Water Source Distance and Its Effects on Population and Water Rate

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Abstract

Humans rely on water in almost every aspect of life, from basic bodily needs to food, manufacturing, irrigation, production of energy, recreation, etc.; it becomes obvious water is of utmost importance to our society. Because of this, no civilization can survive without a reliable source of water. But does water serve as a limiting factor to population growth and the economy, especially given the capacity of modern-day humans to manipulate and manage natural resources? We conducted this study to examine the relationships between a city's growth, its water source proximity, and the cost residents pay for their water; specifically, to determine if proximity and price had a negative effect on population size and if proximity had a positive correlation with price. This was more challenging than originally imagined since many residential water use pricing systems vary city to city (often due to political and social reasons) and do not accurately reflect the cost of transporting said water. Much of the data we collected do not follow any obvious observable trend, although further data analysis may reveal correlations among cities that deploy similar water pricing systems, a focus not undertaken in this study. Our project examines a topic that could yield surprising insights into the interactions between water infrastructure, management, economies, cultures, and human nature as a whole.

Introduction

Our project focuses on the distance of a water source and its effects on population size and water rates. We are investigating to see how the distance of a water source from its users affects the population size of its users. Another variable we investigate is water rates to see if the distance of a population's water source has any effect on them.

The reason we have chosen to investigate this is because some of our group members are from Southern California and we realize that the population is too big for the amount of water that the natural Southern California landscape provides. Because Southern California transports its water a far distance to support its people, we wanted to see if all cities were like this as well or if Southern California was just an exception. We then decided to also look at water rates to see if there was any correlation between how far a city's water comes and how much its water costs because that would be a deterrent for a population to grow there. These variables were examined within six cities located in the United States and five international cities, all of various sizes and geographic location, in order to determine if a universal trend existed or if each city was a unique confluence of political and social circumstances that influenced its water system.

Objective

One of the most important components to a sustainable city is having a sustainable water supply. In our term project, our main objective is to investigate if there is a correlation between distance from water source and population size of different cities throughout the world, with a focus on U.S. cities. We will also investigate if water rates have any correlation with population size and distance from water supplies.

The purpose of this report is to compare a city's distance from its water sources, to its water rates, and to its population size and to compare each of these parameters to each other. To get a world view of our analysis, we each found this information for large cities within the U.S., several large cities outside the U.S., and one small city from the U.S. and one from abroad. After we each gathered information from various cities and towns, we concentrated it within a table and graphed the results to see if there was any relationship between variables.

The first main task of the project was to collect all of data for our selected cities. We needed to find the most recent population figures, the distance that a city is from its main water sources, and the most recent water rate available. We did extensive research online to find all of the data we required.

We then filled in a spreadsheet with all of our data and the citations. Some of the data required conversions to a chosen standard unit. All of these conversions required some simple arithmetic. Once all the data was obtained, we used it to create some graphs to see if there were any trends in the data. After analyzing the graphs, we tried to give possible reasons to explain the trends or the lack of trends.

Hypothesis

Our hypothesis is that the distance between a city and its water supply is positively correlated with the price of water city residents pay, and that both of these variables have a negative relationship with the population of the city. For example, we expect that a large city would have a lower water rate compared to a smaller city. Our rationale for this idea is that in order to sustain a large urban population into the millions, there needs to be a reliable water source nearby that provided enough water of adequate quality.

We also expect that large cities would have water sources that are close by, and conversely, a smaller town would be farther from its water source. We hypothesize that if the water is too far away, it will require more extensive dams, reservoirs, and other infrastructure. The cost to build all of these would be passed on to the water consumers, which would lead to high water costs.

Lastly, we hypothesize that water rates are negatively correlated to population size and positively correlated to distance from water source for the same reasons we have already mentioned. If the water source is far away, it should cost more to bring it to the city. This high water rate would be a deterrent for people looking to move into the region.

Data Sources

The main types of data that we used for this project were population values, water rates, and distances from water source.

