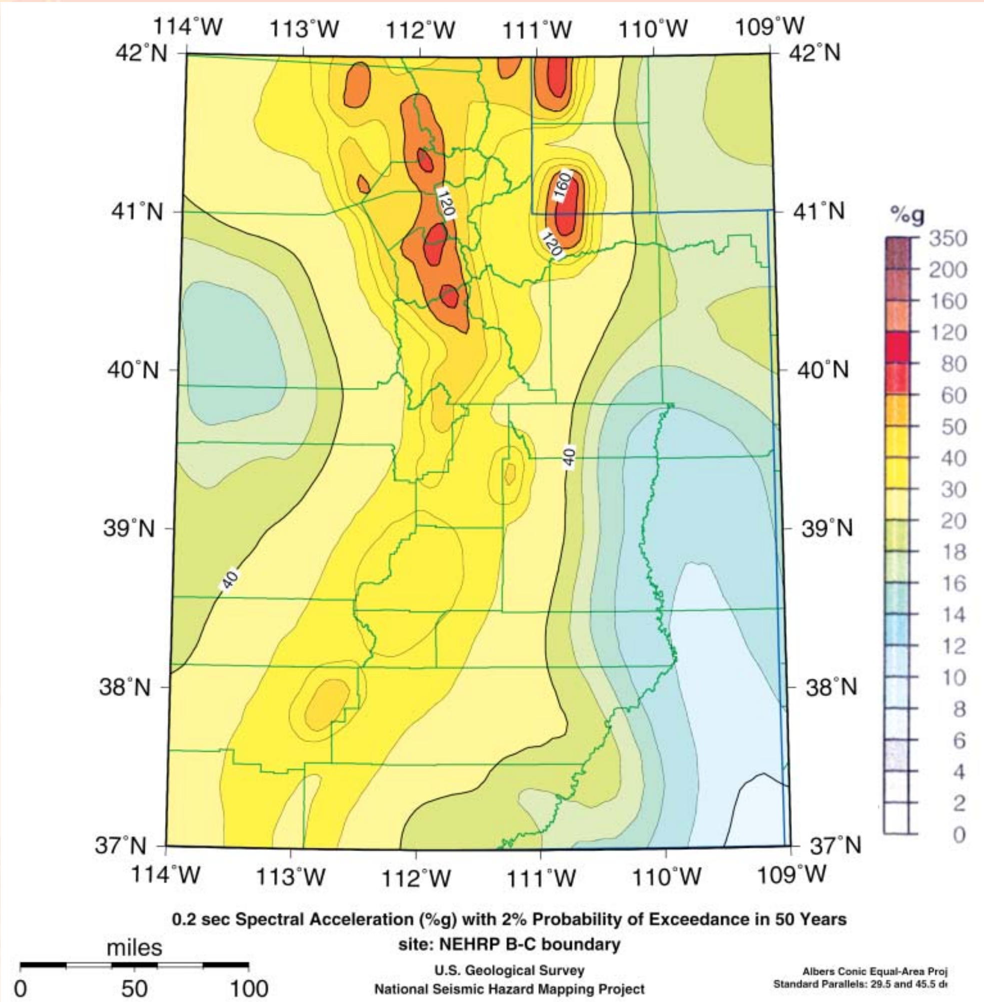
# Utah Earthquake Ground-Shaking Maps

# Which One Do I Use?

Utah Seismic Safety Commission
Geoscience Committee
January 2003

## *Use of Earthquake Ground-Shaking Information in Engineering and Design*

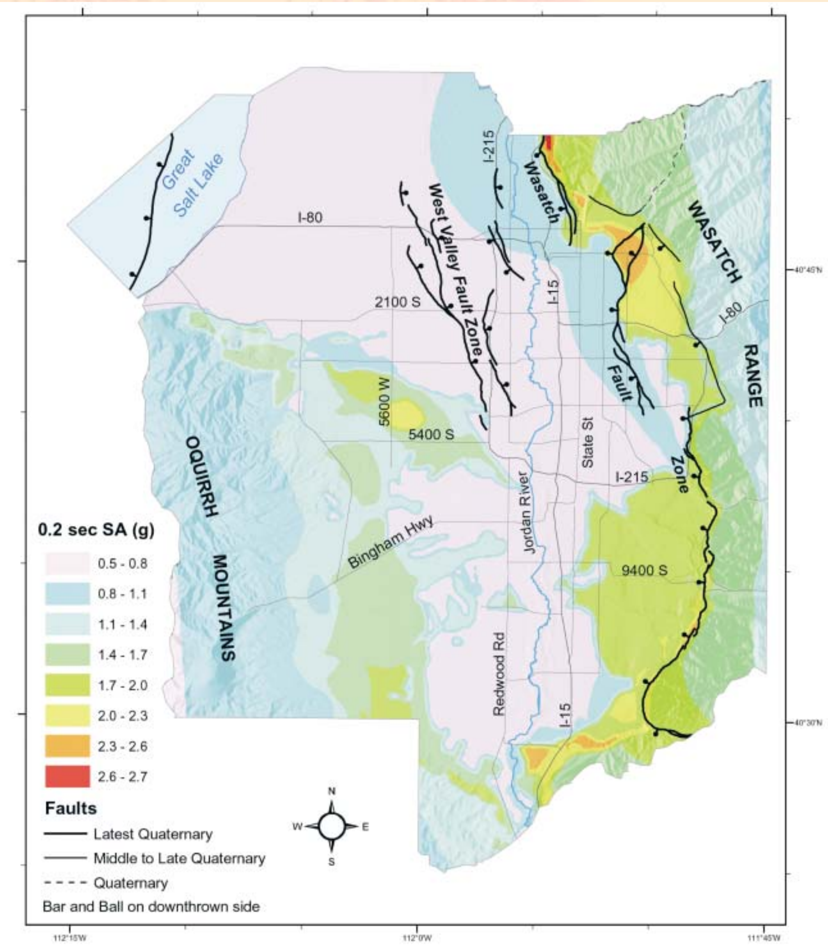
Various regulatory documents specify minimum levels of earthquake ground shaking (usually a peak or spectral horizontal acceleration given as a percentage of the acceleration of gravity, or %g) that must be used in earthquake-resistant design. Such documents include the International Building Code (IBC), which in Utah replaced the Uniform Building Code (UBC) in January 2002, for buildings; the American Association of State Highway and Transportation Officials (AASHTO) bridge design specifications, for highway bridges; and the Utah State Dam Safety rules for dams. In each, minimum levels of ground shaking that must be used in design are given, and the source(s) of the information is specified. Some require "deterministic" analyses, which consider a maximum ground-shaking level or level resulting from a particular specified scenario earthquake, whereas others require "probabilistic" analyses which consider the ground motions expected at a specified annual exceedance probability from all possible sources. Because earthquake ground-shaking evaluation is a complicated and evolving discipline, many constantly updated products are available for various applications. The purpose of this brochure is to identify for structural engineers, architects, building officials, planners, transportation engineers, geotechnical consultants, dam owners/operators, and other design professionals the sources of earthquake ground-shaking information in Utah and to describe their respective uses.




