

U.S. Approach to Share Seismic Awareness, Hazard Assessment and Mitigation Practices with a Larger Universe of Water and Wastewater Utilities

David Goldbloom-Helzner and Craig A. Davis

ABSTRACT

More than 143 million Americans, almost half the population of the United States, live in areas that are vulnerable to earthquakes. The West Coast is particularly susceptible, but earthquakes can happen almost anywhere. For example, in the Central United States, the New Madrid Seismic Zone is a significant threat to eight states. For a community, water and wastewater utilities are critical lifelines and with tens of thousands of utilities located across the country, many are in earthquake hazard areas.

The U.S. Environmental Protection Agency (EPA) wants vulnerable utilities to be aware of this earthquake hazard and the potentially devastating impacts to public health and the environment. A number of large and some medium-sized water utilities have been at the forefront of research efforts and have already implemented earthquake mitigation measures. However, awareness of the threat is much more sporadic at most other utilities. Also, because of the catastrophic nature of earthquakes and the sometimes substantial costs for resilience, utilities may be discouraged to conduct hazard assessments and implement mitigation measures. So how can less informed small, medium, or even large water and wastewater utilities build resilience to earthquake hazards?

The EPA's Office of Water has a mission to help water and wastewater utilities prepare for, mitigate, respond to and recover from various hazards, including earthquakes. With the assistance of an Advisory Review Team composed of utilities, water associations, federal agencies and state mitigation officers, the EPA developed a suite of earthquake resilience products to share lessons learned to a larger universe of utilities. This suite of products includes:

- Earthquake Resilience Video.
- Earthquake Resilience Guide.
- Earthquake Interactive Maps.

The products were based on the latest research by water and earthquake experts. Additionally, the products were designed for water utilities that are located in earthquake-prone areas, but have not yet taken steps to understand their seismic hazards or taken steps to address them. The products also were designed to be easy-to-use and formatted so that best practices can be accessed with only a few clicks. The EPA has also developed an outreach strategy for communicating and sharing these products with utilities prone to earthquake hazards. The earthquake resilience products are available through the EPA's water utility resilience website [<https://www.epa.gov/waterutilityresponse>].

David E. Goldbloom-Helzner, Physical Scientist, U.S. Environmental Protection Agency, 1200 Pennsylvania Ave, NW, Mailcode 4608T, Washington D.C. 20460.

Craig A. Davis, Waterworks Engineer, Resilience Program Manager, Los Angeles Department of Water and Power, 111 N. Hope Street, Room 1345, Los Angeles, CA, 90012

NATIONAL APPROACH FOR EARTHQUAKE RESILIENCE FOR THE WATER SECTOR

More than 143 million Americans, almost half the population of the United States, live in areas that are vulnerable to earthquakes. The West Coast is particularly susceptible, but earthquakes can happen almost anywhere. For example, in the Central United States, the New Madrid Seismic Zone is a significant threat to eight states. For a community, water and wastewater utilities are critical lifelines and with tens of thousands of them located across the country, many are in earthquake hazard areas. Water and wastewater utilities are particularly vulnerable to earthquakes due to their extensive networks of above and below ground pipelines, as well as other facility assets like pumps, tanks, administrative and laboratory buildings and reservoirs (Figure 1).



Figure 1: Damaged Clarifier

A number of large and some medium-sized water utilities have been at the forefront of research efforts and have already implemented earthquake mitigation measures. However, awareness of the threat is much more sporadic at most other utilities. Also, because of the catastrophic nature of earthquakes and the sometimes substantial costs for resilience, utilities may be discouraged to conduct hazard assessments and implement mitigation measures. So how can less informed small, medium, or even large water and wastewater utilities build resilience to earthquake hazards?

The U.S. Environmental Protection Agency (EPA) wants vulnerable utilities to be aware of this earthquake hazard and the potentially devastating impacts to public health and the environment. EPA's Office of Water has a mission to help water and wastewater utilities prepare for, mitigate, respond to and recover from various hazards, including earthquakes. If water and wastewater utilities understand the threat of earthquakes and the potential impacts to both their infrastructure and the community, utility owners and operators can make more informed decisions regarding earthquake mitigation options (Figure 2). While requiring financial investment, earthquake resilience and mitigation projects can significantly reduce or even prevent much costlier damages and economic impacts from future earthquakes. Also, the faster a water or wastewater utility recovers from an earthquake, the faster the community it serves can recover. Because of the factors above, the EPA began to consider developing a national approach to share seismic awareness, hazard assessment and mitigation practices with a larger universe of water and wastewater utilities.



