Water Rates in the United States

Prepared By:
Rachel Turner

GIS in Water Resources
Dr. David Maidment

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1.0 Introduction

Managing water rates in the United States is a complex issue that greatly affects the nation's water resources and economy. The cost of water varies across the nation and is driven by many interrelated and competing factors. Water rates are set by utilities in order to meet their needs and achieve certain goals. The objective of this project is to use GIS as a tool to visualize how water rates vary across the United States and, ultimately, to identify key driving factors behind water rates and attempt to draw correlations between various factors and the cost of water.

2.0 Project Overview

2.1 Background

Water rates have increased nationwide by an average of 23% from 2000-2010 and nearly 1/3 of the nation's utilities have increased their rates over 100%, according to a survey by the American Water Works Association. Population increase and population shift toward water scarce areas, as well as aging infrastructure, contribute to this recent increase. The ASCE annual scorecard estimates that over $1 trillion dollars are needed to fix drinking water infrastructure across the nation and that 7 billion gallons of water are lost daily through leaking pipes in the distribution systems.[11]

Many factors affect the variation of water rates in the United States. The cost of water varies from city to city and fluctuates over time. Some major factors that affect water rates include:

- Type of water source
- Local water availability
- Amount of water usage by consumers
- Population
- Climate
- Type of rate structure
- Condition of existing infrastructure
- New, more stringent regulations on water quality
- Cost of treatment

For example, a utility may raise their water rates during prolonged drought, as water availability is low. Also, as the nation's infrastructure is aging, many cities need to replace their old water distribution pipes. Water rates may increase to finance these improvement projects. More stringent drinking water quality regulations may also lead to increased water rates, as the cost of treatment is greater.

2.1.1 Rate Structures

Understanding rate structures is central to the discussion of water rates. Different utilities use different forms of rate structures depending on their needs and goals.

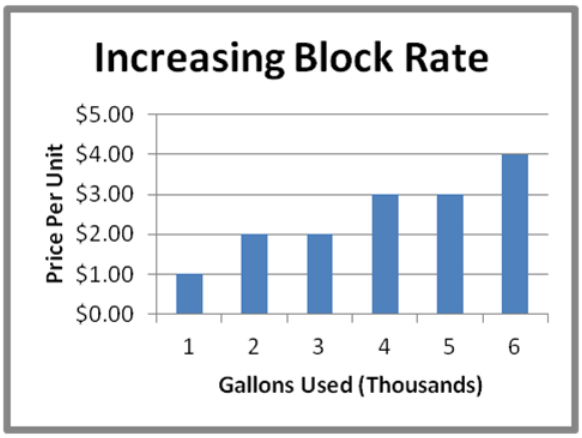

Figure 1: Increasing Block Rate Structure

Most utilities use some form of an increasing block rate structure (**Figure 1**) which charges an increasingly higher unit price for increasing blocks of usage. This structure is designed to promote conservation. It is typically used in combination with a fixed base rate. "Fixed charges generally include the price the customer pays as a base charge to help cover costs for maintaining existing infrastructure and repaying loans and bonds used to build that infrastructure. Variable charges are the price the customer pays per volume of water used, which reflect the costs of providing water, such as costs for chemical treatment to provide safe water and energy to move and deliver water."[23] Thus, the rate structure is closely related to many of the factors that are investigated as part of this project. Other common rate structures[23] include:

- Declining block rate: used primarily in rural areas where water is plentiful
- Seasonal rate: used to encourage conservation during peak use periods
- Drought rate: rates adjusted to encourage conservation depending on the local area's drought level
- Water budget based rate: households are given a "water budget" based on their anticipated needs and charged different rates if they stay within or exceed their budget

Some utilities base their rates in reference to a household's average winter consumption (AWC) instead of actual usage. AWC is the water usage averaged over several winter months (i.e. September-February), and the block structure is used in reference to the AWC throughout the entire year instead of in reference to actual monthly usage. Also, many utilities use a combination of two rate structures, for example, a seasonal, increasing block rate structure.

2.2 Objective

In order to better understand how and why the cost of water varies, GIS is used as a tool to visualize how specific factors individually affect water cost. Ultimately, this project seeks to identify key driving factors behind water rates and to draw correlations between various factors and the cost of water.

Specifically, water rates for a collection of major cities and various controlling factors are mapped in conjunction with each other. Additionally, spreadsheet software is used for tabulation and numerical analysis of the raw data to plot trends between variables and water cost.