U.S. Geological Survey map of Utah (12/2002) showing 0.2 sec. spectral acceleration (%g) with a 2% probability of exceedance in 50 years; IBC maximum considered spectral response acceleration maps used in design are based on USGS maps.

## United States Geological Survey Probabilistic Maps

Whereas design under the UBC was based on a seismic zonation map in the code giving seismic coefficients for each zone, the current editions of the IBC and AASHTO bridge design specifications give appropriate design values based on maps by the U.S. Geological Survey (USGS) National Seismic Hazard Mapping Program (Frankel and others, 1996). USGS maps show peak horizontal ground accelerations and horizontal spectral accelerations for 0.2-, 0.3-, and 1.0-second periods. Maps of these parameters were made for three annual exceedance probabilities (10, 5, and 2 percent probability of exceedance in 50 years, or about 500-, 1,000-, and 2,500-year average return periods, respectively). The maps are updated periodically, and the most current maps can be obtained from the USGS website (http://geohazards.cr.usgs.gov/eq/index.html) based on zip code or latitude-longitude. The values are for a uniform rock site condition (considered to be site class B in the IBC) and must be adjusted for other geologic site conditions to determine final accelerations. The USGS values for an appropriate annual exceedance probability, corrected for site conditions, can also be used to determine appropriate minimum ground motions in liquefaction and earthquake-induced landslide analyses.



