LIQUEFACTION HAZARDS IN UTAH

By Mark Milligan | Utah Geological Survey Public Information Series 100
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A small car presumably sunk into a large sand blow on a road damaged by liquefaction during the 2011 Christchurch, New Zealand, earthquake. In this extreme example, sand covered the road due to ground-surface subsidence and sand blows. Image courtesy of Mark Lincoln.

Most earthquake damage is caused by ground shaking. However, large-magnitude earthquakes cause damage in other ways: surface fault rupture, ground deformation, triggered landslides and rockfalls, tsunamis and other flooding, and **LIQUEFACTION**.

WHAT IS LIQUEFACTION?

Liquefaction is a process by which strong shaking during an earthquake causes the ground to temporarily lose its strength and behave like a viscous liquid rather than a solid. Liquefaction can cause buildings to tip and settle; roads to crack, deform, and flood; buried storage tanks to rise up towards the surface; and other types of damage to buildings and infrastructure.

WHY IS LIQUEFACTION A CONCERN IN UTAH?

Utah's population is concentrated in the valleys of the Wasatch Front. Susceptible soils*, shallow groundwater, and a relatively high probability of moderate to large earthquakes make these valleys especially vulnerable to liquefaction.

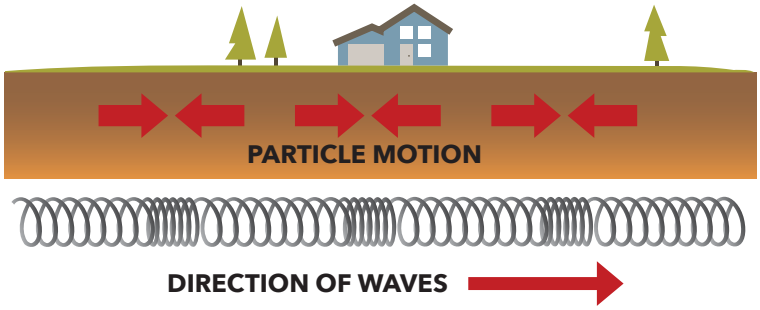
*For this publication, *soil* includes all earthen material at or near the surface that is not rock.

HOW DOES LIQUEFACTION OCCUR?

Earthquake-produced energy waves traveling through water-saturated, loose, sandy or silty soils can cause liquefaction.

Earthquakes result from ruptures (movement along a fault) within the earth's crust. Earthquake ruptures generate energy waves that travel away from the initial rupture zone similar to waves moving away from a stone dropped into a pond. Different types of seismic waves travel across the surface (surface waves) and through (body waves) the earth. Relevant to liquefaction are compressional body waves, called P or primary waves. P waves are the fastest type of seismic wave, and depending upon sediment or rock type, can travel over 14,500 miles per hour! P waves alternately compress and expand the materials they travel through. A similar compressional wave is experienced when a loud clap of thunder rattles house windows. The windows rattle because sound waves are pushing and pulling on the window glass.

As P waves travel, the intermittent compression increases the water pressure between soil grains, which forces the grains apart, causing the soil to lose its strength and flow like a viscous fluid. This is how earthquakes cause liquefaction.



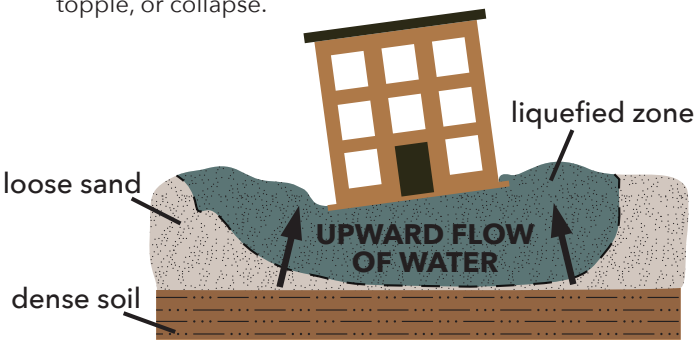
P waves are compressional waves that alternately expand and compress soil and rock. Such waves can be seen in an expanding and contracting spring.

Normally, water-saturated soil grains touch and friction holds the soil together. When seismic waves compress soil, the increased water pressure within the pore space forces grains apart, friction is lost, and the soil loses strength and liquefies.