3.0 Methodology

3.1 Data Collection

3.1.1 Water Rates and Usage

Prior to mapping and analyzing each location's characteristics and water cost, data was collected for the water rate at each location. First, a representative sample of major U.S. cities was selected. Next, the rate schedule for each city was located, and the cost of water was calculated for a given monthly usage for each rate schedule. This project focuses solely on single-family residential water use.

Water rates depend on water usage. Two water costs were calculated for each location:

1. Cost for a fixed usage of 7,500 gallons/month/household (**Figure 2**)
   - This fixed usage was chosen because it is approximately the national average monthly usage per household.

2. Cost for the average monthly water usage specific to each location

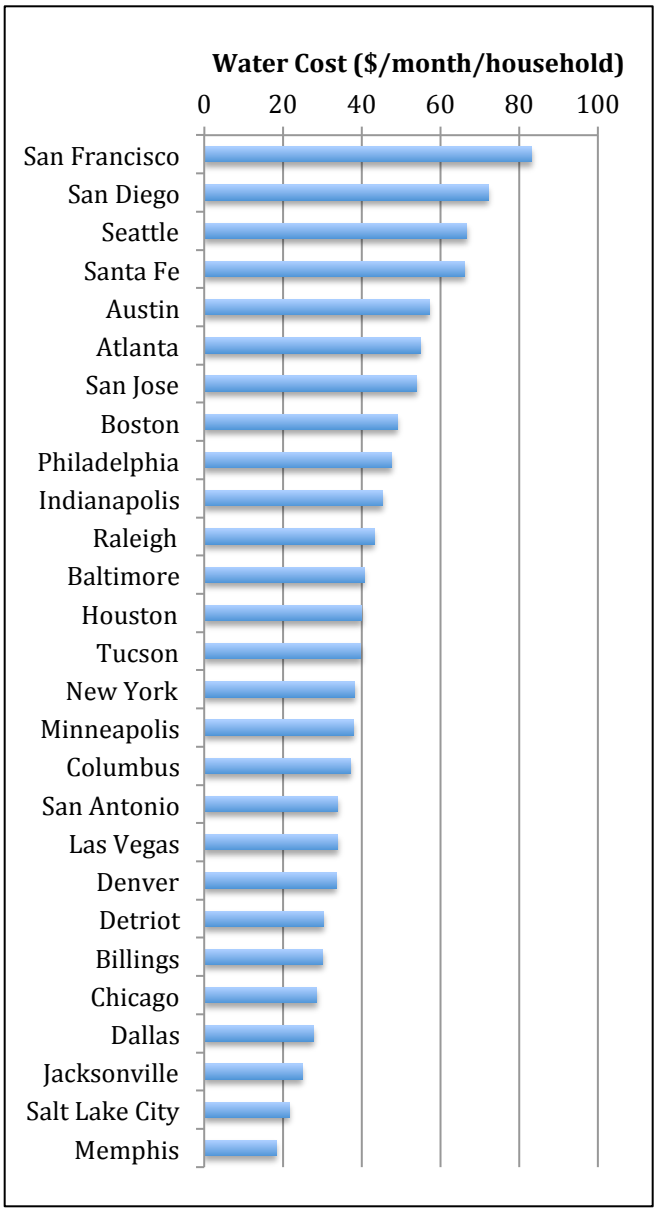

Figure 2: City Ranked Water Rates at Fixed Usage

The USGS *Estimated Use of Water in the United States County-Level Data for 2010*[4] was used to determine average water usage for a given city. From this USGS data, values for total domestic use and population served were used to calculate the average per capita monthly water use.

Water rates are charged per connection, and a single-family household typically has one connection with a 5/8" water meter. Thus, the per capita monthly water use was multiplied by the average number of persons in a household[10] to determine average monthly water use per household.

Each city's current water rate schedule can be found on their utility website and applied with their average monthly water usage to determine the total monthly amount charged for an average single-family residential unit.

3.1.2 Potential Rate-Driving Factors

Data was also acquired for various driving factors such as precipitation, drought, temperature, population, and primary water source. The PRISM Climate Group provides spatial climate datasets for short- and long-term climate patterns. These datasets[7] were used for mapping 30-year average annual precipitation and temperature. Data was also retrieved from the National Oceanic and Atmospheric Administration (NOAA)[1] for specific values of average annual precipitation and temperature for each city. Existing GIS datasets were used for mapping temperature.

Drought intensity maps were found from the National Drought Mitigation Center's U.S. Drought Monitor[5], which is a weekly map of drought conditions based on climate, hydrology and soil conditions, among other data. A week snapshot was chosen that was approximately representative of the year, as the drought map does not change drastically from month to month. Lastly, population density was mapped from existing GIS datasets.

