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NR427: Programming for GIS II
4.28.2023
Final Project

Quantitative and Spatial Data Analysis: Colorado Groundwater Data

Overview:

Short Project: The purpose of this short project is to conduct data analysis on a dataset using the matplotlib and pandas libraries in PyCharm. More specifically, this project will gather summary statistics for the entire dataset, as well as for a given year- 2014. Also, the project will generate figures that illustrate the water level and well depth across elevations for the entire dataset and 2014.

Final Project: The purpose of the final project is to create additional data to give readers a better understanding of wells and groundwater data in Colorado. The script does so by creating maps of wells across the state and incorporating the statistics generated in the short project to inform the spatial analysis component. For the spatial analysis, the script primarily uses the libraries matplotlib, pandas, and geopandas.

Process:

Short Project:

1. Gather data and save a local copy to the working directory, source: https://data.colorado.gov/api/views/jh9r-rskp/rows.csv?accessType=DOWNLOAD&bom=true&format=true
2. Perform some initial data cleaning, filter outliers that would skew the data
3. Get the columns of interest: Well Depth, Water Depth, Elevation
4. Generate summary statistics and figures for the entire dataset
5. Repeat the process to generate summary statistics and figures for the year 2014
6. Write summary statistics to a text file, export plots so they may be displayed elsewhere.

Final Project:

1. Further clean the data from step one in the short project to ensure that it can be processed and plotted using geopandas and matplotlib. (The coordinates in the CSV are read in as a string (latitude, longitude), and must be converted into two separate columns as integers.
2. Import a map of Colorado from a URL to use as a basemap, giving users a better sense of where wells are located within the state.
3. Create a map of wells across the state of Colorado
4. Group wells by the aquifer that they are associated with, and plot wells across Colorado that are colored by their respective aquifer.
5. Create data subsets for wells falling within the 25^{th} and 75^{th} percentile for the categories: ELEVATION, WELL DEPTH, and WATER LEVEL DEPTH, as identified in the summary statistics table provided in the short project results section.
6. Create additional data subsets for these categories for western and eastern Colorado to further explore hypothesis on the spatial distribution of wells in each region of the state for the categories: ELEVATION, WELL DEPTH, and WATER LEVEL DEPTH

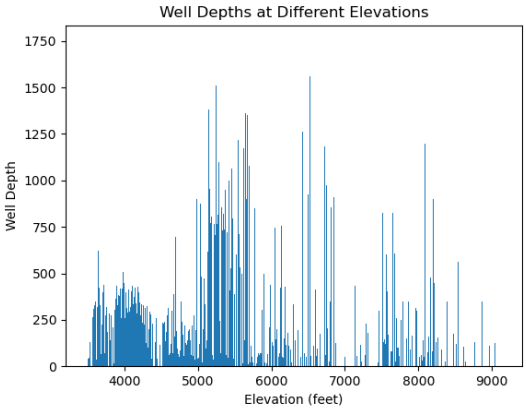
Short Project Results:

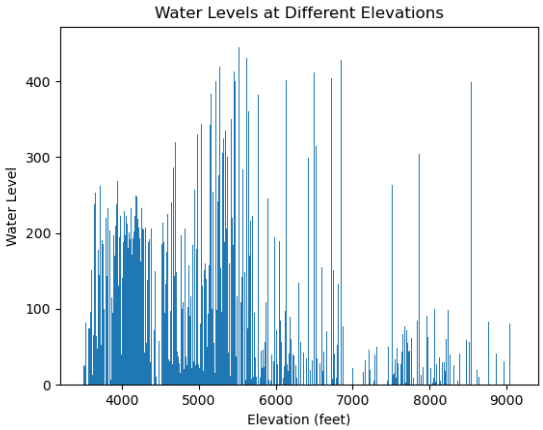
Summary Statistics:

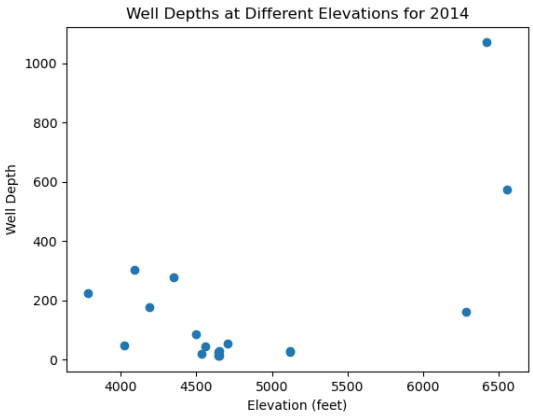
```
Statistics for the entire dataset:
Well Depth statistics:
count    19263.000000
mean       168.905363
std        214.996798
min         10.000000
25%         38.000000
50%         77.000000
75%        250.000000
max       1748.000000
Name: Well Depth, dtype: float64
Water Depth statistics:
count    19263.000000
mean        67.202045
std         78.311843
min          0.100000
25%         13.400000
50%         30.000000
75%        100.900000
max        449.800000
Name: Water Level Depth, dtype: float64
Elevation statistics:
count    19263.000000
mean      5137.134282
std       1202.645527
min       3483.510000
25%       4191.840000
50%       4913.790000
75%       5635.200000
max       9127.560000
Name: Elevation, dtype: float64
```

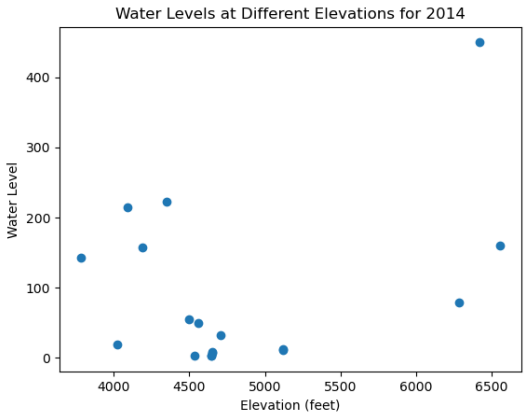
```
Statistics for the year 2014:
2014 Well Depth statistics:
count      18.000000
mean      176.388889
std       266.831548
min        12.000000
25%        27.750000
50%        50.500000
75%       211.750000
max      1070.000000
Name: Well Depth, dtype: float64
2014 Water Depth statistics:
count     18.000000
mean      90.388889
std      117.472474
min        2.400000
25%        8.800000
50%       40.850000
75%      153.475000
max      449.800000
Name: Water Level Depth, dtype: float64
2014 Elevation statistics:
count      18.000000
mean     4824.120000
std       809.886709
min      3779.560000
25%      4385.387500
50%      4646.810000
75%      5016.250000
max      6559.000000
Name: Elevation, dtype: float64
```

Figures:





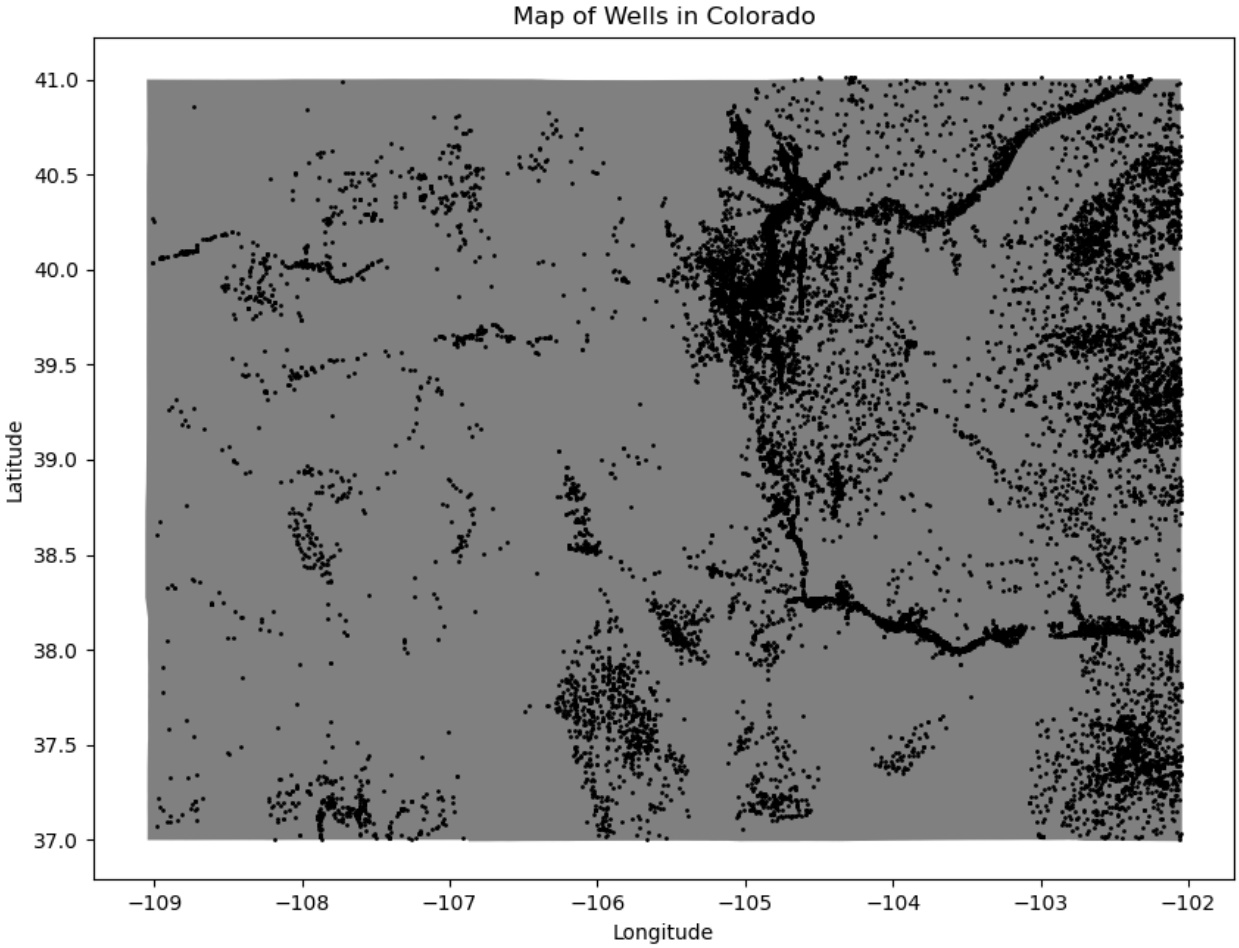




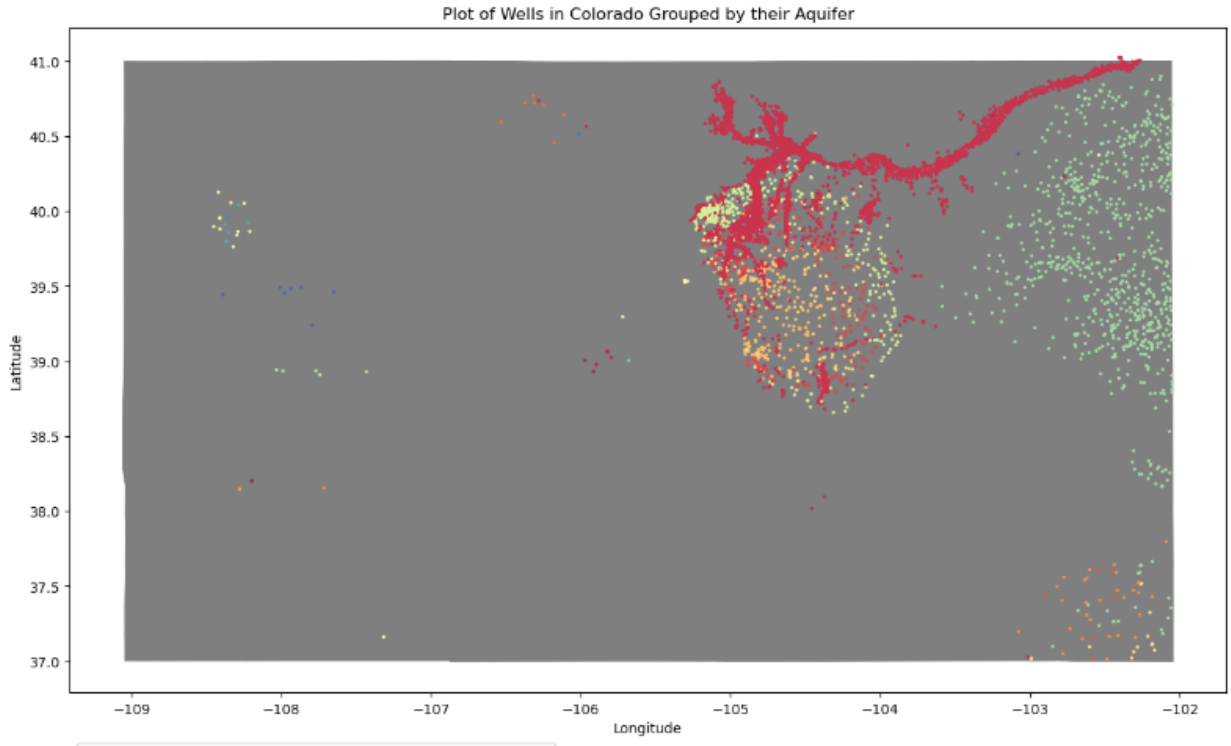
Short Project Conclusion:

This script illustrates a workflow to create and write summary statistics from a CSV dataset to a text file, as well as to generate figures on the data using matplotlib. Because there are coordinates tied to each well in this dataset, a potential further extension of this analysis using geopandas is possible.

Final Project Results:



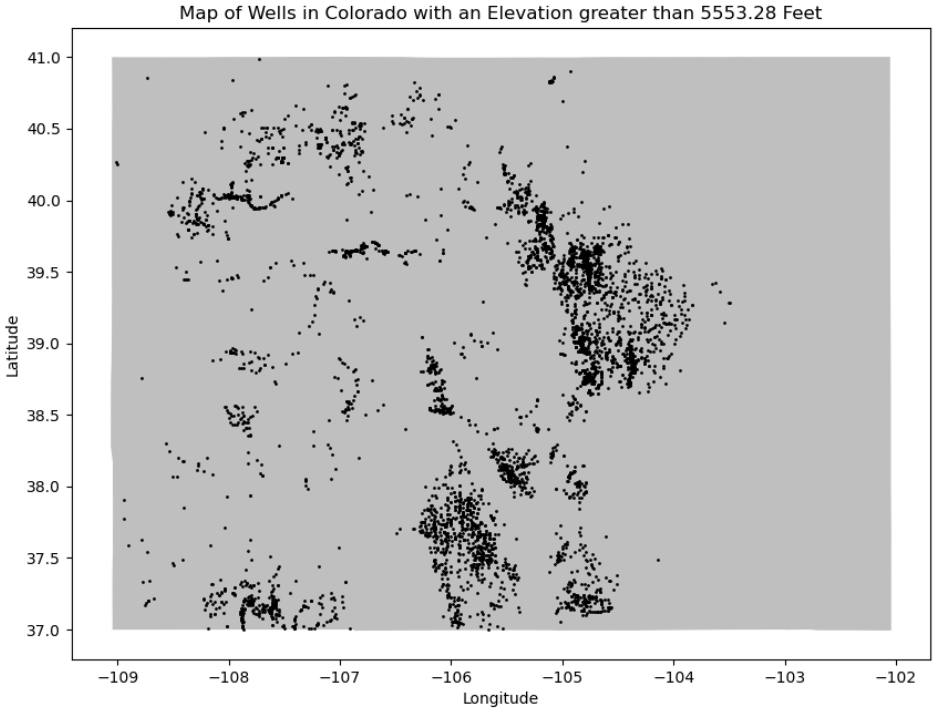
This map shows the general distribution of wells across the state of Colorado. From this map it is clear that wells are generally more concentrated on the eastern side of the state where there is lots of agricultural activity as well as a large aquifer- the Ogallala Aquifer.