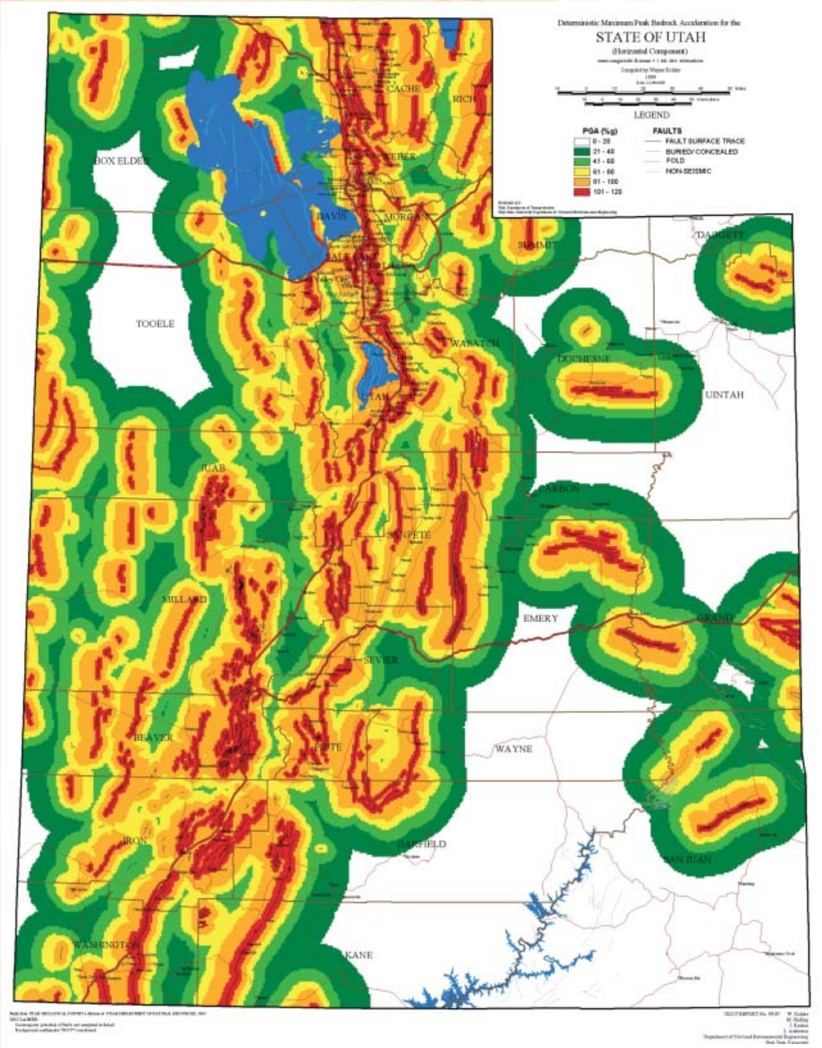

URS Corporation map of the Salt Lake Valley showing 0.2 sec. spectral acceleration (%g) with a 2% probability of exceedance in 50 years.

## URS Corporation Probabilistic and Scenario Maps

URS Corporation, in cooperation with the Utah Geological Survey, University of Utah Seismograph Stations, and Pacific Engineering and Analysis, has completed a suite of 9 maps (printed at 1:75,000 scale; six probabilistic and three scenario) for the Salt Lake Valley showing contours of peak horizontal accelerations and 0.2- and 1.0-second horizontal spectral accelerations (Wong and others, 2002). The two sets of three probabilistic maps are for the 10 and 2 percent probability of exceedance in 50 years (500- and 2,500-year average return periods, respectively), and the set of three scenario maps is for a magnitude 7.0 earthquake on the Salt Lake City segment of the Wasatch fault. One major difference between these maps and the USGS maps is that the URS maps account for generalized site response in the ground-motion contours and show actual expected ground motions, whereas the USGS maps are for a uniform site class and must be adjusted manually for site effects. Therefore, the URS maps illustrate the predicted effects of geologic site conditions on ground accelerations. Neither the URS or USGS maps consider near-fault, topographic, or basin effects.