3.2 Data Visualization

3.2.1 Rate Maps

After data collection, the data was imported from Excel into GIS for visualization of rates and their driving factors. First, the cost of water is mapped at constant usage rate (**Figure 3**). This allows for visualization of how the cost of water varies among major cities across the United States.

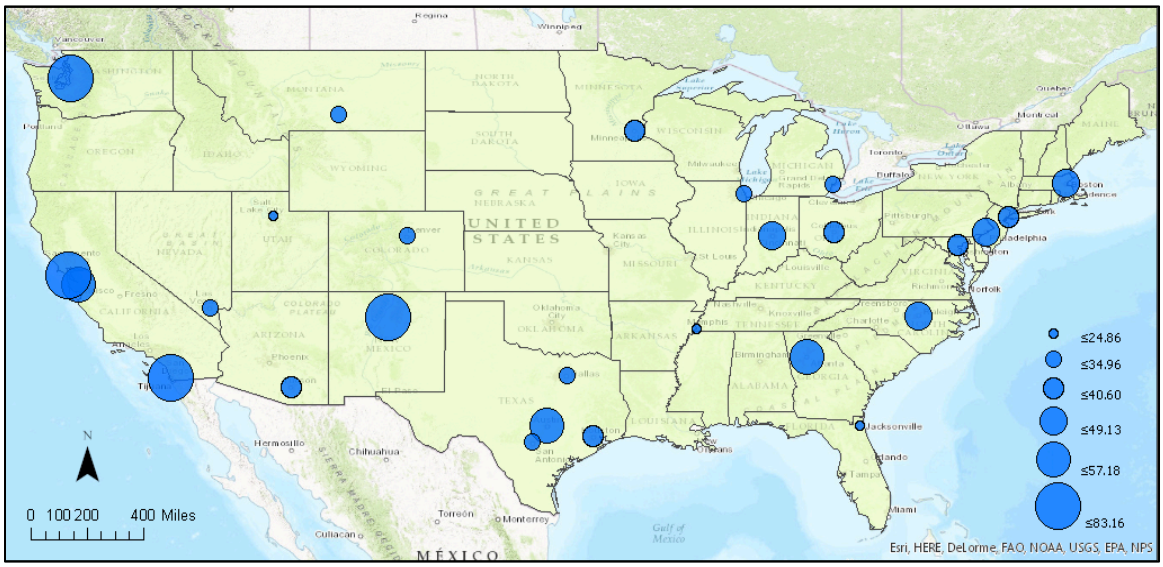

Figure 3: Water Cost ($) at Fixed Usage (7,500 gal/month)

The cost of water was also mapped for the location-specific average water usage with this average usage now incorporated in the water cost (**Figure 4-5**). This shows how a city's water usage affects their cost of water. For example, cities in the northeastern United States use less water per household than most cities in the southern and western regions. As discussed previously, some rate structures are designed to charge more for increasing blocks of usage. This results in a decrease in total water cost in the northeast and an increase in total water cost in the southwest, on average, which can be seen by comparing **Figure 3** and **Figure 5**.