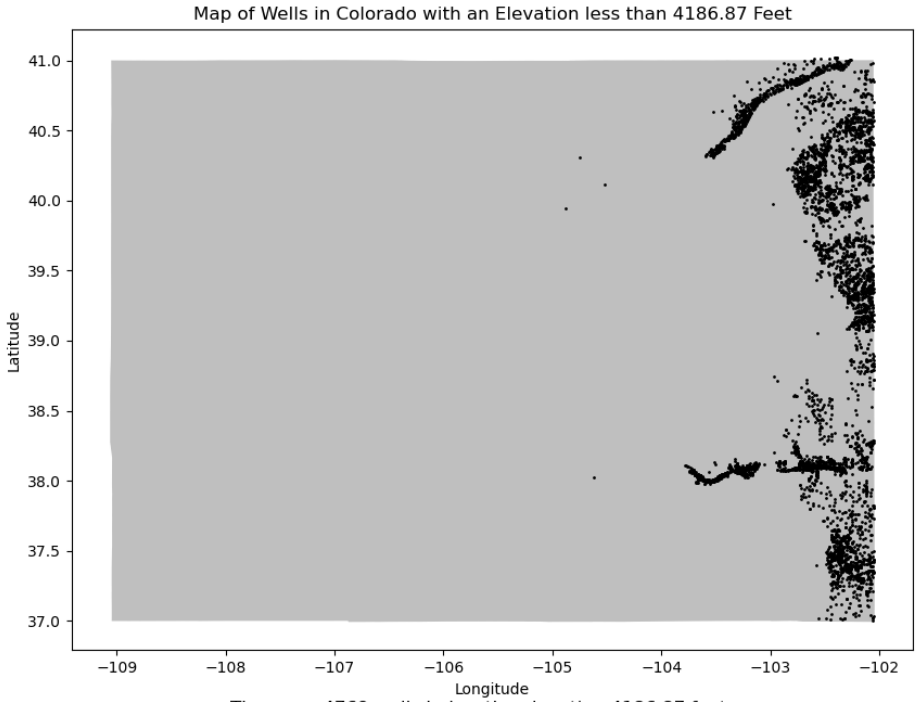
This map illustrates the distribution of wells across the state, grouped by the aquifer that they belong to. One important component that this map highlights is the high number of wells that belong to the Ogallala Aquifer in Eastern Colorado; this aquifer is one of the largest groundwater sources in the world. There are also many wells that are either a part of the Alluvial aquifer, or are tied to unnamed aquifers as indicated by the different shades of dark red.

The next set of maps use the summary statistics text file that was generated in the short project analysis; these plots generate figures based on percentiles for elevation, well depth, and water depth to gain a deeper understanding of the spatial distribution of wells within the dataset by visualizing their location with respect to these variables.

Elevation:



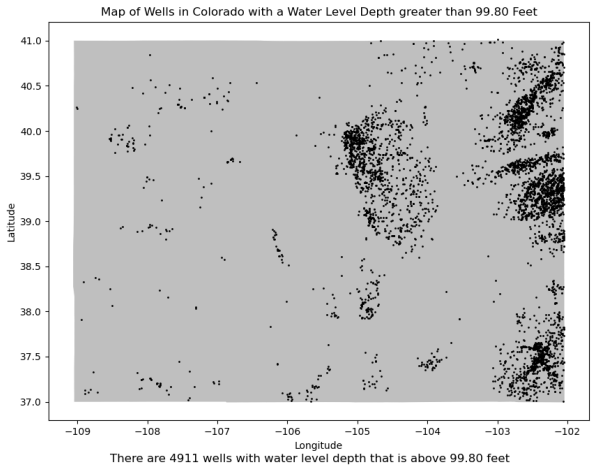
There are 5084 wells above the elevation 5553.28 feet



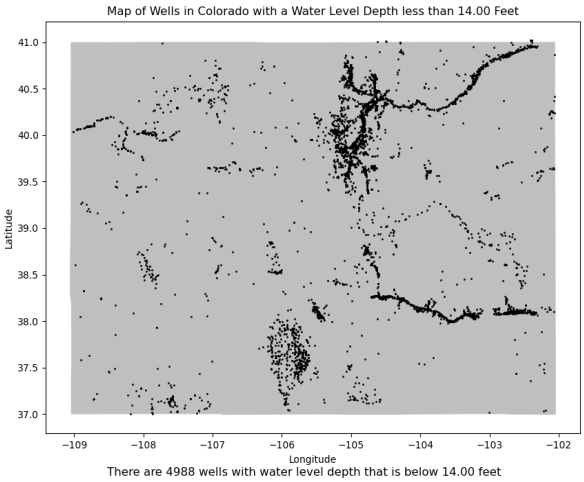
There are 4769 wells below the elevation 4186.87 feet

These maps illustrate how the high elevation wells are in the mountainous western part of Colorado and the low elevation wells are in the eastern plains of the state.