Population Data:

- US Population Data: U.S. Census Bureau
- Cape Town Population: Statistics South Africa
- Derby, AU Population: Australian Bureau of Statistics
- St. Petersburg Population: World Population Review
- Shanghai Population: National Bureau of Statistics of China

- Mumbai Population: Population Census India

Water Rates Data:

- Shanghai Water Rates: Shanghai Water Authority
- Mumbai Water Rates: The Bombay Community Public Trust
- New York Water Rates: New York City Water Board
- St. Petersburg Water Rates: Vodokanal of St. Petersburg
- Los Angeles Water Rates: Los Angeles Department of Water and Power
- Cape Town Water Rates: City of Cape Town
- Chicago Water Rates: City of Chicago
- Houston Water Rates: The City of Houston
- San Francisco Water Rates: San Francisco Public Utilities Commission
- Hilo Water Rates: Department of Water Supply, County of Hawaii
- Derby Water Rates: Water Corporation

Distance Data:

- Shanghai: Pure Living China
- Mumbai: The Bombay Community Public Trust
- New York: New York City
- St. Petersburg: Vodokanal of St. Petersburg
- Los Angeles: City of Los Angeles Department of Water and Power
- Cape Town: City of Cape Town
- Chicago: City of Chicago
- Houston: The City of Houston
- San Francisco: San Francisco Public Utilities Commission

- Hilo: Department of Water Supply, County of Hawaii
- Derby: Department of Water, Government of Western Australia

Methods and Assumption

We were able to obtain most of the data necessary for our project from online sources (enumerated above and in the reference section) with only minimal calculations necessary.

First off, we had to determine the distance between a city and its water source(s). In most cases, the websites belonging to the local water districts did not specify the exact distance that the water travelled to reach its customers. There were occasions where they provided the total length of all of the pipelines in the system, but these numbers were too large and could not be used a reasonable distance for the water source. In these cases, we resorted to the best approximation we could make using Google Maps. Whenever the pipeline map was available, we tried to match this path with the driving path as closely as we could. We then used that value for the distance from the water source. In other cases where we didn't have any guide to follow, we simply used the shortest distance that was provided.

Sometimes groundwater was the sole water supply and since that is located directly beneath a city we set the distance between a city and its groundwater to zero. This project only measures the distance water travels horizontally along the Earth's surface, not vertically up to the surface, since that typically doesn't deter water extraction unless the water table is significantly lower than usual. This is the same when a river runs through a city (as is the case in St. Petersburg) or any other instance when a city is located directly next to its water source (i.e. Chicago and Lake Michigan) meaning even if they don't extract the water as it flows through the city, the relative distance travelled is negligible compared to those of other water sources.

Another hurdle is that many cities retrieve their water from multiple sources at varying distances from the city. In order to accurately compare the distance a city's water travels to its population, we again needed to standardize the measurements. In this case, it wasn't just a unit conversion, but rather an averaging of distances from the different sources. We determined the amounts of water extracted from a city's various sources and used that to find the percentage each source contributes to a city's total water usage. Once we had those values, we found the weighted average of the distance by multiplying the source distances by the fraction of water they contribute to the total water usage of the city. Those values were then averaged to become the final distance between a city and its water source.

The data for the water rates and the distance from water source proved to be a challenge. The water rates data was obtained from various websites that belonged to the local water districts of the areas we were interested in. We encountered a few complications during this process. The first one that we faced was unifying the different units and currencies used to describe the water rate. Some places used liters or kiloliters to measure the water; other places used cubic feet or cubic meters instead of gallons to measure the water used. All of these values had to be converted to gallons, a unit we decided on because of its common use in the United States.

Once these volumes were standardized, we then had to consider the time period over which the water was measured. Again, each region had its own way of setting this. We saw places that charged every month for water, others that charged every three months or every six months, and even one place that had a yearly water rate. We had to adjust each of these time frames because the locations that had a tiered system over longer periods presented their rates in larger quantities.

