Sustainable water management in the Southwestern USA:

A case study of Phoenix, AZ; and Las Vegas, NV.

by

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Abstract:

Las Vegas and Phoenix are the fastest and second fastest growing cities in the U.S. respectively. Paradoxically, both cities are located in the most arid region of the U.S. One approach to deal with water scarcity is to reduce water demand per capita. Water pricing is a simple parameter that easily provides the incentives for conservation. Tiered water structures can help reduce demand, and can aid in the conservation and sustainable use of water. The price structures of Los Angeles, Las Vegas, and Phoenix were compared against data collected on the average per capita water (GPCD) use in the three cities over the past 20 years, to see how changes in price has effected water consumption. In addition, Phoenix and Las Vegas' current water policies and water use were evaluated using sustainability criteria to determine the relative sustainability of the water management. Findings indicate water is inexpensive in Phoenix and slightly more expensive in Las Vegas with some presence of a tiered water structure in both cities. Las Vegas currently has a higher GPCD than Phoenix, but it also has many goals and measures to decrease demand. Las Vegas' water use has been decreasing more rapidly than Phoenix's due to demand side water management policies. Results also indicate that water in Los Angeles is significantly more expensive, and GPCD is lower than in both Phoenix and Las Vegas. Connecting price to GPCD, we can see that as price increases demand for water decreases. In my sustainability analysis, I found that Las Vegas is closer to making sustainable policies, but both still have room for improvement, such as implementing tiered structures based on both volume and season, and creating a system for public involvement.

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List of Abbreviations

LVVWD: Las Vegas Valley Water Department

LADWP: Los Angeles Department of Water and Power

SNWA: Southern Nevada Water Authority

GPCD: gallons per capita per day

CAP: Central Arizona Project

SRP: Salt River Project

MWD: Metropolitan Water District

Chapter 1

Introduction

Figure 1.1 Lake Mead, February 2011 at 40% capacity. Photo Courtesy of Samantha Weidendorf.

Water may be the next limiting resource on earth. Water resources in the United States have multiple issues. Cities face degrading water infrastructure and conflicts over water sources. In the country farmers face a decreasing groundwater table and few options to manage drought. Climate change threatens to affect the supply of water throughout the country by changing rainfall patterns and amounts (Intergovernmental Panel on Climate Change, 2007). Many of these challenges are hard for water managers to control, but both consumers and managers are still obligated to deal with the consequences. The following quote summarizes the state of water resources in the United States: "The United States is heading toward a water scarcity crisis: current water use practices are unsustainable, and environmental factors threaten a water supply heavily burdened by increased demand" (Glennon, 2005, p 1873).

The historical American mindset for centuries has been that if people can control nature to suit their needs then they will have finally won in the battle with nature. We have dammed almost of all of our large rivers multiple times, flooding breathtaking canyons and changing the paths of rivers to suit our needs. We have straightened once meandering streams and concretized the banks of others. Whenever we need water, whether we are in the desert or in a swamp, we find a way to get that water to us. Unfortunately, we are arriving at the point in our history where we have taken as much from nature as possible, and now our natural resources are finally running out. To remedy this, we must learn how to live symbiotically with nature, while living in accordance with the natural systems that are vital to ecosystems.

In Las Vegas, Phoenix, and Los Angeles, water management challenges are similar, yet each city has taken their own approach to promoting sustainability. According to the Brundtland report (1987) sustainable development is: "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (Brundtland Report, 1987, p 24). Applied to sustainable water management, sustainable water use is defined by the 6 criteria that I lay out in chapter 3, that include provisions such as fairness, ecological sustainability, and pricing and policies contributing to lower GPCD. I apply the sustainability concept to water management by analyzing municipal water prices, and policies related to water conservation. Figure 1.2 nicely summarizes the concept of sustainable development:

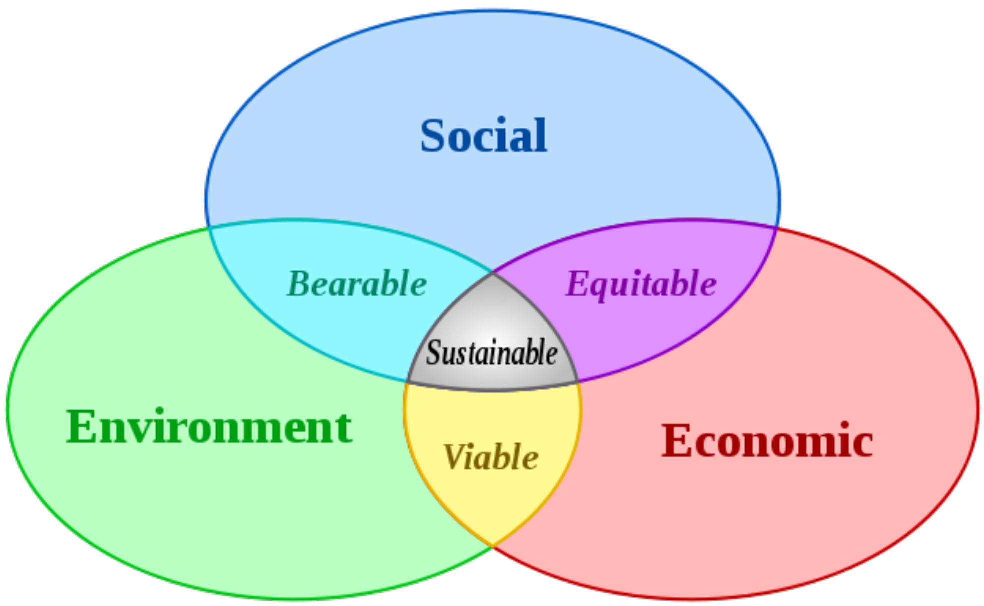

Figure 1.2 Sustainable development (United Nations, 1987)[1]

I expand this definition by applying the concept of sustainability as defined here to natural habitats, social equity, public opinion, price of water, economic concepts, and the possible effects of climate change. To place these terms in the context of Figure 1.2, natural habitats and climate change would be under "environment". Social equity and public opinion would be part of "social", and pricing and economic concepts would go under "economic".

[1] Courtesy of Johann Drejo. Brundtland Report (1987). "Our Common Future". *Oxford University press.*

The aim of my work is to examine water pricing in Phoenix, Las Vegas, and Los Angeles, and then determine if efficient pricing encourages water conservation, and ultimately, sustainable water management. I include the city of Los Angeles in this study because it employs a more sophisticated water price structure than Phoenix or Las Vegas. Ultimately, I seek to understand whether Los Angeles' approach encourages greater water conservation. Furthermore, I analyze past and present water policies in each city to better understand how these policies affect water use and sustainable water management.

1.1 History

Water is a unique resource that is despised, taken for granted, and fought over, depending on where it is located. Throughout history, many cities were purposefully located, and have grown because they were on the banks of a river or a lake. This characteristic is common of cities in the eastern U.S., such as Chicago, Boston, and New York, as well as settlements in the west that were situated on large aquifers or canals, such as the Hohokam civilization near present day Phoenix.

In the 19th century the American government wanted to put the vast amount of land they had acquired through the Louisiana Purchase to use. To encourage western settlement, Congress passed the Homestead Act was passed in 1862, which allowed settlers to claim land as their own as long as they lived on it for five years (Reisner, 1993). Unfortunately the congressmen who passed the Homestead Act did not understand the conditions that settlers would face in many of the western states, especially the lack of water (Reisner, 1993). To make up for this mistake, the federal government undertook countless water projects, many of them costing more than they yielded in economic benefits.

Congress envisioned the west as a vast farmland where agricultural production would thrive and produce enough to feed the more populous eastern cities that were slowly expanding into their surrounding farmlands. This eastern vision for the west laid the foundation for the tradeoff between water used for agriculture and water used for people who lived in cities in the west. Since the Homestead Act, farming has been seen as a right of western farmers, even if farming in the west is often inefficient because of the arid climate and lack of rainfall. Because of this perceived right and lack of rainfall, there have been extensive government infrastructure projects to supply water to these farmers, including the Central Valley Project in California, and the Central Arizona Project in Arizona. Today, about 80% of water in the west is allocated to the farmers rather than the city dwellers (Reisner, 1993), even though the number of people in cities is far greater than the number of farmers (Reisner, 1993). Water rights in the west are determined by who used the water first, and because of the early focus on providing water for agricultural production, farmers now typically hold the most senior water rights (except for Indian reservations).