Figure 2: Mitigation for Basin

In addition, the timing seemed right for developing such an approach. The EPA spoke with and obtained support from government stakeholders in earthquake resilience, including our federal partners including the U.S. Geological Survey (USGS) as well as state partners representing water primacy agencies, state geological agencies and state hazard mitigation officers. The EPA's efforts were consistent with other associated federal activities, notably the Federal Earthquake Risk Management Standard that governs federal facilities. Also, over the last several years, certain water and wastewater utilities have established best practices for earthquake resilience, although the dissemination of this information was somewhat limited. When the EPA reached out to small utilities located in earthquake vulnerable areas (Figure 3), there was generally an enthusiastic response for the EPA to provide technical assistance and tools for earthquake resilience. This sentiment was best represented by a small water utility in western Tennessee that said that the EPA's earthquake resilience guidance



Figure 3: Partnership Approach

“is long overdue and I am happy EPA recognizes this very real threat.” Overall, there seemed to be a strong interest in a national approach to address earthquake resilience for water and wastewater utilities.

After consideration, the EPA decided to develop a national approach that includes:

- A series of earthquake resilience products.
- Targeted outreach efforts to the water sector.

EARTHQUAKE RESILIENCE PRODUCTS

To help develop earthquake resilience products, the EPA established an Advisory Review Team composed of utilities, water associations (e.g., Association of State Drinking Water Agencies and American Water Works Association), federal agencies (e.g., USGS) and state hazard mitigation officers. The Review Team included water utilities that are leaders on earthquake resilience (e.g., Los Angeles Department of Water and Power and East Bay Municipal Utilities District, California) as well as small utilities (e.g., Mount Pleasant Waterworks, South Carolina) that might be users of the products. The EPA developed several products to share lessons learned to a larger universe of water utilities. These include:

- Earthquake Resilience Video.
- Earthquake Resilience Guide.
- Earthquake Interactive Maps.

The target user group was comprised of small and medium utilities that are located in earthquake-prone areas, but have not yet taken steps to understand the hazard or taken steps to address them.

The products were based on the latest research and efforts by water and earthquake experts. Additionally, the products were designed with easy-to-use and accessible formats; for example, the video is animated and the guide is clickable to quickly access the needed information. The EPA is currently in the process of communicating and sharing these products to utilities that are vulnerable to earthquake hazards. Below is a description of each product.

Earthquake Resilience Video

This animated video, *Surviving the Quake* (Figure 4), is an awareness video targeted to utilities, but can also be useful for city or town managers and funding agencies. The video shows the types of



Figure 5: Animated Utility

damage that earthquakes can cause to water and wastewater utilities (Figure 5), as well as the greater community. The video also discusses the concept of earthquake resilience and the way

that utilities can evaluate the hazard, assess vulnerable assets and implement and fund mitigation measures. Additionally, the video points to the other EPA tools including the Earthquake Resilience Guide and Earthquake Interactive Maps.



Figure 4: Awareness Video

Earthquake Resilience Guide

This Guide (Figure 6) helps water and wastewater utilities to be more resilient to earthquakes. The Guide outlines steps to evaluate the earthquake hazard and mitigate impacts. The three steps include:

- Step 1 - Understand the Earthquake Threat.

This step informs the user about different types of earthquakes (e.g., natural, induced) and ground movements (e.g., shaking, liquefaction, subsistence). It also links the user to the Earthquake Interactive Maps tool which will be discussed later.

- Step 2 - Identify Vulnerable Assets and Determine Consequences.

This step discusses the vulnerability of specific water utility assets to earthquakes, including a characterization of potential earthquake impacts to building structures, pipelines, tanks, reservoirs, pumps, lift stations, wells, treatment facilities and power assets (Figure 7). It also covers how an asset's construction material, design or age can affect its vulnerability. For example, one table shows anticipated earthquake damage to different building structures, while another table assesses earthquake vulnerability of pipeline materials and joint types.

- Step 3 - Pursue Mitigation and Funding Options.

This step contains best practices from water utilities that have used mitigation measures to address the earthquake threat. The user can simply click on photographs to identify mitigation measures and strategies.

Here, the Guide includes numerous tables that list mitigation measures and the relative costs of implementing these measures. Some tables identify mitigation measures for life safety (Figure 8), while others do so for specific utility assets, such as pipes and tanks.

Finally, the step summarizes how to implement and fund mitigation through government funds, capital improvement planning and asset management.

Small and medium utilities, especially those in lesser known earthquake hazard areas like the New Madrid Seismic Zone, will benefit from the information in this Guide. However, the Guide cautions water utilities about proposing major seismic upgrades based solely on this information - a more detailed on-site analysis is recommended.



