**Earthquakes and Injection Wells**

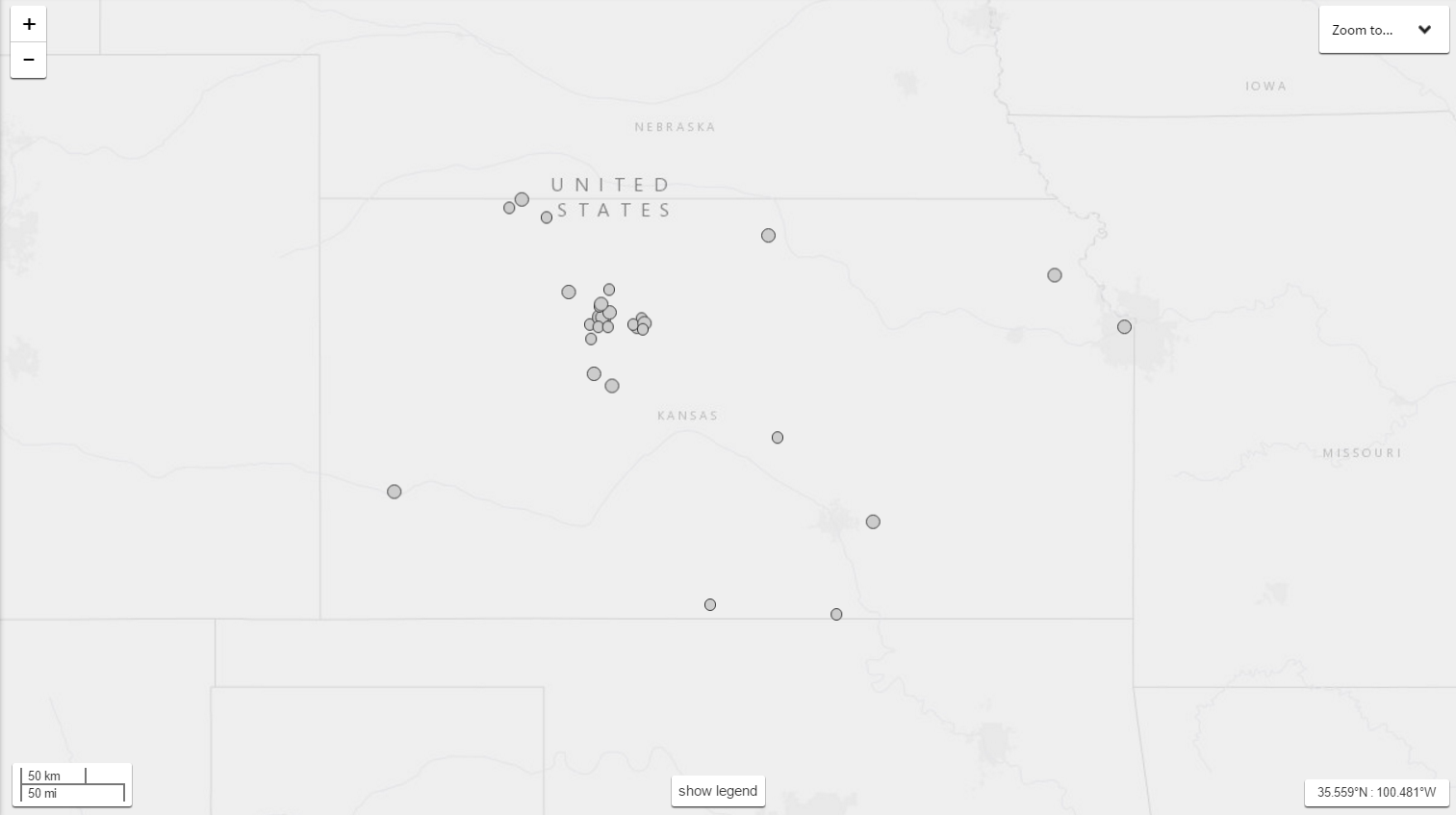
Injection wells are used to place unwanted fluids deep underground into permeable rock formations. There are many uses for injection wells including disposing of waste, storing gases, and disposing of salt water that arises as a byproduct of oil production. Some of this wastewater is produced by the process of fracking, which involves pumping millions of gallons of water deep underground to open fissures and extract the gas or oil from those fissures. Although some of this water will remain deep underground within the fissures, some of it will also come back to the surface as “flowback” [1] that must be dealt with. Some oil companies will reuse a lot of this wastewater such as Marcellus Shale production, out of Pennsylvania, that reuse up to 87 percent of their flowback or wastewater generated [1]. While fracking produces a certain amount of wastewater, most of the wastewater produced comes from the deposits of oil and gas themselves. These deposits often contain sizable amounts of salt water that arises when the oil or gas is removed from its deposit. While it is possible to treat this water, and reuse it like the flowback, most of the water ends up being pumped deep into injection wells.