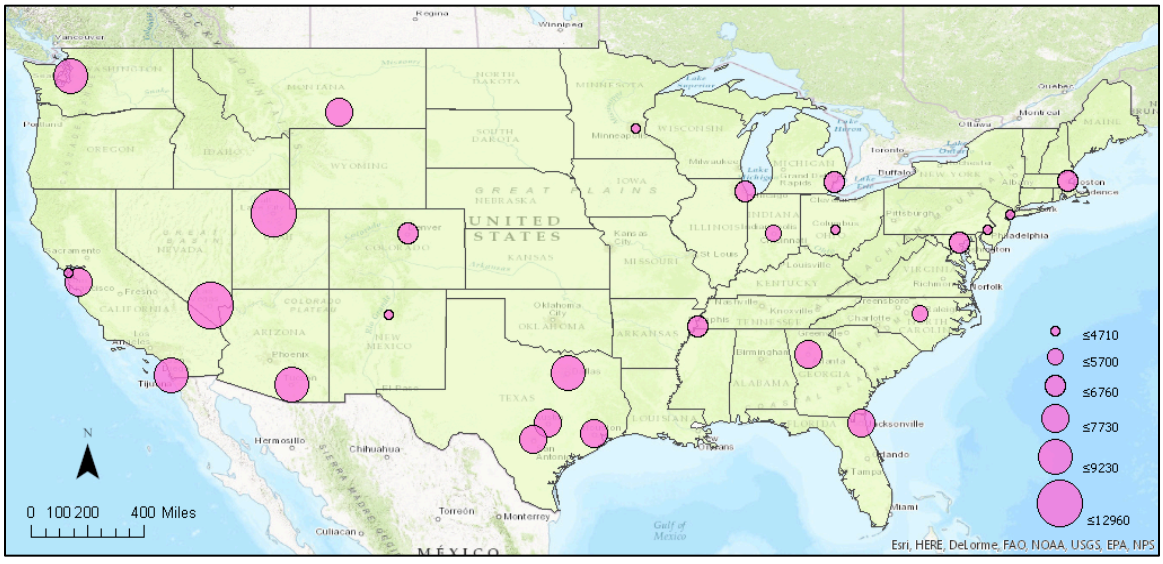

Figure 4: Average Water Usage (gal/month/household)

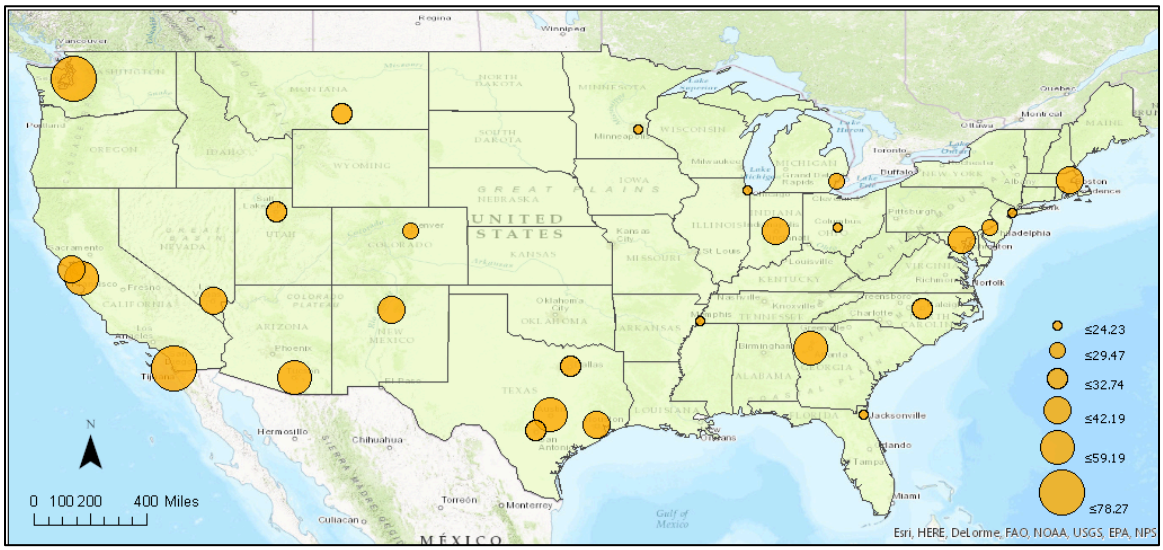

Figure 5: Water Cost ($) at Average Monthly Usage

3.2.2 Map Overlays

Useful comparisons can be made by overlaying water cost over maps of potential driving factors such as precipitation, drought, and temperature. From the map in **Figure 6**, there does not appear to be an obvious trend with precipitation and water rates, but an actual numerical analysis is discussed subsequently in **Section 3.3**.