WHAT ARE THE EFFECTS OF LIQUEFACTION?

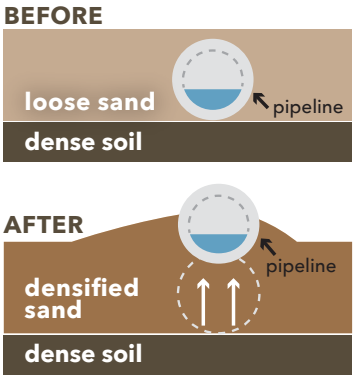
Liquefaction can cause different types of ground failure, which in turn produce different types of damage:

1. Loss of bearing strength can cause buildings to settle, tilt, topple, or collapse.



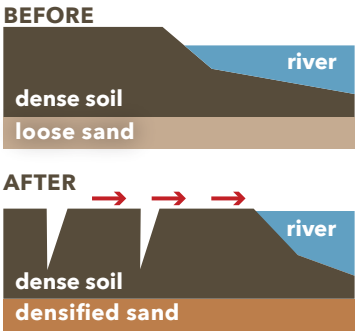
2. With a loss of soil strength, buried objects such as large pipes and tanks can be damaged when buoyed towards the surface.

Manhole and underground utilities buoyed above the ground surface during the 2010 Canterbury, New Zealand, earthquake. Photo courtesy of Jim Harding.



3. Lateral spreads may form where blocks of gently sloping (generally less than 3 degrees) land move sideways over a liquefied layer, causing ground deformation and cracking. Lateral spreading is expected to cause major damage during an earthquake along the Wasatch Front.

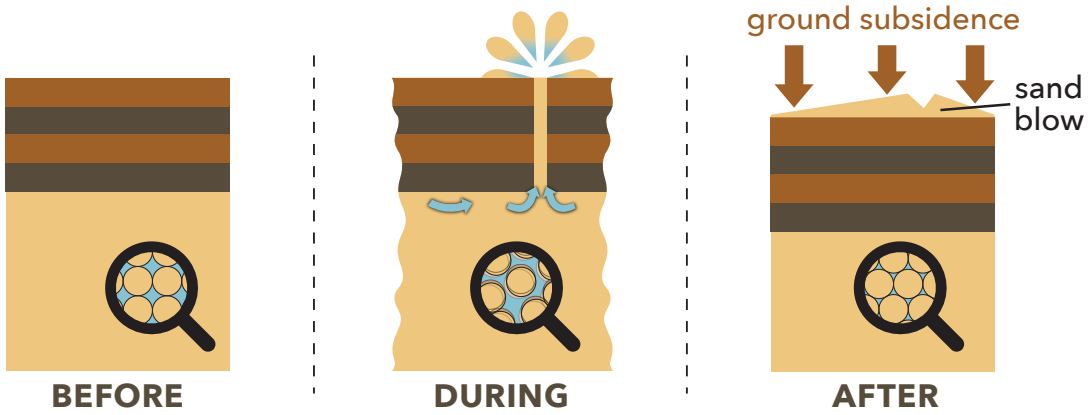
Lateral spread landslide triggered during the 2011 Christchurch, New Zealand, earthquake. This slide occurred 120 miles from the earthquake epicenter. Photo courtesy of M.J. Crozier.



Ground cracks caused by lateral spreading triggered during the 2011 Christchurch, New Zealand, earthquake. Photo courtesy of Schwede66 (Own work) [CC BY-SA 3.0 (http://creativecommons.org/licenses/by-sa/3.0) or GFDL (http://www.gnu.org/copyleft/fdl.html)], via Wikimedia Commons.