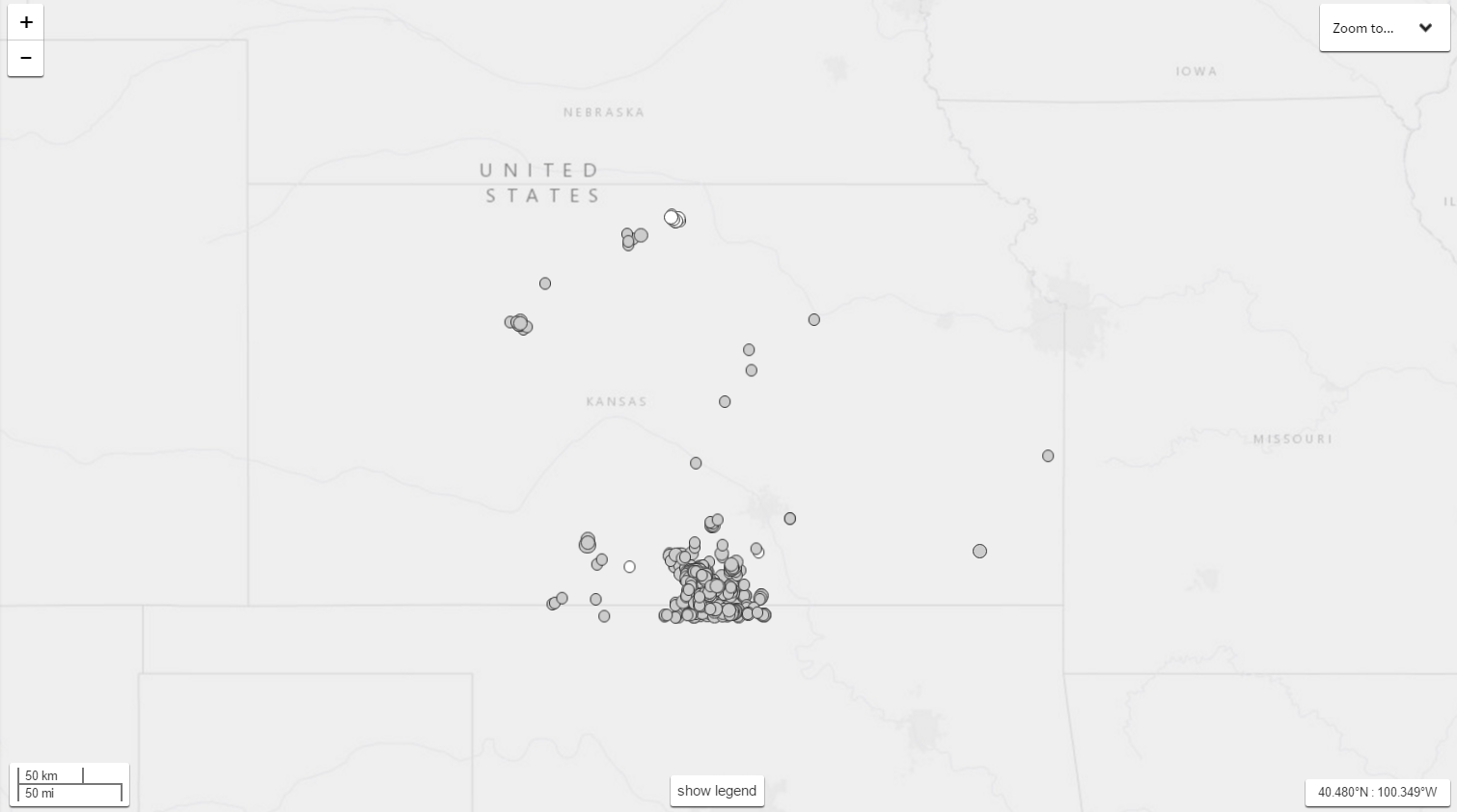
In recent years, amidst the fracking boom in the Midwest and California, scientists have been searching for the link between injection wells and earthquakes. A good number of credible scientists have stated or found that the risk of earthquakes associated with injection wells is low, with the U.S. Geological Survey saying that “only a small fraction of these disposal wells have induced earthquakes that are large enough to be of concern to the public” [2]. The important question to take away from this quote is what the USGS would define as an earthquake large enough to concern the public. The reason this is noteworthy is that in the Midwest the number of earthquakes that they face per year has grown exponentially in the past four years. In Kansas, before 2013 they had only experienced 40 earthquakes, with 6 of those being greater than magnitude 3.5, but since the start of 2013 they have experienced 2,190 earthquakes with 89 of those being of magnitude greater than 3.5. While magnitude 3.5 earthquakes are not the greatest feat, they can still be felt and there is still a very noticeable increase in seismicity in Kansas. Once again in Kansas, before 2013 they had only experienced 1 magnitude 4.0 or greater earthquake, which according to the USGS can be felt indoors by many with walls, windows, and doors being disturbed, while after the start of 2013 they have experienced 15 of said earthquakes. In the eastern region of Oklahoma, before 2013 they had only experienced 483 earthquakes, with 9 of those being of magnitude greater than 4.0, while after the start of 2013 they have had 7,053 earthquakes with 49 of those being of magnitude greater than 4.0. There could be many causes for this increased seismicity, with early scientists finding that injection wells are not linked to these earthquakes, but our group is looking for the correlation, if it exists, by using machine learning to cluster earthquake data on top of a map of wells in Kansas.