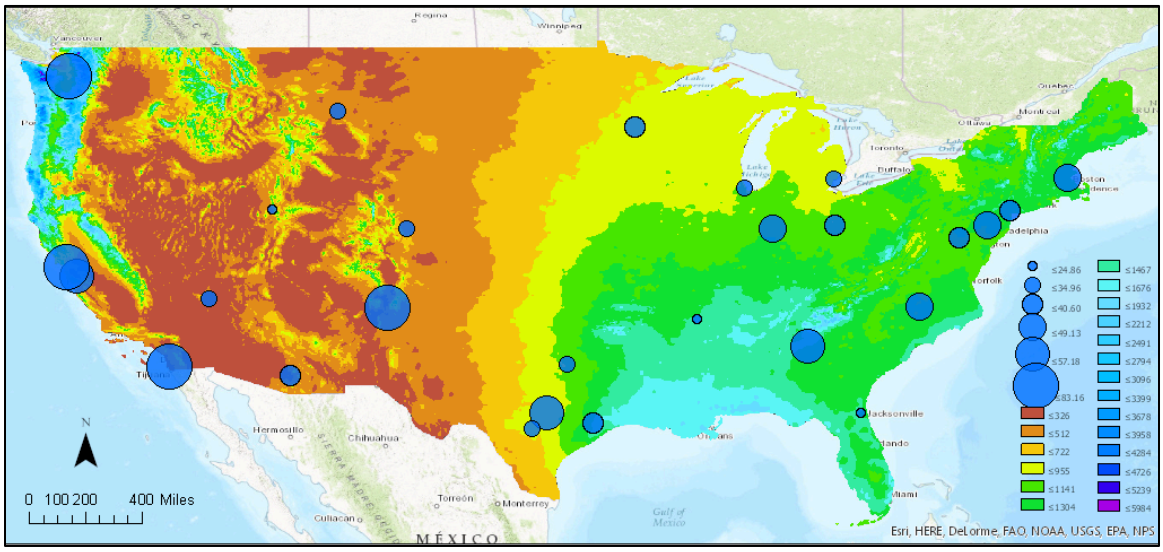

Figure 6: Average Annual Precipitation (inches) and Water Cost ($)

Drought intensity, however, does appear to have a correlation with water cost. As shown in **Figure 7**, areas of extreme drought are shown in red and tend to correspond to higher water costs. This trend agrees with expectations that areas experiencing prolonged drought would potentially increase their water rates to balance supply and demand.

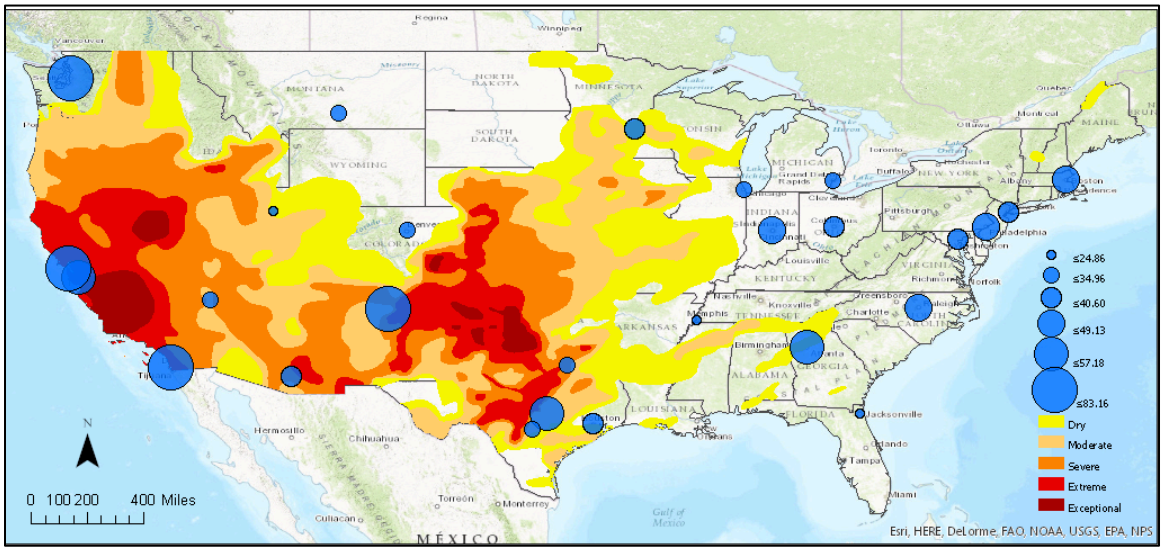

Figure 7: Drought Intensity and Water Cost ($)

Temperature (**Figure 8**) appears to have even less of a correlation than precipitation, as water rates do not correspond with temperature steadily increasing from north to south.

