed along the Wasatch Front are about three times more likely to collapse from a large Wasatch fault earthquake than new buildings constructed near the San Andreas fault in San Francisco are to collapse from a large San Andreas fault earthquake. The reason is that the code requires new buildings in San Francisco to be designed for the higher potential shaking levels, but the building code along the Wasatch Front does not, for the reasons noted above. In addition to the resulting casualties, there will likely be many people who are left without shelter or without a place to work. This situation will significantly impact Utah's ability to recover.

15. Your Utah, Your Future Disaster Resilience Vision.

For very little additional cost, buildings along the Wasatch Front can be constructed stronger than the current building code requires, which will reduce the chance of collapse. A study by the Structural Engineers Association of Utah (SEAU) shows that the increase in construction cost for these stronger new buildings would be 0.25% for single-family homes, less than 2% for multistory multifamily residences, and 2–5% for commercial buildings.[16]

Stronger new buildings will result in a more resilient Wasatch Front. There will be a higher probability that emergency services will remain operational. Schools will be safer and able to be used as emergency shelters. More residents will be able to remain living in their homes. More buildings will be safe to be occupied following a Wasatch fault earthquake. More businesses will be able to stay open. There will be fewer deaths and injuries. There will be fewer collapsed buildings and buildings that must be torn down, and buildings will be less expensive to repair following the earthquake. Wasatch Front buildings will also be a better investment for lending institutions and insurers.

Every new building constructed will likely be around for many decades. It is much more cost-effective to ensure the building is resilient when first built than to retrofit the building later. If we begin today, in 30 years about one-half of the building stock will consist of stronger, more resilient buildings.

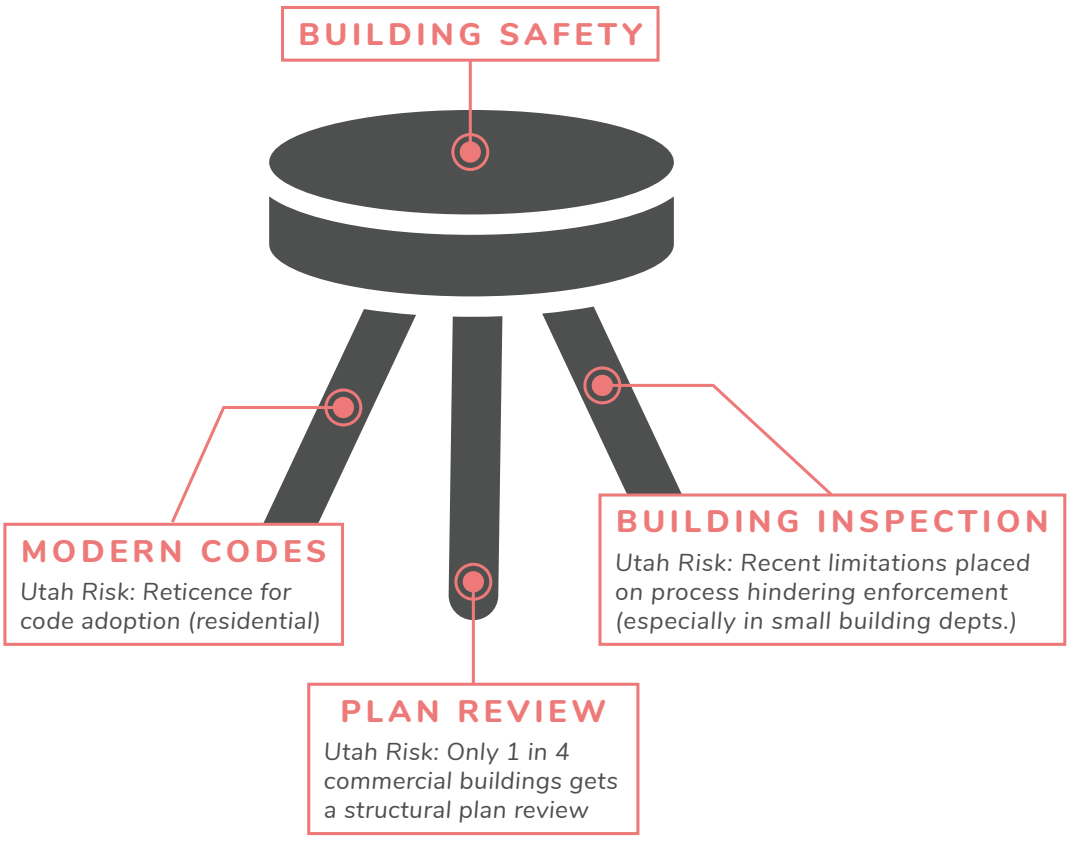
Studies have shown that the economic and safety benefits of strengthened buildings will result in a savings of $4 for every dollar spent. Further discussion and Utah-specific cost-benefit analysis are needed to determine whether and to what level to increase structural design standards in the Utah building code. Such higher standards would be needed only for a special seismic zone within the Wasatch Front area. A more detailed analysis could be funded for approximately $300,000. The building code is a critical issue that affects many groups of stakeholders. Actions should be taken to invite all those groups to participate in evaluating the costs and benefits of of an enhanced code for a limited area.