The URS maps should not be used in engineering design because they have not been adopted in any codes or by any regulatory body. The maps are designed mainly for use in emergency-response planning, HAZUS loss estimations, and earthquake scenario development, with the understanding that accelerations are only a gross indication and not the best measure of likely damage to existing buildings. However, because the URS maps represent a state-of-the-art regional analysis, comparison of these maps with final design ground motions is useful to understand code performance levels and identify future research needs to explain differences. The maps and accompanying report are available in the Natural Resources Bookstore (UGS Miscellaneous Publication MP-02-05).

---

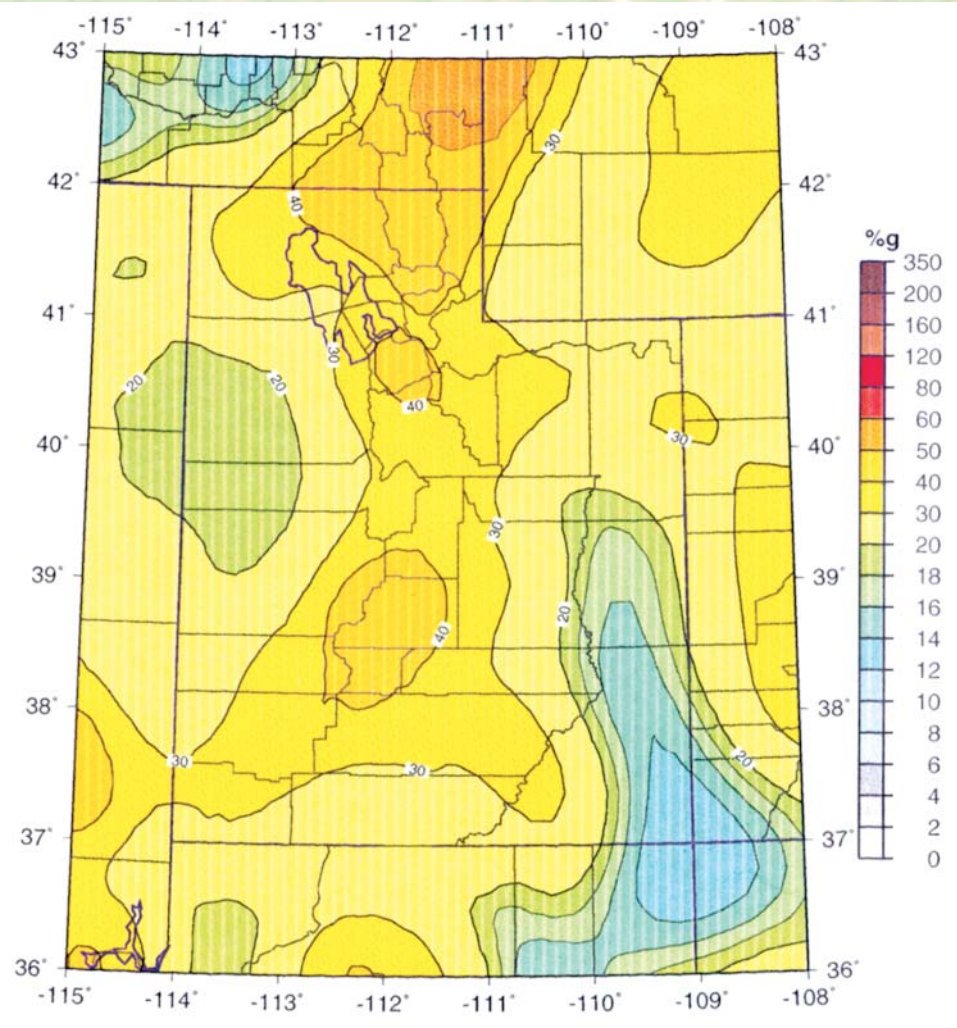



Utah State University deterministic map of Utah showing peak horizontal ground acceleration (%g) using mean magnitude and mean+one standard deviation ground motions using the Abrahamson and Silva attenuation relation.