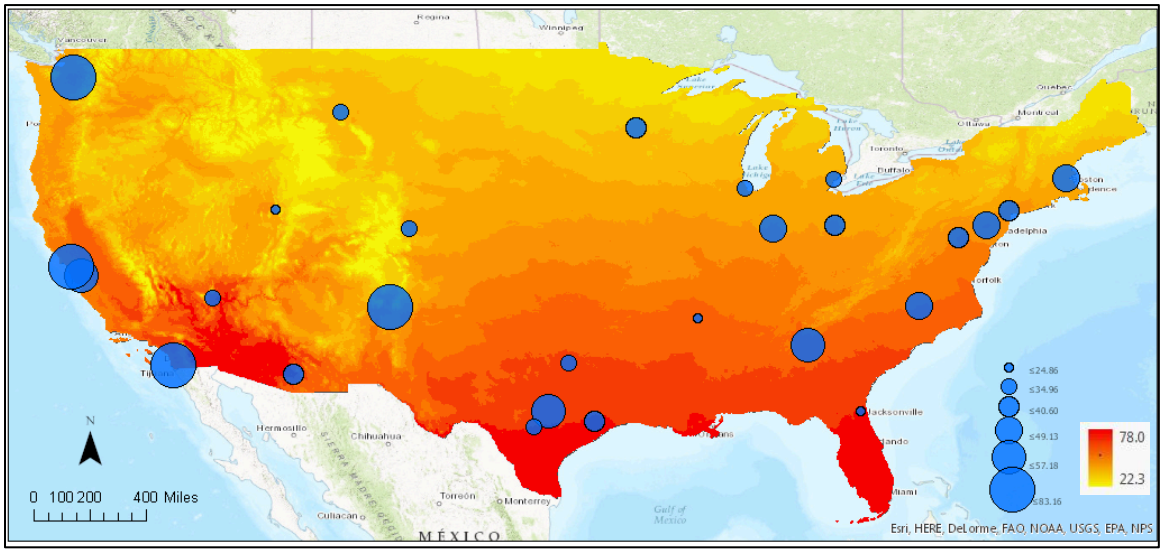

Figure 8: Temperature and Water Cost ($)

3.2.3 Additional Maps

Additional factors were considered such as primary water source and population. As shown in **Figure 9**, most cities use surface water as their primary water source, but many use a fair amount of groundwater to diversify, as well. Therefore, it is difficult to see a direct trend between water source and water cost as sources typically consist of primarily surface water with some groundwater or vice versa. Few cities rely solely on one type of source or an even split between two sources.

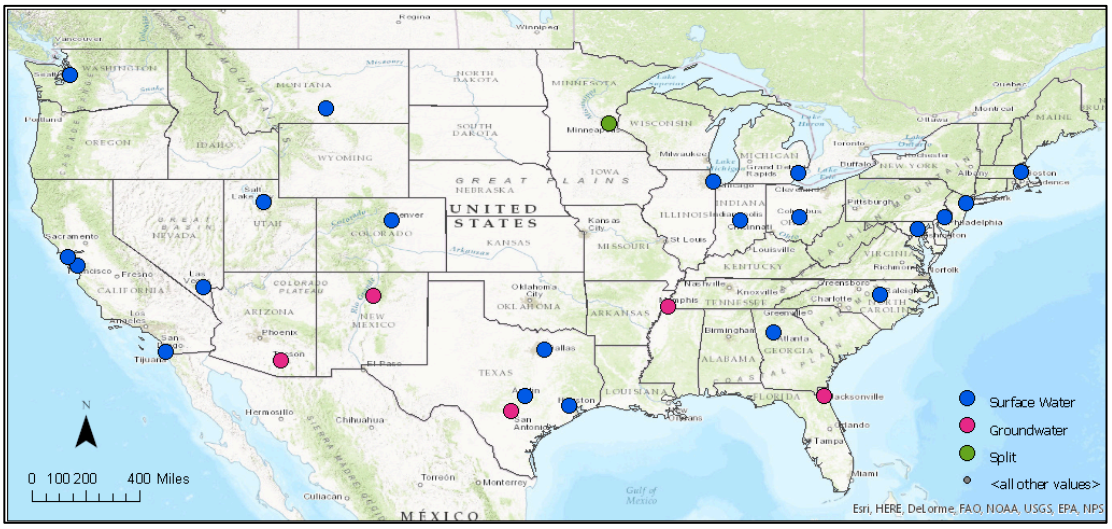

Figure 9: Primary Water Source

Since the project focused on comparing major cities across the nation, most of the data points selected are located in large, metropolitan areas. Therefore, a map of population density (**Figure 10**) was not very telling, but population density was also compared numerically and is discussed further in **Section 3.3**.