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

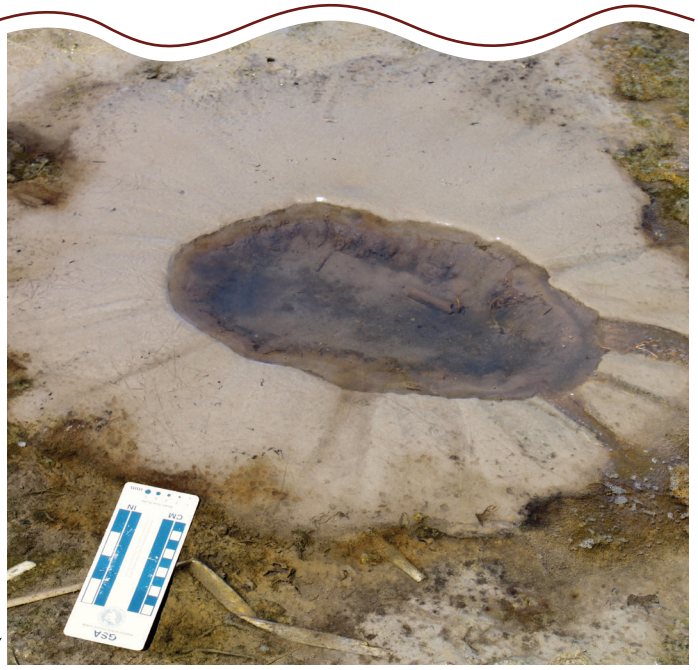
5. Ground subsidence may occur during liquefaction, when soil grains rearrange to denser packing and decreased volume. This decrease in volume causes ground-surface subsidence, ground cracks, and may cause the eruption of sand blows. Whereas uniform subsidence over large areas may be unnoticeable, differential subsidence can cause ground deformation and cracking leading to building and infrastructure damage.



WHERE IS LIQUEFACTION LIKELY TO OCCUR IN UTAH?

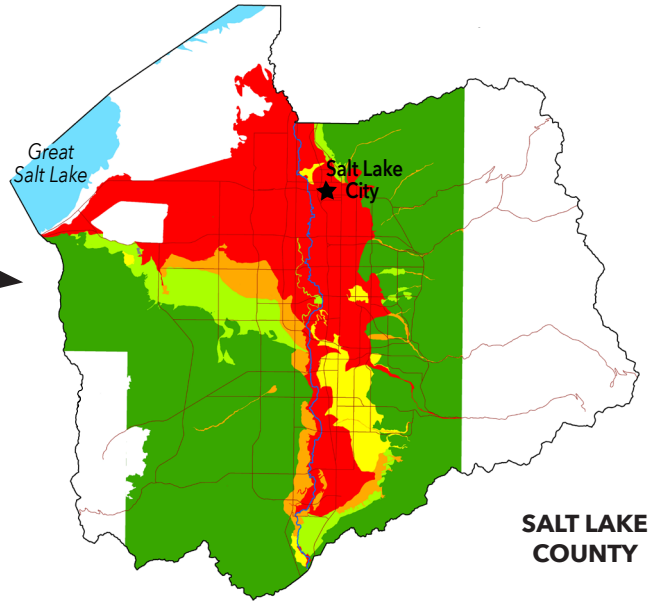
Liquefaction is likely to occur where the following conditions are present:

1. The occurrence of a moderate to large earthquake – Activities such as blasting, pile driving, or anything else that causes soil to vibrate can cause small-scale liquefaction, but damaging, large-scale liquefaction is caused by moderate to large-magnitude earthquakes.
2. Sandy or silty soils – Clays and gravels tend not to liquefy.
3. Loose soils – Compacted soils tend not to liquefy. Generally, the younger the deposit, the less dense and more liquefiable the soil.
4. Saturated soils within about 30 to 50 feet of the surface – Dry or unsaturated soils do not liquefy.



Liquefaction-induced sand blow from the 2010 Randolph, Utah, earthquake. Liquefaction is rare in earthquakes under magnitude 5. At magnitude 4.6, the Randolph earthquake was one of the smallest earthquakes known to generate liquefaction. Photo courtesy of Christopher DuRoss.

Although moderate to large earthquakes are possible in many areas of Utah, they are most probable along the Wasatch Front, where the Wasatch fault, Utah's most active fault, is located. Generally, the Wasatch fault is most likely to trigger liquefaction in the central parts of Wasatch Front valleys, especially near lakes and along stream and river corridors where groundwater is shallow.



Preliminary and generalized map showing the probability of liquefaction triggered by a magnitude 7 Wasatch fault earthquake in the Salt Lake Valley area. Other Utah valleys have a similar pattern of high potential in the low-lying central parts of the valleys. Modified from Utah Liquefaction Advisory Group unpublished online map (http://www.civil.utah.edu/~bartlett/ULAG/M7_Liq_trig_prob.jpg).