While I will not be focusing on farmer's use of water in the west, the interplay between farmers and city dwellers in the west is an important one. Federal projects to bring water to farmers, especially in the last 50 years, have also brought cities more water. Some federal projects, such as the Central Arizona Project, have been more costly than originally planned, and the only consumers who can now afford the expensive water are consumers in cities (Hanemann, 2002). In contrast, farmers are accustomed to paying virtually nothing for their water, as a result of federally subsidized water supply projects. While these large projects make little economic sense in terms of direct costs and benefits, without these large federal projects such as Hoover dam, the Central Arizona Project, and the Colorado River Aqueduct, cities like Las Vegas, Phoenix, and Los Angeles would not have been able to grow to their current sizes.

"In the East, to 'waste' water is to consume it needlessly or excessively. In the West, to waste water is *not* to consume it-to let it flow, unimpeded and undiverted down rivers" (Reisner, 1993, 12). Water law is also very different in the west than in the east. In the east, where water and rainfall are more abundant, the riparian doctrine prevails, which states that whoever owns land abutting a water body has the right to make a reasonable use of the water (Pisani, 1992). The date the water was first used and that volume of water form the core of an appropriative right for water. Unlike the east, appropriative water rights are property rights that can be bought and sold. Also, in the west, it is generally perfectly acceptable to take water from a body of water without ever returning it.

One of the major differences between the east and the west is that the west has far fewer people per square mile than the east, and the vast majority of them are located on the coast in California. However, with dams and modern technology, some desert cities have bloomed into thriving metropolises. These cities have experienced rapid growth for several reasons, including innovation in technology, plentiful job opportunities, and a good climate (Reisner, 1993). "Given the opportunity, people were happy to leave temperate climates with cold winters for desert climates with fierce summers" (Resiner, 1993, 260). This migration west still resonates. For example, Michigan was the only state to lose population[2], while the City of Phoenix grew by about 83,000 people over the past decade[3]. What is ironic about this population shift is that Michigan is surrounded by the great lakes, and will probably never have a water shortage, while Phoenix is in the middle of the desert. Because of these population shifts, and our dependence on a finite resource, it is vital to study water policy in these western desert cities.

1.2 The Value of Water

To understand the value of water, two important concepts must be introduced. One is the idea of water as both a public good and a private good. A public good is a resource that everyone has access to, and therefore is non-excludable. This good also cannot be exhausted after one use (Hardin, 1968). In contrast, a private good is excludable and could be used up after one use. Water can be both a public and a private good. Water as a public good is water in a river or lake that people use for fishing, swimming, and other recreational activities. Water is a private good when it is sold, or excluded from use. Municipal water is a private good, because it is purified before being distributed to the city. Because of this quality as private good, municipal water should not be subject to the "tragedy of the commons" that public goods are subject to. The tragedy of the commons is what

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[2] http://www.mlive.com/politics/index.ssf/2010/12/michigans_population_loss_in_c.html

[3] http://phoenix.gov/planning/resdat27.pdf

occurs when too many people have access to a public good, which causes this good to become degraded or unfit for use or enjoyment.

A welfare state is a society that provides for its people when they cannot provide for themselves (Barr, 1993). A welfare state only provides necessities that are needed to live. Because necessities include water, water is a unique good in that it is often subsidized through the welfare state as a necessary commodity for life. Pricing water so that its availability is ensured to everyone is an obstacle in creating conservation minded price structures. This leads to lower than efficient prices for municipal water. There are other factors affecting the price of municipal water, including political influences, and legal influences. City governments are the supplier of water for 85% of the United States (Hanemann, 1993). If water management is to be sustainable, then water prices must include all costs of distribution, the scarcity of the water supply, and a tiered structure based on volume and season. Sustainable management must also include conservation oriented policies, and fair decision-making. Water pricing is an important tool, because it can induce consumers to change their water consumption, especially when they are using water in ways that are not essential. It is one of the aims of my thesis to determine if current water prices in Las Vegas and Phoenix lead to sustainable water use.

1.3 Why Las Vegas and Phoenix?

Las Vegas and Phoenix, shown in Figure 1.3, are the fastest and second fastest growing cities in the country, respectively.

Figure 1.3 Map of Los Angeles, Las Vegas, and Phoenix[4].

