

Groundwater Essay The Effect of Earthquakes on Groundwater

In 6th grade, my class went on a field trip to the Edwards Aquifer. It was the first trip of the year and I remember being incredibly excited. When we arrived, our tour guide began to discuss the history of the aquifer and its importance. He also discussed the effect of pollution on the aquifer. At the time, my interest encompassed natural disasters, specifically earthquakes. After our field trip, I started my own research in hopes of finding a correlation between earthquakes and groundwater. I was surprised later on to learn through my own research that groundwater can be heavily affected by earthquakes.

Seismic waves that cause earthquakes have two main effects on groundwater: oscillations and permanent offset. Oscillations are the repetitive movement of the groundwater. One theory made by Cooper and later enforced by Liu stated that seismic waves cause the expansion and contraction of an aquifer, which causes oscillatory pore pressure changes. Pore pressure changes are used to determine the permeability of the rock through a long process that requires extensive knowledge of several theories and techniques, which are difficult to explain. (Falcon) However, Cooper and Liu present an interesting statement that if the aquifer has enough transmissivity, which is the rate of flow through a unit of width of the aquifer, the pressure change causes flow into and out of the well. Testing of the theory resulted in the conclusion that the pore pressure changes in the aquifer are relatively the same size as the fluctuations of the water level. ("Groundwater effects from Earthquakes") In accordance with this, the seismic waves actually induce higher pore pressure changes on the subsurface formations than scientists had previously thought. This typically results in higher chances of pollutants getting into the

groundwater. On the other hand, fault offset is the production of permanent expansion and contraction of surrounding rocks. (USGS) This is typically expected near the earthquake and it is based on the types of wells. Some wells will exhibit offsets, while others won't. For example, a hot-water well will exhibit more offsets than a cool-water well. Furthermore, offsets always occur in the same direction, up or down. Most scientists agree that the permanent deformation that occurs due to the offset depends on the type of aquifer as well. A confined aquifer will most likely show a response to the deformation that was caused. However, the changes that are caused by the permanent deformation typically last until the pressure is in equilibrium with the water table. Otherwise, the pressure can greatly damage the aquifer further increasing risk of pollution in the groundwater. (“Groundwater Effects from Earthquakes”)

Moreover, earthquakes can affect groundwater systems due to the influx of water released from the aquifers after an earthquake. To understand this effect, one needs to understand the organization of the groundwater systems. Groundwater systems typically consist of layers of permeable rock or the aquifer, which are separated by low-permeability layers called aquitards. (Morton) Permeability is the quality of a material that allows fluids to pass through, which is important because it explains the movement of the groundwater and allows for the extraction of groundwater for our purposes. According to a study conducted by Zheming Shi, during an earthquake, the subsurface pressure changes, and new fracture networks open new pathways for groundwater movement. The movement of groundwater can affect its quality after an earthquake. Furthermore, the study showed that an increase in the aquitard's permeability makes the groundwater more susceptible to pollutants. (Morton) By paying attention to the aquitard, scientists can indict the aquifer's vulnerability to pollution, which can allow them to

prevent the contamination of the groundwater. However, if an earthquake were to change the permeability of the aquitard, the groundwater's movement as a result can increase the risk of contamination. (Wiener-Bronner)

After all of this, one must be wondering about the significance of groundwater. Well, groundwater is used for irrigation systems in rural towns and is a form of recharge for streams, lakes and rivers. However, the increasing extraction of groundwater from wells and other resources has left many states in harm's way; specifically California. The popular practice of extracting groundwater to irrigate the agriculture belt of California has put stress on the San Andreas fault resulting in more earthquakes to occur in the region. Scientists believe that an increase in human activity may give rise to the occurrence of earthquakes in vulnerable areas. (Wiener-Bronner) Many people have argued that the pumping of groundwater has only caused small earthquakes and is not as harmful as scientists are making it out to be. Geoscientist Roland Burgmann disagrees, he argues that the magnitude of the earthquakes does not matter as much as the integrity of the fault. The extra small stresses due to the extraction of the groundwater can result in the fault failing. This would be detrimental because it would result in a process called liquefaction, which occurs when the shaking of the earthquake causes the land to behave like quicksand and collapse on itself. (Baker) According to the *Los Angeles Times*, the depletion of groundwater can result in the lifting of the Earth's upper crust, pushing nearby mountains. The constant shift of the mountains would aggravate the fault line and trigger more earthquakes in the area. Continuing with this idea, the removal of groundwater can also reduce the forces that keep the fault together, which results in more small earthquakes especially in dry seasons. (Wiener-Bronner) The growing presence of earthquakes could also contaminate the groundwater.

The collapse of the land means contaminants from common products used by residents could contaminate the water. Additionally, the earthquakes can make it difficult for wells to reach the groundwater, leaving residents without a reliable water source. The depletion of groundwater for our own needs could result in detrimental effects on the residents. (Singh)

On the other hand, in another study by the Ecole Normale Superieure in Paris found that presence of pressurized fluid in surrounding rocks can actually reduce the intensity of earthquakes. Some earthquakes are not naturally made; these are what are called induced earthquakes. Induced earthquakes result from mining, gas and oil extraction, construction of tunnels and geothermal energy. These earthquakes can cause a lot of damage such as derailing projects. (Perrin) According to Marie Violay who runs LEMR (Laboratory of Experimental Rock Mechanics) injecting highly pressurized water into the earth's crust can affect rock equilibria and trigger nearby faults. Although, most induced earthquakes may have low intensity; they are still bothersome to locals. Rock friction generates a large amount of heat that can be absorbed into the surrounding rock. Their experiment showed that the closer the fluid's initial pressure is to the critical pressure of the water, the lower the intensity of the earthquake. (Volay) Francois-Xavier Passelegue, a LEMR researcher, argues that initial fluid pressure is critical especially in areas commonly reached by geothermal activities. (Perrin) These scientists believe that the best way of reducing the intensity of earthquakes is tapping into the groundwater, which is already at the specified pressure required. Ironically, groundwater and earthquakes have an interesting relationship. Earthquakes can damage the water table resulting in contamination of the groundwater. However, the depletion of groundwater can increase the intensity and frequency of earthquakes. (USGS)

This research helped me learn about a completely different topic that I would never have paid attention to. Unfortunately, as of recently, most earthquakes are due to human activity in businesses such as oil and mining, which many people aren't focused on stopping. These activities provide businesses a lot of money at the cost of one of our most important water sources. I learned that it is important to bring awareness to this issue that plagues our consumer society. If we aren't able to at least lessen these activities, we can forever damage a pertinent resource to the survival of our society.

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