**Earthquakes Data**

Our project sets out to create a k-means cluster of the earthquakes on the map of the wells to show the correlations that exist. To do this, we first had to find the earthquakes data. Keegan found a search tool from the USGS Earthquake Hazards Program that would take parameters such as location, magnitude of the earthquake, and how far back to get data for and output a CSV of the earthquakes that occurred within the parameters. For our purposes, Keegan searched through the conterminous United States for earthquakes of magnitude 2.5 or greater that can at least cause minor damage dating back to 1980. Once he had obtained the dataset, he created a simple python program to read in the CSV and arrange each of the columns into its own list i.e. time, latitude, longitude, and magnitude lists. The goal of the program was for the earthquakes data to easily be implemented with the wells data for a k-means cluster. Furthering the work on the program, he also created a simple search tool that will print out the number of earthquakes in the dataset before and after a certain time. He also implemented another search tool that will search for earthquakes that had a magnitude larger than a given magnitude for before and after a specific year. The reason for this was that we can now see how many more earthquakes have happened in recent years than have happened in the past 30 years.

For the two maps below, I used the search tool from the USGS to map out the earthquakes in Kansas before 2013 (the first map) and after the start of 2013 (the second map) [4].





1. <https://energyindepth.org/wp-content/uploads/2015/02/Wastewater-Disposal-Q-and-A1.pdf>
2. <https://www2.usgs.gov/faq/categories/9833/3424_home>
3. <https://earthquake.usgs.gov/learn/topics/mag_vs_int.php>
4. <https://earthquake.usgs.gov/earthquakes/search/>