NOT MAPPED	VERY LOW	LOW	MODERATE	HIGH	VERY HIGH

WHEN WILL DAMAGING LIQUEFACTION OCCUR IN UTAH?

Evidence of prehistoric liquefaction is common along the Wasatch Front and elsewhere in Utah. In historical time, the Wasatch Front has experienced a magnitude 5 or greater earthquake on average about every 10 years. The 1934 Hansel Valley (magnitude 6.6) and 1962 Cache Valley (magnitude 5.7) earthquakes caused liquefaction and property damage in Utah. However, although scientists can identify areas that are susceptible to liquefaction and forecast the potential of a liquefaction-triggering earthquake in a particular region within some given amount of time, they cannot predict when and where a specific earthquake will occur.

WHAT IS THE LIQUEFACTION RISK IN UTAH?

Nearly 80 percent of Utah's population is concentrated along the Wasatch Front, which has a high probability of large earthquakes along with susceptible soils, shallow groundwater, and many unreinforced masonry buildings that are susceptible to severe damage or collapse. Thus, Utah has a significant liquefaction risk.

WHAT CAN BE DONE ABOUT LIQUEFACTION?

A site-specific geotechnical investigation by a Utah Licensed Professional Engineer and Geologist is needed to determine the liquefaction potential of any specific site. Where a liquefaction hazard exists, three main hazard-reduction techniques may be considered:

- Ground stabilization – These methods are generally designed to drain and de-water building sites or increase soil density through compaction.
- Special building foundation design – Strengthened foundations or deep pile foundation systems, which include vertical structural elements driven or bored deep into non-liquefiable soil or rock, are examples of methods used to protect foundations and their overlying structures.
- Strengthening structures – Buildings and infrastructure that have had ground stabilization and/or special foundation designs can also be designed to resist predicted ground movements.

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. According to a 2015 report by the Utah Chapter of the Earthquake Engineering Research Institute, Salt Lake City, with its many unreinforced masonry buildings, will likely have up to 2,500 fatalities and 9,300 life-threatening injuries when a large-magnitude earthquake strikes! Photo courtesy of the Earthquake Engineering Research Institute.

"When I was a kid, they warned us about devastating earthquakes, yet none have happened. Are these geologists full of hot air?" No. Geologic evidence shows a large earthquake (about magnitude 7) has ruptured the Salt Lake City segment of the Wasatch fault every 1,200 to 1,400 years (average for the past 6,000 years). It has been about 1,200 to 1,500 years since the last large earthquake on this fault segment. Based on this timing information, the Salt Lake City segment is due for a large earthquake—plus or minus about 300 years. Furthermore, while moderate magnitude earthquakes (magnitude 5 to 6.5) can cause liquefaction and significant damage and deaths, they do not leave a reliable geologic record. The area's written history only dates back to 1847; since then, there has been one moderately damaging earthquake in Salt Lake County—the 1962 magnitude 5.2 Magna earthquake. Tectonic forces still pull at the Wasatch and other major faults in the region, and they will rupture again. However, geologists cannot predict if the next moderate to large earthquake will happen several generations from now or before you finish reading this brochure. Just because there has not been a devastating earthquake in recent memory, it does not mean the hazard does not exist. The earthquake clock is still ticking.

Damage to a bedroom in Salt Lake City from the 1962 magnitude 5.2 Magna earthquake. Photo courtesy of Deseret News, Salt Lake City, Utah.

WHERE CAN I GET MORE INFORMATION?

Liquefaction susceptibility maps are available for the Wasatch Front, Cache Valley, and selected areas in southwest Utah. These maps are suitable for land-use planning and management and show the relative distribution and magnitude of liquefaction hazards. More information can be found online at:

Utah Geological Survey – geology.utah.gov/hazards/earthquakes-faults/liquefaction/
Utah Liquefaction Advisory Group – geology.utah.gov/?p=6500 and civil.utah.edu/~bartlett/ULAG/
Utah Seismic Safety Commission – ussc.utah.gov
Putting Down Roots in Earthquake Country, Your Handbook for Earthquakes in Utah – http://1.usa.gov/1XBEVfm