Figure 6: Homepage of Guide



Figure 7: Manhole Floats from Liquefaction

✓	Mitigation Options for Immediate Life Safety	Cost
1. Protect your employees		
	a. Make sure employees know your emergency response plans and practice emergency action drills.	\$
	b. Maintain emergency generators (seismically certified) at employee locations to help mitigate widespread power outages.	\$\$
	c. Retrofit buildings to prevent collapse of occupied buildings. For seismic protection, follow the ASCE 7 Standard Minimum Design Loads for Buildings and Other Structures (2016) for new buildings and ASCE 41-06 for retrofit buildings. This could be accomplished by adding new seismic bracing or shear walls.	\$\$\$
	d. Anchor equipment (e.g., computers, bookshelves) as well as laboratory equipment and chemical/fuel tanks.	\$
	e. Identify people who can perform post-earthquake building inspections for safety.	\$
2. Protect the public from catastrophic failures of vulnerable storage tanks or reservoirs		
	a. Seismically retrofit water tanks (e.g., anchoring to foundations).	\$\$\$
	b. Strengthen concrete tank walls, replace non-flexible connections, and improve roof structures over large reservoirs.	\$\$\$
	c. For new tank installations in high risk seismic zones, determine if liquefaction or other permanent ground movements are possible. If so, stabilize the foundation to minimize movement. Design the tank height to safely account for sloshing forces during an earthquake.	\$\$\$
3. Plan for emergency public health and firefighting		
	a. Work with community and state officials to develop a plan to provide emergency drinking water.	\$
	b. Develop a plan for emergency sewage capability, including portable or improvised chemical toilets.	\$
	c. Plan for use of temporary bypasses to move wastewater flow away from the public following ground movement.	\$\$
	d. Address high consequence sewers like those that are difficult to repair (e.g., under rivers, highways, or buildings).	\$\$\$
	e. Coordinate with firefighting agencies on a plan for obtaining alternate water supplies if the water system is disrupted. For example, consider swimming pools, reclaimed water, and pressurized seawater.	\$

Figure 8: Mitigation Options for Immediate Life Safety

Earthquake Interactive Maps

The Earthquake Interactive Maps are a series of maps showing natural earthquake hazard, liquefaction, faults, induced earthquakes and earthquake history. Water utilities can zoom into their own location within each of the maps. Examples of the Earthquake Hazard and Liquefaction Maps are shown in Figures 9 and 10, respectively. The Earthquake Interactive Maps help water utilities better understand their seismic hazard, and are based on the latest data from the U.S. Geological Survey and state agencies. Also, the maps present the experiences and stories of