## Utah State University Deterministic Maps

For certain types of structures (critical buildings, bridges, dams) and for comparison to probabilistic ground motions, a deterministic maximum expected ground-shaking level is important. For design purposes, this ground-shaking level requires site-specific studies to identify and characterize major nearby earthquake sources, usually faults, which yield the highest accelerations at the site. To estimate maximum peak horizontal and vertical ground accelerations from individual fault sources, Utah State University (USU) has completed a set of GIS maps (scale 1:1,000,000) showing major fault sources and deterministic ground motions predicted from the largest expected earthquake on each source (Halling and others, 2002). These maximum magnitudes are estimated based on length of fault rupture and slip type (generally normal, dip-slip motion in Utah) expected in an earthquake. Three sets of maps are presented using three different attenuation relations, one of which is specific to extensional tectonic regimes as found in Utah, and two others for comparison.

As in the USGS probabilistic maps, the USU deterministic maps assume a uniform site condition (rock/soft rock, depending on the site condition used in each attenuation relation) and therefore do not consider site effects. The maps are not intended for design, but rather for use in comparing with results of probabilistic analyses or for initial screening of sites to identify significant earthquake sources for site-specific study. The maps




U.S. Geological Survey map of Utah (12/2002) showing 5,000-year "background" peak horizontal ground acceleration (%g).

and report are available in the Natural Resources Bookstore as UGS Miscellaneous Publication MP 02-11. A CD is provided for GIS users to produce custom maps for individual or groups of fault sources for each attenuation relation using various statistical parameters (mean and mean + 1 standard deviation values for both magnitude and peak ground motions) for both vertical and horizontal ground motions.

Only mapped fault sources are considered in preparing these maps, that is, no “background earthquake” (generally less than or equal to M6.5) from a fault not on the Quaternary Tectonics Map of Utah (Hecker, 1993) is modeled. In areas generally more than several tens of miles from the nearest known fault, the maximum ground-shaking level may be from the “background earthquake.” For dams, the Utah Division of Water Rights Dam Safety Section requires determination of the maximum credible earthquake (MCE) ground-shaking hazard at a dam site. To determine the “background earthquake” ground-shaking level, a map specially prepared by the USGS showing the 5,000-year return period peak horizontal ground acceleration from background source zones and historical seismicity only (no faults) is used. Values from this map are available at the Division of Water Rights website (http://waterrights.utah.gov/daminfo/default.htm) on the Dam Inventory basic-data screen for each dam. To determine the design MCE ground motion, the deterministic peak horizontal ground acceleration from nearby fault sources is compared to that from the “background earthquake.” The higher of these two values represents the MCE acceleration used as a design input to the stability/deformation analysis of the dam.

## References

Frankel, Arthur, Mueller, Charles, Barnhard, Theodore, Perkins, David, Leyendecker, E.V., Dickman, Nancy, Hanson, Stanley, and Hopper, Margaret, 1996, National seismic-hazard maps – documentation June 1996: U.S. Geological Survey Open-File Report 96-532, 110 p., website: http://geohazards.cr.usgs.gov/eq/index.html.

Halling, M. W., Keaton, J.R., Anderson, L.R., and Kohler, Wayne, 2002, Deterministic maximum peak bedrock acceleration maps for Utah: Utah Geological Survey Miscellaneous Publication MP 02-11 (in cooperation with Utah Department of Transportation, UDOT Report UT-99.07), 57 p.

Hecker, Suzanne, 1993, Quaternary tectonics of Utah with emphasis on earthquake-hazard characterization: Utah Geological Survey Bulletin 127, 157 p.

Wong, Ivan, Silva, Walter, Olig, Susan, Thomas, Patricia, Wright, Douglas, Ashland, Francis, Gregor, Nick, Pechmann, James, Dober, Mark, Christenson, Gary, and Gerth, Robyn, 2002, Earthquake scenario and probabilistic ground shaking maps for the Salt Lake City, Utah, metropolitan area: Utah Geological Survey Miscellaneous Publication MP 02-05, 50 p.

Cover photos: Damage to an unreinforced masonry building and older highway overpass in the 1994 M6.7 Northridge earthquake in Los Angeles, California.

USSC

Published by the Utah Seismic Safety Commission, 2003

Additional copies available from the Utah Geological Survey at the Natural Resources Bookstore, 1594 W. North Temple, Salt Lake City, UT 84116.