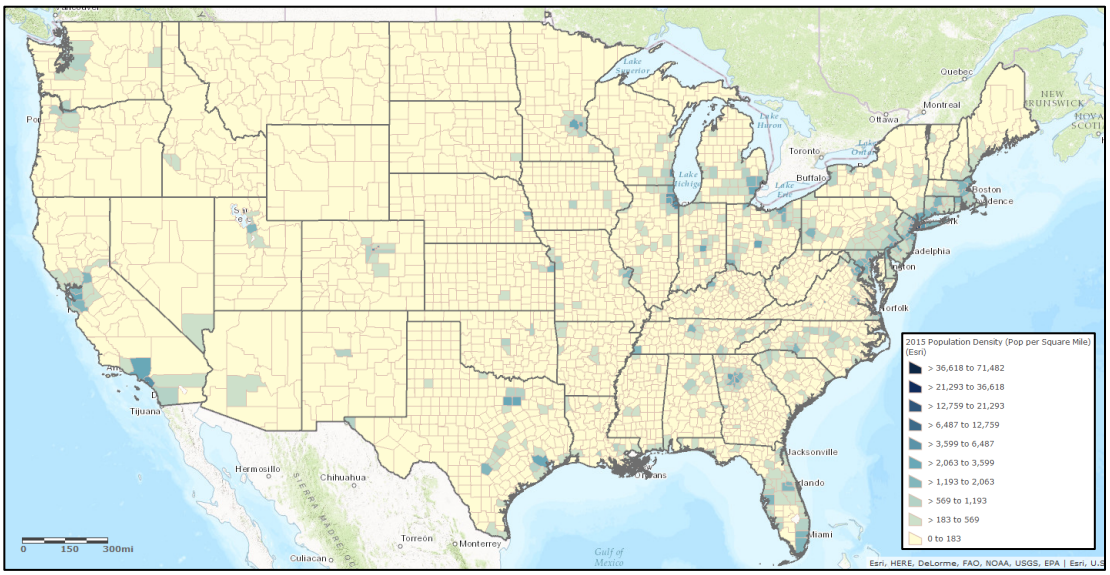

Figure 10: Population Density

3.3 Data Analysis

Refer to **Appendix A** for the tabulated data that was used for numerical analysis. From the analysis, each factor was plotted against water cost to observe if a trend was present. This allows for some of the trends observed (or not observed) on the comparison maps to be quantified. **Figure 11** and **Figure 12** illustrate the relationship between water cost and water usage and between water cost and average annual precipitation, respectively. Although both result in a weak correlation, they are trending in the direction that might be expected.

In **Figure 11**, as water usage increases, so does water cost. This would be expected as most cities use increasing block rate structures, which charges more as usage increases.

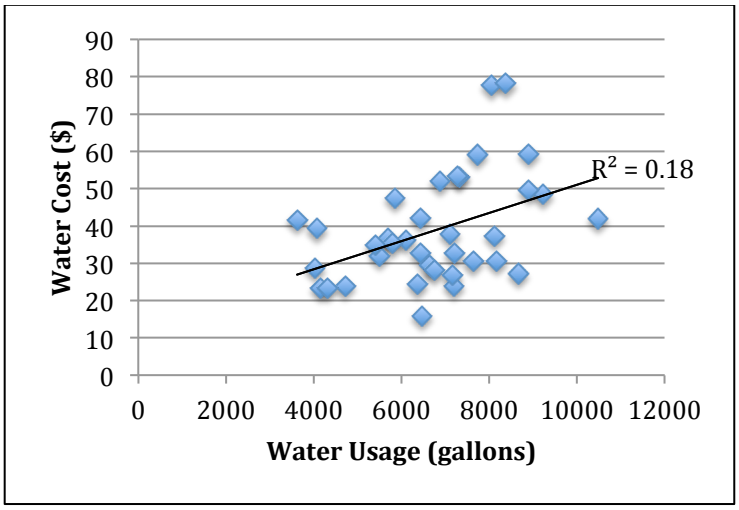

Figure 11: Correlation between Water Cost and Water Usage

In **Figure 12**, locations with more precipitation tend to have lower rates. This follows expectations that as water availability increases, its cost would decrease.

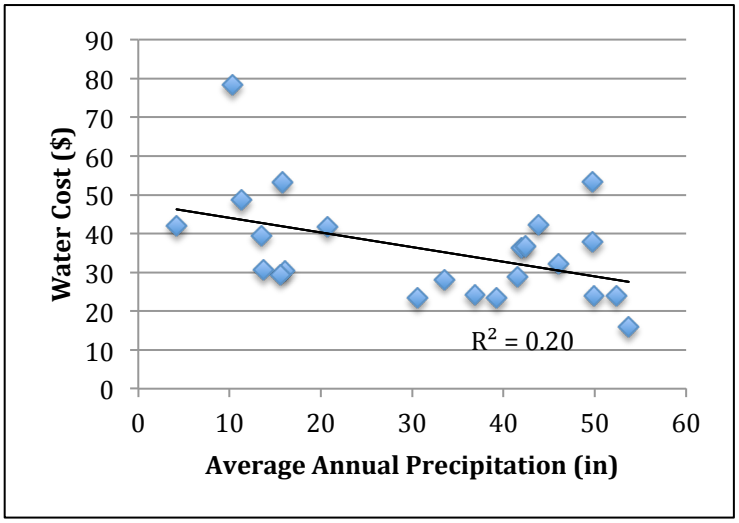

Figure 12: Correlation between Water Cost and Average Annual Precipitation

The results of other factors investigated—population, temperature, type of rate structure, primary water source—are not included, as they showed no correlation with water cost.