The population of Phoenix is currently 1,445,632[5] and Las Vegas is 606,656[6]. Las Vegas is expected to grow by 165,443 people, a 27 percent increase, by 2020[7]. Phoenix is expected to grow by 574, 368 people, a roughly 40 percent increase, by 2020[8]. They are also located in the driest region of the United States, the Southwest. Patricia Mulroy, Director of the Southern Nevada Water Authority described Las Vegas as "a canary in a mine shaft" (The Economist, 2011) in that it may run out of water quicker than many other western cities, due to the fact that it relies on Colorado River water for 90% of its municipal water supply (The Economist, 2011),

[4] historiayculturab2010.blogspot.com
[5] http://phoenix.gov/CITYGOV/stats.html
[6] http://www.lasvegasnevada.gov/files/PopGrowth30LargestCities.pdf
[7] Las Vegas Master Plan 2020. City of Las Vegas.
http://www.lasvegasnevada.gov/files/Population_Element.pdf
[8] Water Resources Acquisition. The City of Phoenix.
http://phoenix.gov/WATER/wraffinal2.pdf

while other western cities often have a more diverse water source portfolio. So, although Phoenix may have a more diverse water source portfolio, it has unique problems of its own, such as very inexpensive water and a focus on supply side policies.

Given the population and resource stress facing arid cities such as Las Vegas and Phoenix, it is necessary to examine how water is managed and whether that management promotes the sustainable use of water resources in each city. Without sustainable water resources management, it is probable that Las Vegas and Phoenix may face critical water shortages in the future. Although there have been studies on the state of water management in Las Vegas, these studies do not show the link between pricing and sustainability. There have been no studies focusing on water management in Phoenix.

One of the vital steps needed to determine the sustainability of water management in each city is to consider the price of municipal water in each city and how that price is determined. Once the price structure of water is determined for each city, it becomes possible to better understand the relative value of water to consumers. In addition to pricing information, I also collect data on water use and evaluate policies that promote demand side management (i.e. water conservation) or supply side management (i.e. expanding sources or water). Finally, the information about the price structure and evaluation of cost, supply, demand, and use information are used to define more sustainable, tiered water price systems designed specifically for each city.

1.4 Why Los Angeles?

Los Angeles is included in this study because it is a city that is similar to Phoenix and Las Vegas in many ways (i.e. urban, arid, population growth), but that has been more successful than Phoenix or Las Vegas in reducing per capita water consumption (LADWP, 2010). Like Phoenix and Las Vegas, Los Angeles is located in an arid climate, and it too relies partially on the Colorado River. For these reasons Los Angeles should conceivably have similar pricing and conservation measures as Phoenix and Las Vegas.

I chose to study Los Angeles, rather than other successful western cities like Santa Fe that also employ innovative pricing and management approaches, because Los Angeles is more similar in size to Las Vegas and Phoenix. Los Angeles is the second largest city in the country, Phoenix the fifth, Las Vegas the 26th, and Santa Fe is ranked below 300, with a population of 75,764[9]. Water in Santa Fe is over four times as expensive as water in Phoenix and Las Vegas, but Santa Fe is much smaller. In contrast, a large city, like Los Angeles is a better choice for comparison, because Los Angeles shows that even a huge desert city can have low per capita water use and water that is priced at a level that promotes sustainability.

Los Angeles did not initiate more sustainable water pricing and management by happenstance. In 1993, Los Angeles experienced a severe drought and because of this they changed their water price system to promote the conservation of water (Hanemann, 1993). According to Hanemann (1993), tiered water systems were more efficient because not all people have the same demand for water. This

[9] U.S. Census Bureau, 2010.

diversity in water demand arises from different needs for water depending on the income of the consumer and the season (Hanemann, 1993). Water demand during the summer months is 50-70% higher than demand during many of the winter months (Hanemann, 1993). During the summer, people in desert cities want to keep their yards green and to do this a lot of water are needed. However, people have different preferences for green lawns, and those who have a high preference for green lawns should be willing to pay more for this water. This is the idea that underpins a water use price systems based on timing, quantity, and quality. The water price system in Los Angeles is used as an example of a more sustainable water pricing approach that other desert cities such as Phoenix and Las Vegas might emulate. Although Hanemann (1993) did not mention sustainability in his work, Los Angeles' approach may be a good model for developing more sustainable pricing approaches for Phoenix and Las Vegas.