CODE ENFORCEMENT: PLAN REVIEWS

Ensuring building seismic safety is like a three-legged stool. One leg is adoption of comprehensive building codes, the second is quality structural plan reviews, and the third is building inspection. Without all three legs, seismic resilience is not guaranteed in our communities.

While it is essential for building codes to have appropriate standards, when plans are not adequately reviewed or buildings are not appropriately inspected, many buildings can still be unsafe, as was seen with the Surfside condominium tower collapse in Florida. Plan reviews and inspections are particularly important for larger, more complex structures, yet SEAU has estimated that only one in four of the commercial buildings in Utah receive a structural plan review from a qualified reviewer.[17]

FEMA takes Utah's adopted building codes and enforcement into account when evaluating Utah grant requests. In other words, Utah's ability to access millions of dollars in federal funding for disaster mitigation depends on ensuring codes are up to date and enforced. The State of Utah regularly reports on the status of code adoption



16. Cost to Protect New Buildings from a Wasatch Fault Earthquake.
17. Survey by the Structural Engineers of Utah (SEAU) Seismic Committee in 2012.

and building inspection to determine our eligibility. As a result, adopting and enforcing the latest version of the International Building Code (IBC) is important to obtaining federal grants.

Currently, many buildings undergo plan reviews for fire, egress, and other life safety measures, but structural engineering reviews are often neglected or performed by individuals without sufficient technical knowledge of structural seismic codes. It is likely that many buildings could underperform during and after a major earthquake—particularly larger, more complex buildings.

The IBC assigns risk categories to buildings based on the consequences and risks in the event of building failure. The intent is to assign higher risk categories, and hence higher design criteria, to buildings or structures that provide essential community services necessary to cope with an emergency situation or for which a structural failure would have grave consequences to either the building occupants or the population around the building.

The highest risk categories—Categories III and IV—include buildings occupied by large numbers of people, police stations, schools, hospitals, and utility infrastructure like power stations. Because of the importance of these buildings, as well as their structural complexity, the USSC recommends that plan reviews by a Utah-licensed Professional Structural Engineer be required for structures classified as Risk Categories III and IV and buildings greater than 200,000 gross square feet that are occupied by people.[18]

People in our communities expect to be safe in their homes, schools, and places of business. Only by ensuring that new construction meets the standards of modern building codes, through plan review and building inspection, can we meet this expectation and ensure that we make a full economic recovery after a seismic disaster.

New construction provides an opportunity to build resilient communities in Utah.

GEOTECHNICAL HAZARDS

While building codes require geotechnical hazards like soil liquefaction or landslides to be identified and mitigated, the codes do not present specific seismic design criteria for appropriate mitigation. Consequently, there is significant variability in how well engineers address these hazards in the design of new infrastructure and buildings. Past research has shown that large areas of the Wasatch Front are highly susceptible to soil liquefaction.