Similarly, when dealing with the international cities, we had to convert the local currency into U.S. dollars. We used the most current exchange rate to make the conversion. All of these conversions required some simple but lengthy arithmetic. We created several graphs using this data that will be presented subsequently in the report.

Calculation/Results

City	Population	Distance (miles)	Price ($/1000 gal)
Shanghai, CN	23,019,148	0	0.99
Mumbai, IN	12,478,447	0	0.24
New York, US	8,244,910	108.9	4.24
St. Petersburg, RU	4,848,742	0	2.25
Los Angeles, US	3,819,702	292.4	4.39
Cape Town, ZA	3,497,097	61.4	0
Chicago, US	2,707,120	0	2.51
Houston, US	2,145,146	38.6	4.46

San Francisco, US	812,826	180	1.74
Hilo, US	43,263	0	0.89
Derby, AU	3,093	0	1.51

Table 1. This table summarizes the population size, distance from water source, and water rates for the cities we investigated.

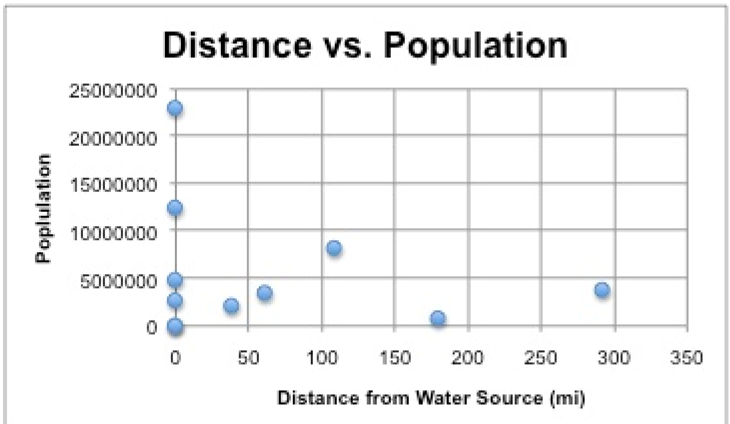

Figure 1. This graph shows the relationship between a cities distance from its water source and its population size.

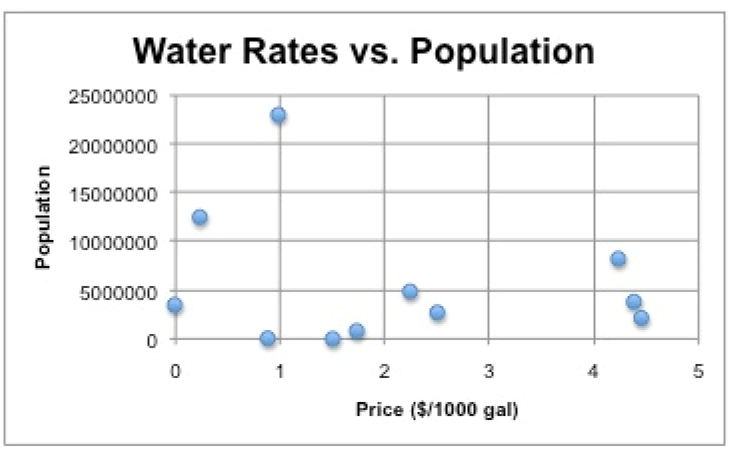

Figure 2. This graph shows the relationship between a city's water rates and its population size.

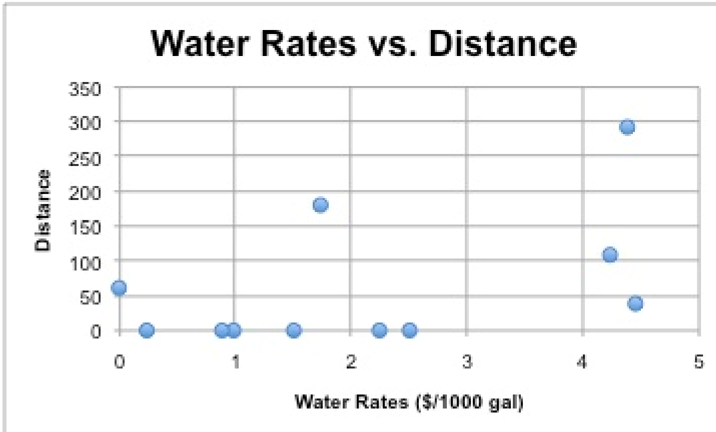

Figure 3. This graph shows the relationship between a city's water rates and the distance from its water source.