Water Level Depth:

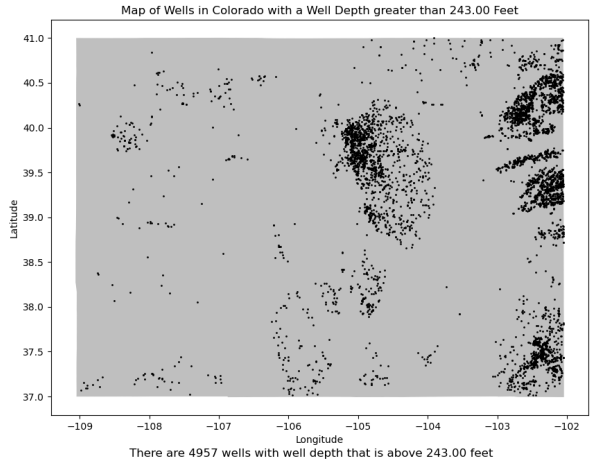


There are 4911 wells with water level depth that is above 99.80 feet

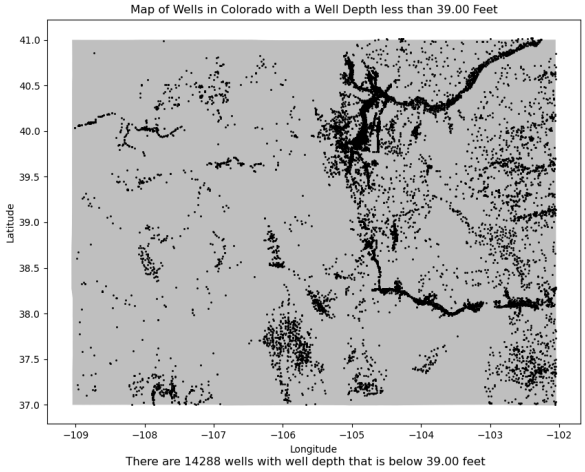


There are 4988 wells with water level depth that is below 14.00 feet

Well Depth:



There are 4957 wells with well depth that is above 243.00 feet

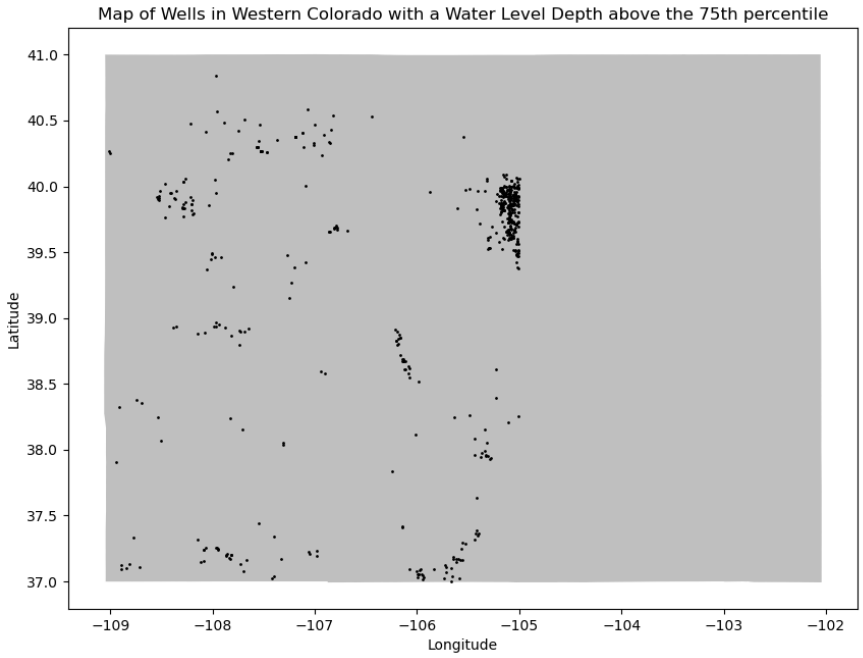


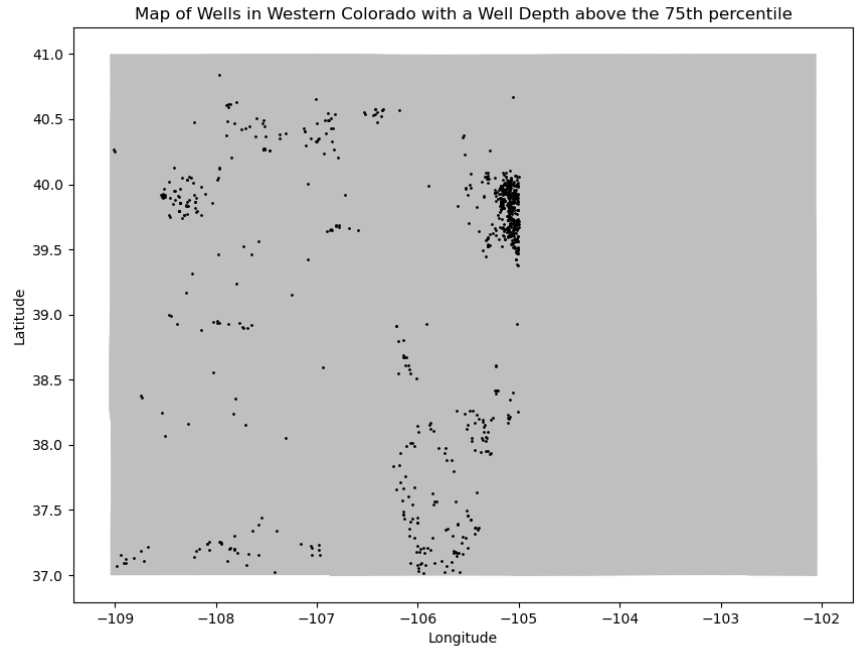
There are 14288 wells with well depth that is below 39.00 feet

These figures further illustrate the interesting characteristics describing the spatial distribution of Colorado wells, which can speak to the water supply in the state. The Ogallala aquifer, one of the largest aquifers in the world partially underlies the eastern plains of Colorado. As these maps indicate, the wells with the highest water levels as well as the deepest wells are also concentrated in this region. Conversely, in the remaining portion of the state moving west, there are more shallow wells and lower water depth.

To support this observation, by isolating the data into eastern and western portions of the state, plotting the well and water data 25th and 75th percentiles for each part can show these outliers. *To recap, the observation above is that wells in western Colorado will generally have lower water level and well depth, whereas wells in eastern Colorado will have higher water levels and deeper wells.* To explore areas where this is not the case, the script below creates plots of wells in western Colorado whose well depth and water levels are above the 75th percentile, and wells in eastern Colorado whose well depth and water levels are below the 25th percentile.

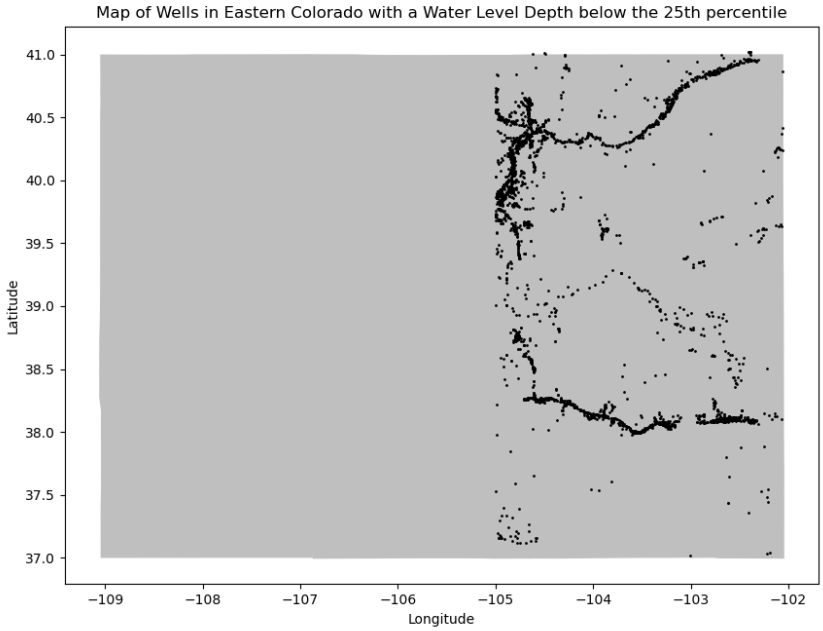
Western Colorado outliers for well depth and water level depth:

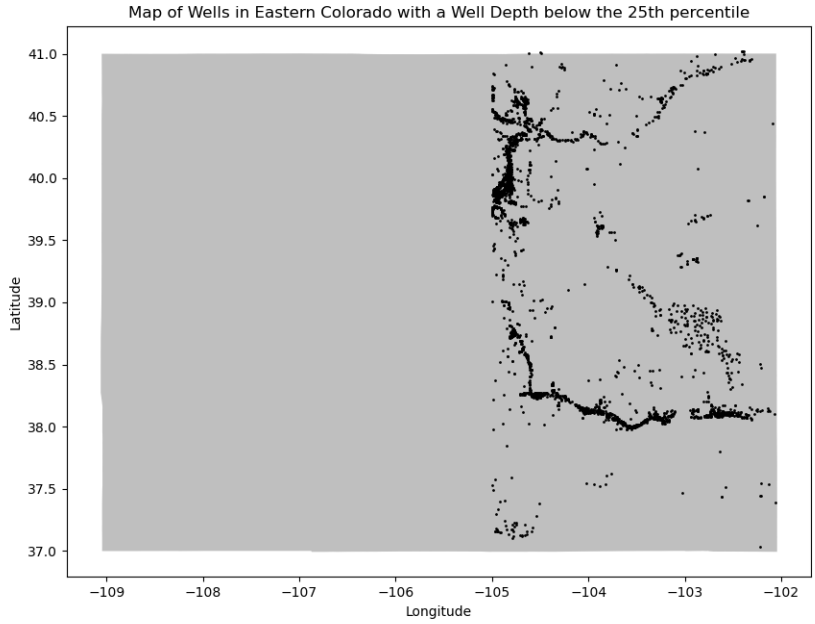




These maps illustrate wells with high water and well depth in western Colorado. The concentrated area with many wells is near the Denver metro area, which still relatively eastern. Moving further west, the number of wells with high water levels / well depth becomes more diffuse.

Eastern Colorado outliers for well depth and water level depth:





These maps illustrate wells with low water and well depth in eastern Colorado; there are many more wells shown on these maps, which is because there are more wells overall on the eastern portion of the state compared to the west. There is a more even distribution between the 25th and 75th percentile for well depth / water depth, whereas in western Colorado, it was very obvious that there were more wells in the 25th percentile for well depth / water depth compared to the number of wells at the 75th percentile.

To recap the results illustrated in the maps of eastern and western Colorado:

For Western Colorado:

- There are 560 wells whose water level depth is above the 75th percentile, and there are 2025 wells whose water level depth is below the 25th percentile.
- There are 813 wells whose well depth is above the 75th percentile, and there are 1557 wells whose well depth is below the 25th percentile.

For Eastern Colorado:

- There are 4320 wells whose water level depth is above the 75th percentile, and there are 2962 wells whose water level depth is below the 25th percentile.
- There are 4143 wells whose well depth is above the 75th percentile, and there are 3281 wells whose well depth is below the 25th percentile.

Final Project Conclusion:

This project analyzed Colorado well and groundwater data through both quantitative and spatial analysis using matplotlib, pandas, geopandas, and several other packages. The results have shown interesting trends on the spatial distribution of well depth, water level depth, and elevation of wells across the state. Most important among these trends is the observation that eastern Colorado tends to have deeper wells, and higher water levels compared to those of western Colorado. This makes sense because the Ogallala aquifer, one of the largest aquifers in the world partially underlies the eastern plains of Colorado. As these maps indicate, the wells with the highest water levels as well as the deepest wells are also concentrated in this region. Conversely, in the remaining portion of the state moving west, there are more shallow wells and lower water depth.