1.5 Thesis

"Nothing is more useful than water; but it will purchase scarce anything; scarce anything can be had in exchange for it"(Smith, 1904, p 84). I examine water prices, and water price systems in Los Angeles, including rebates, subsidies, and tiered water price systems. Then, I compare the water price systems in Los Angeles to the approaches employed in Las Vegas and Phoenix. I analyze policies implemented in Las Vegas, Phoenix, and Los Angeles to better understand current practices and to make informed decisions about recommended changes to their water pricing systems. Next, I examine the gallons of water used per capita per day (GPCD) in these three cities over the past 20 years to see how use has changed over time. Then, I compare the policies implemented in these three cities to make informed decisions about their water pricing systems. I match these policies and pricing changes with changes in GPCD. I also analyze each city against 6 sustainability criteria.

While there has been extensive research on water pricing, there is seldom a link between water pricing and sustainability. I not only link water pricing and sustainability, but I also propose a quantitative measure of sustainability to more effectively compare the three cities. I hypothesize that Los Angeles will have lower GPCD than Phoenix or Las Vegas, especially after the implementation of its conservation oriented price structure. Lastly, to achieve similar reduction in GPCD in Las Vegas and Phoenix, I propose possible solutions for Phoenix and Las Vegas to promote water conservation in these cities and move towards more sustainable water management.

Chapter 2

Background

2.1 Policies and Compacts

Price is an important tool in encouraging sustainable water management. According to a joint publication by the UN, Global Water Partnership, and the EU Water Initiative (2008), economic tools such as pricing, taxes, and subsidies are an efficient way to achieve policy objectives. Water pricing is also important because it affects people who cannot afford to pay a lot for their water, which is why equity in water management is important. Price structures that provide the proper incentives for the conservation of water are the focus of this research.

Though farmers use 80% of water in the west, my focus is on cities, because cities face critical issues in the management of water resources under conditions of scarcity and rapid population growth. Farmers in the west for centuries have benefited from inexpensive water in exchange for growing much of the country's crops. Changing this arrangement would be a major social and political challenge. Conversely, increasing water conservation in the cities will be somewhat easier, especially as consumers continue to learn more about and understand the importance of conserving water. It also helps that most residential consumers in cities use water for basic needs rather than large quantities needed for farms or industry. For these reasons, I believe that it is more feasible to conserve water in cities than in the country.

As mentioned previously, both Las Vegas and Phoenix are dependent on the Colorado River. Both these cities have the right to Colorado River water from the Colorado River Compact that was ratified in 1928 (Reisner, 1993). The Colorado River Compact divided the average flow of the Colorado River between the upper basin states (Colorado, Wyoming, Utah, and New Mexico) and the lower basin states (California, Nevada, Arizona) (Reisner, 1993). Deciding how much water different states received was more political than scientific. California, with the largest population got the most water, even though rainfall in California does not contribute at all to the flow of the Colorado. Nevada received 300,000 acre-feet of water, while Arizona received 2.8 million acre-feet (Reisner, 1993).

Las Vegas is about 30 miles from Lake Mead, the reservoir on the Colorado River created by the Hoover dam. On the other hand Phoenix is hundreds of miles from the Colorado River. To fix this problem, and ensure that Arizona was able to use its 2.8 million acre-feet of Colorado River water, the Central Arizona Project (CAP) was built. The CAP is a canal running from Lake Havasu (an impoundment on the Colorado River) in northern Arizona through central and southern Arizona to Tucson and Phoenix. It was built on the principle of providing water for Arizona's struggling farmers, but was also meant to supply water to Phoenix and Tucson (Hanemann, 2002). While the canal remains essential for agriculture (agriculture crops use 85% of Arizona's water), building such as expensive system to support farming makes little economic sense because agriculture contributes merely 2% to the economy of Arizona (Glennon, 2005). The CAP cost around $5 billion, and was completed in November 1992 (Hanemann, 2002).

Given the size, expense, and support for the CAP, it is unsurprising that the project had issues. Funding for the project was one of the largest issues, due to the fact that the water would have to be transported uphill for hundreds of miles from source to use, which is energy intensive. Even today, the CAP is the costliest water transfer program in the U.S. at 5 billion dollars (Hanemann, 2002). The agriculture industry was to receive 60-80% of the water. As it happened however, the high cost of CAP water ultimately precluded farmers' use and instead much of the water now is allocated to urban consumers (Hanemann, 2002). CAP was built ostensibly for Arizona's farmers; however, the farmers did not actually expect to pay much for the water (Hanemann, 2002). The expectation of cheap water was consistent with expectations around past large, federally funded infrastructure projects. According to Reisner (1993), "The farmers had become the very embodiment of the costly, irrational welfare state they loathed" (p. 301). Yet, the federal government was less willing to subsidize CAP at the level of past projects because the inefficiencies of past projects had become clear. Instead, there was a greater expectation of cost sharing between the state and water users and the federal government. This meant CAP water was to be priced closer to cost, making it far more expensive than groundwater. As a result, many farmers would sooner go out of business than buy CAP water. Ultimately, the CAP is a good example of policy makers who were too concerned about increasing supply without considering the importance of demand and water pricing. This is a good lesson to learn for municipal water departments as well, because increasing supply is only beneficial if there is enough demand to meet it.