Figure 1 graphs the distance from water source and compares it to the population size of each of the cities. As can be seen from the graph, several cities do not have any distance to its water source meaning they get their water from either groundwater or a local surface water source. There is one outlier that gets its water from a great distance of almost 300 miles, that city being Los Angeles. San Francisco is the other outlier collecting its water from a source over 150 miles away.

In Figure 2 the graph shows the relationship between water rates and population size. It can be seen that a few cities charge hefty prices of over $4 per 1000 gallons of water. It is also seen that the largest city, Shanghai, does not have the lowest water rates but rather a rate of about $1 per 1000 gallons.

On the Water Rates vs. Distance graph, Figure 3, it compares water rates of the cities and their distances. The graph shows that the city with the farthest distance from its water source, Los Angeles, does not have the most expensive water. The most expensive water belongs to Houston with an average distance of about 39 miles from its water source.

Conclusions

Our original hypothesis was that Distance from a Water Source and Population were negatively correlated but this was not the case with the cities we studied. The cities that we gathered data from did not show any relationship between distance from their water source and their population (Figure 1). We found that Los Angeles and San Francisco were two cities that got their water from the farthest distances but their populations did not compare with the international cities such as Shanghai (Table 1). Although, when looking at the cities that transport their water from far distances, only five cities did and four of them are in the United States. This shows that water transportation may mainly be a problem in the United States. Looking even deeper into the numbers, the top two cities that transported their water from great distances, Los Angeles and San Francisco, are in California. While this may be a problem throughout the United States this problem seems to be prominent in California. This may just be a problem in the United States, mainly California, and our perception of water transportation is influenced because California is where we reside.

Our second hypothesis was that water rates were negatively correlated with population size. This hypothesis was also inconclusive. The water rates had no real correlation with population size (Figure 2). Although, of the five cities with water costs over two dollars per 1000 gallons four of them were in the United States. This relates to the previous conclusion and makes sense that the cities in the United States have higher costs because we have to transport their water.

The last hypothesis was that water price would be positively correlated to distance from the water source. This also showed mixed results from the data we gathered from the different cities. This again relates to the first conclusion that only five cities transported their water and four of them being in the United States. Although, even if we just look at the cities in the United States there is no correlation between water rates and distance from their water sources. The main finding here is that water transportation only seems to be a problem in the United States. This also does not show a correlation in the water rates and distances, which could mean that water rates can also be affected by the amount of groundwater available. The reason this might be the case is because places that do not transport their water could be overdrafting it from the ground, which would also increase prices. At the same time this might not do much because as we saw in figure 2, there was no correlation between population and water rates. This shows that there are more complicated factors that are involved when it comes to water pricing and population sizes within cities.

Recommendation/Limitations

Because we were unable to come to any concrete conclusions, we recommend that further study and analysis be undertaken in order to tease apart the interactions between a population's water source, size, and water rates. Other considerations could also be included to focus on a specific subset of cities (i.e. founded pre-20th century, groundwater dependent, etc.) or those in climates with similar hydrological characteristics. California could also be excluded from national studies or specifically studied in isolation since the data seems to suggest that California cities are unlike others within the United States and around the world. We can conclude though that there is no universal trend amongst cities around the world between size, proximity to water source, and water price. Beyond that, the data does not yield much at first glance due to the variety of water management systems in place and socioeconomic factors that surround water rates. This project was limited mostly by the small sample size, focus on developed areas, and focus only on these three variables (i.e. water quality). This is an area relatively unexplored and rarely discussed, further research and outreach to water managers and city planners could lead to interesting results.

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