4.0 Results and Conclusions

It appears that water rates are generally higher in the south and western regions of the United States where drought intensity is higher. Also, weak trends are observed with a few factors such as precipitation and water usage. However, overall, there are no strong correlations that can be drawn between the factors investigated and the cost of water. From research into even more comprehensive studies that have been completed, similar conclusions were made that weak correlations exist at best.

This result is not entirely unexpected and further emphasizes the complexity of water rates and their highly variant driving factors from city to city. Cities have unique problems and goals, which they address in many different and unpredictable ways. For example, some cities overestimate future growth and demand, which results in an overinvestment in new infrastructure and the need to increase rates to resolve the debt to pay for the new infrastructure. Often, this rate increase leads to a decrease in demand as consumers practice conservation in order to save money, which leads to long-term financial difficulties for the utility.[11] Alternatively, some cities do not invest enough leading to higher maintenance costs or use rates that are insufficiently covering their operating costs.

In the future, if this work could be expanded upon to consider more locations with more varying utility sizes, perhaps trends could be observed more clearly. Also, if data could be collected on key variables for utilities' actual rate-setting process, such as operating costs, more direct correlations could surely be made, in comparison to externally related factors such as those explored in this project.

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Appendix A: Rate Data

Location	Water Cost at Fixed Usage (7,500 gal/month) ($)	Water Cost at Average Usage ($)	Rate Structure	Monthly water usage (gal/month/household)	Average Annual Precipitation (in)	Average Annual Temperature (°F)	Primary Water Source	Population Density (/sq mi)
Atlanta	54.96	53.31	3	7,280	49.7	62.55	1	3,360
Austin	57.18	59.19	3	7,730	34.2	69.4	1	3,358
Baltimore	40.60	36.37	3	6,100	41.9	58.45	1	7,672
Billings	30.10	30.54	3	7,630	13.66	48.05	1	2,400
Boston	49.13	42.19	3	6,440	43.8	51.4	1	13,841
Chicago	28.58	24.23	1	6,360	36.9	51.3	1	11,864
Columbus	37.14	23.39	3	4,150	39.3	52.9	1	3,624
Dallas	27.73	30.62	3	8,180	37.6	64.3	1	3,645
Denver	33.49	29.47	4	6,640	15.6	50.7	1	4,044
Detroit	30.32	28.06	2	6,760	33.5	48.7	1	5,142
Houston	39.92	37.92	3	7,110	49.8	69.05	1	3,662
Indianapolis	45.42	36.67	2	5,700	42.4	53.1	1	2,273
Jacksonville	24.86	23.96	3	7,200	52.4	67.9	2	1,142
Las Vegas	33.95	41.94	3	10,480	4.2	69.3	1	1,660
Memphis	18.41	15.88	1	6,470	53.7	63	2	2,000
Minneapolis	38.00	23.38	2	4,310	30.6	46.15	3	7,485
New York	38.20	23.99	1	4,710	49.9	55.15	1	28,053
Philadelphia	47.69	28.73	3	4,030	41.5	55.85	1	11,635
Raleigh	43.20	32.06	3	5,510	46	60.8	1	3,159
Salt Lake City	21.64	30.47	5	12,960	16.1	54.8	1	643
San Antonio	33.96	32.74	5	7,210	32.3	68.7	2	3,000
San Diego	72.20	78.27	3	8,380	10.3	63.65	1	4,003
San Francisco	83.16	41.62	3	3,620	20.7	57.3	1	18,451
San Jose	53.89	53.14	3	7,330	15.8	61.55	1	5,700
Santa Fe	66.18	39.47	3	4,080	13.5	49.9	2	1,927
Seattle	66.64	77.61	5	8,060	37.7	52.65	1	8,161
Tucson	39.82	48.55	3	9,230	11.3	70.9	2	2,794

Rate Structure Legend:
1 Uniform
5 Uniform (base and volume rate)
2 Increasing block rate (base and volume)
3 Increasing block rate (AWC-based)
4 Increasing block rate/seasonal

Water Source Legend:
1 Surface
2 Ground
3 Split