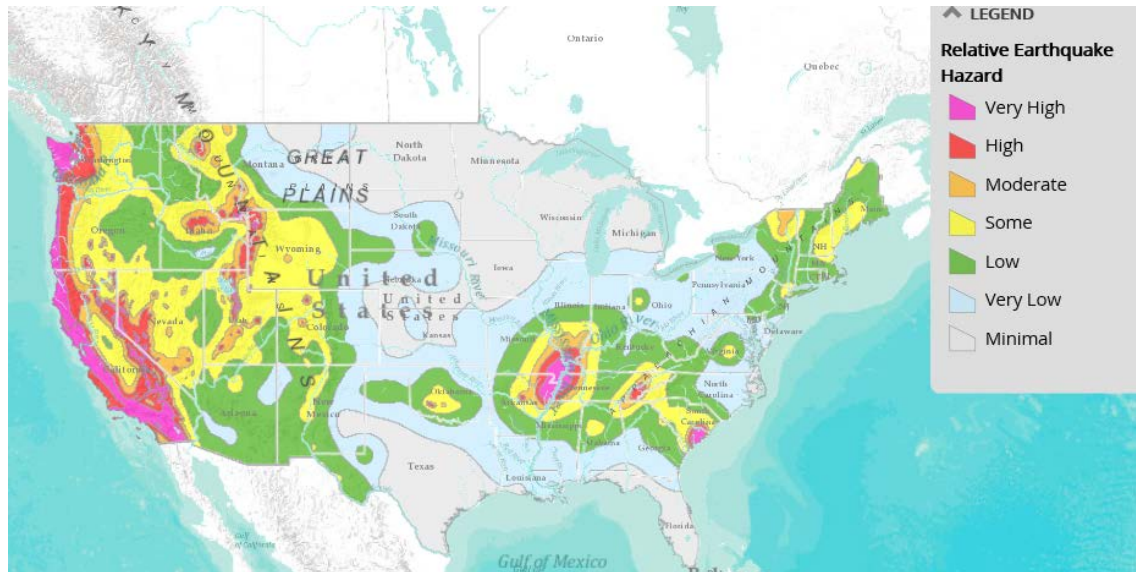


Figure 9: Earthquake Hazard Map from U.S. Geological Survey

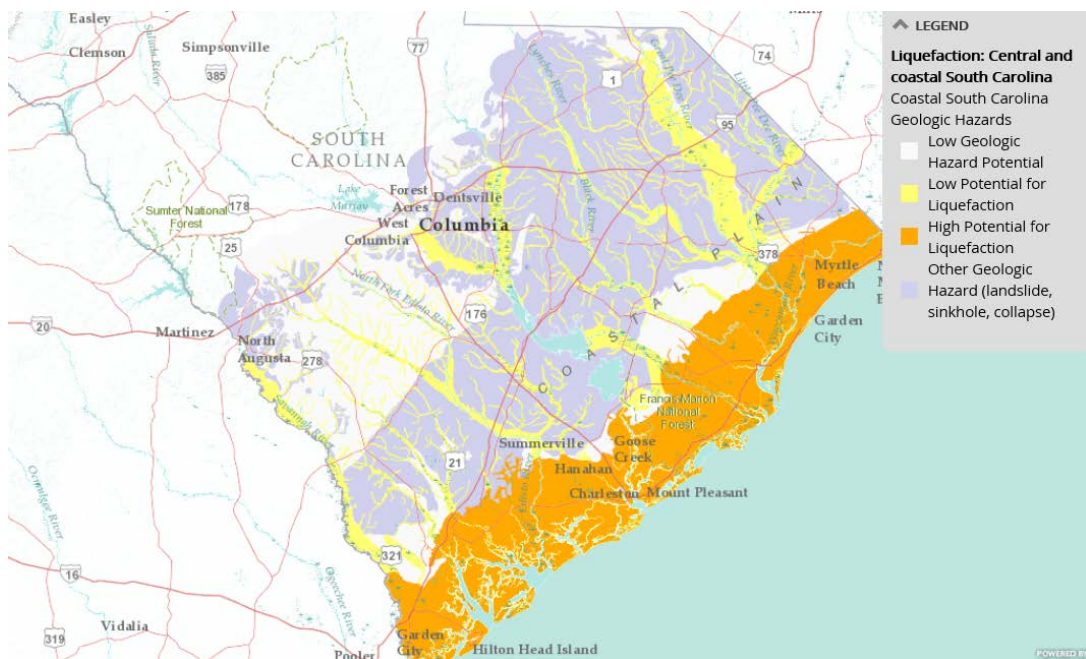


Figure 10: Liquefaction Map of South Carolina

several water utilities that have implemented measures to become more resilient to earthquakes (Figure 11).



Figure 11: Utilities Examples - shared experiences in mitigating impacts to earthquakes

OUTREACH FOR EARTHQUAKE RESILIENCE PRODUCTS AND EFFORTS

EPA has also developed an outreach strategy for communicating and sharing these products with utilities that are vulnerable to earthquake hazards. The strategy includes the following activities:

- Post products on the EPA website.
The earthquake resilience products will be available in late fall 2017 on the EPA's water utility resilience website at <https://www.epa.gov/waterutilityresponse>.
- Conduct expert panel webinar.
The EPA plans to hold a webinar on earthquake resilience for water and wastewater utilities. The Video, Guide and Maps will be introduced, and earthquake resilience experts will present and be available to answer questions from water utility participants.
- Present at conferences.
EPA will actively promote the products at water and wastewater sector conferences, as well as selected earthquake and mitigation conferences.
- Demonstrate liquefaction.
EPA has developed a small scale model to demonstrate the effects of liquefaction on water and wastewater system assets. To be used at conferences and poster sessions, this model demonstration can help communicate the importance of considering liquefaction in mitigation planning.
- Author journal articles.
For water and mitigation trade publications, the EPA plans to write several journal articles on earthquake resilience for the water sector.
- Promote earthquake resilience during visits to selected communities.
The EPA proposes to visit a number of communities in earthquake prone areas like the New Madrid Seismic Zone to promote the earthquake resilience tools and perhaps conduct workshops and site visits to assess the hazard and propose mitigation strategies. The EPA

would facilitate such visits with EPA and FEMA regional staff, state primacy agencies, state mitigation agencies, local political officials and local mitigation and emergency managers, as well as the water and wastewater utility representatives.

- Participate in New Madrid Recovery Exercise in 2018.
The EPA plans to participate and involve the water sector in the Department of Homeland Security New Madrid Recovery Exercise in 2018.

CONCLUSION

The EPA is supporting a national strategy to help small and medium water and wastewater utilities build resilience to earthquakes. Such efforts are key for communities nationwide to prepare for and recover from such disasters. In concert with other water stakeholders, the EPA has developed a suite of easy-to-use products to help water utilities become aware of the earthquake hazard, identify vulnerable assets, and mitigate potential damage and service disruptions. The products include an Earthquake Resilience Video, Earthquake Resilience Guide, and Earthquake Interactive Maps. The EPA also has a robust outreach strategy to promote the use of these products by water utilities and their communities.