The diverse and devastating nature of earthquake-induced soil liquefaction was brought to the attention of civil engineers through the occurrence of two large earthquakes in 1964: the Good Friday Alaska earthquake and the Niigata, Japan earthquake. In the Good Friday Alaska earthquake, extensive damage was done to a wide variety of bridge foundations as liquefied soils spread laterally toward stream channels. Weakened soils also triggered large landslides in the cities of Anchorage, Seward, and Valdez. In the Niigata, Japan, earthquake, thousands of buildings

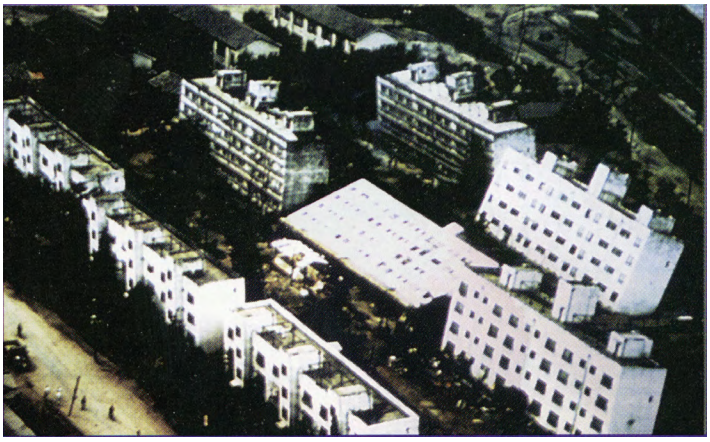
18. These guidelines are a rough approximation of the boundary used by the Professional Engineers and Professional Land Surveyors Licensing Act. Ut Code 58-22-102 (14).

were damaged when their foundation soils liquefied. Many of these buildings settled several feet and tilted severely due to differential movement. Since that time, soil liquefaction damage has been noted in almost every major earthquake around the world, with extreme liquefaction damage resulting from earthquakes such as the 1999 Kocaeli, Turkey, and 2011 Christchurch, New Zealand, earthquakes. Observed failures range from tilted buildings to floating pipes and from failed dam foundations and bridge abutments to lateral spreading and landslides.

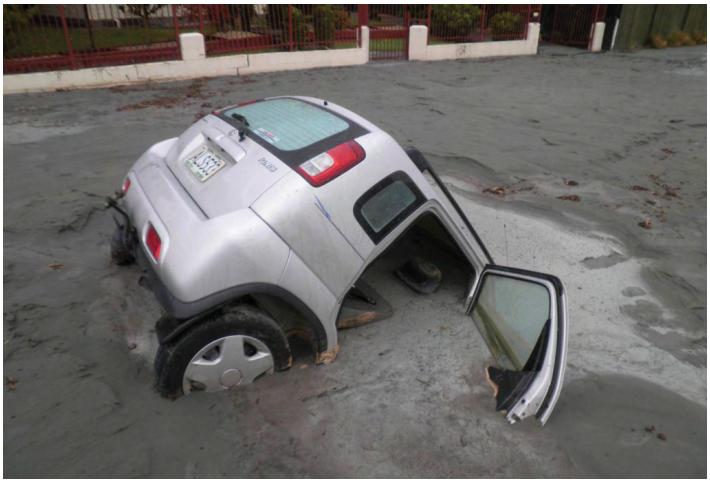
Since all of these failures result in the loss of money and potentially lives, predicting and mitigating the risk of earthquake-induced soil liquefaction is one of the most important tasks that a civil engineer is faced with in seismically active regions. For example, following the series of earthquakes that hit Christchurch, New Zealand, in 2010–2011, researchers found that loss estimates were under-predicted by six to eight times without proper consideration for liquefaction damage.

Presently, the loss estimates for a large Wasatch fault earthquake do not include proper consideration of direct liquefaction damage to critical lifelines like water, sewer, electrical, gas, and communication infrastructure. Furthermore, the longer-term economic losses resulting from significant repair times required to fix miles and miles of infrastructure have not been accounted for. It is clear that geotechnical hazards like soil liquefaction need greater attention as we prepare to be more resilient in the face of a large Wasatch fault earthquake.

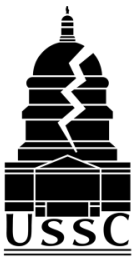
Further study and analysis are needed to understand what steps should be taken to address these geotechnical hazards.



Liquefaction caused these apartment buildings to tip over during the 1964 Niigata, Japan, earthquake (magnitude 7.5). However, the buildings were built of reinforced concrete and did not collapse even when resting on their sides. Largely because of such construction, only 26 people died during this earthquake. Photo courtesy of the Earthquake Enginnering Research Institute



A small car presumably sunk into a large sand blow on a road damaged by liquefaction during the 2011 Christchurch, New Zealand, earthquake. Photo courtesy of Mark Lincoln.



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