A second source of Phoenix's water is the Salt River Project. The Salt River Project is comprised of a series of dams on the Salt and Gila Rivers that supplies 2.3 million acre-feet of water annually for the city of Phoenix[10]. The Salt River Project is first and foremost a hydropower project. The Salt River Project, much older than the CAP, was one of the first of its kind, and was used as an example for many subsequent projects. Taken together, water from the CAP and Salt River Project, have markedly increased Phoenix's water supply even though both are relatively costly water development projects. Given these supplies, Phoenix is comfortable enough to store some of this water and use it later or sell it.

2.2 Las Vegas

There are numerous springs in the Las Vegas area, which gave the city its Spanish name for "the meadows"[11]. In the mid 19th century Las Vegas was used as a Mormon supply checkpoint between Salt Lake City and Los Angeles. In addition to the Mormons, Anasazi and Paiute Indians occupied Las Vegas for a short time. However, since the 20th century Las Vegas has had a reputation for being the "sin city" of the United States. This reputation started with Nevada's lenient laws towards divorce, gambling, and prostitution. Las Vegas' reputation of indulgence applied to water use as well, and Las Vegas has historically had higher per capita water use than almost any other city in the U.S (Morris, 1996).

The average summer temperature in Las Vegas is around 100 degrees Fahrenheit, with only 10 cm of rainfall annually[12]. Given the lack of rainfall, it is

[10] http://www.srpnet.com/about/history/legacy.aspx
[11] http://www.lasvegasnevada.gov/FactsStatistics/history.htm
[12] http://www.vegas.com/weather/averages.html

unsurprising that 96% of water use in Las Vegas during the summer months is used for landscape irrigation (Pacific Institute, 2007). Las Vegas relies on a combination of water stored above ground and below ground (i.e., aquifers, reservoirs). Las Vegas relies on Colorado River water for around 90% of its water (The Economist, 2011). The Hoover Dam enables Las Vegas to extract this water from Lake Mead, which is located about 30 minutes from the city. The rest of Las Vegas' water comes from groundwater extraction (Pacific Institute, 2007).

Water in the Las Vegas area is governed by both the Southern Nevada Water Authority (SNWA) and the Las Vegas Valley Water District (LVVWA). The SNWA is responsible for implementing conservation policies, and facilitating communication between the seven water departments. The LVVWA is responsible for rate setting and monitoring water use in Las Vegas. Las Vegas has significantly reduced water demand in the past 10 years, reducing total water use, even as population increased. However, Las Vegas' per capita water use is still above many other western cities (Walton, 2010). The population of Las Vegas is projected to grow by 87% by 2035, though demand for water is expected to decrease by 7% by 2035 (Pacific Institute, 2007). The reason for this is because the SNWA expects conservation of water to increase in the future, causing the GPCD in Las Vegas to fall, and therefore the total water use of the city. The SNWA is the policy maker in terms of reducing demand and increasing supply for the Las Vegas area. It is also the governing body for the LVVWA and six other districts in the surrounding area[13]. Las Vegas has a tiered

[13] http://www.snwa.com/html/about_index.html

rate structure that has price increases as the water consumption increases (Walton, April 2010).

Las Vegas water management is included in the SNWA, which encompasses seven municipal water districts, including the Las Vegas Valley Water Authority. The SNWA was started in 1991, as a unified effort of the seven agencies in the surrounding area to work together to find water solutions (Pacific Institute, 2007). Recently the SNWA has made large strides towards managing water more efficiently, such as initiating new water pricing, incentives, regulations, and educational programs (SNWA, 2009). Water pricing efforts include policies that are meant to use price as an indicator of the actual value (and scarcity) of water. Some of the policies that the SNWA has implemented include the water smart landscape project, rebate coupons, and water efficient technologies. To understand how these policies interact with water pricing, I later focus on how each policy has affected the consumption of water and the price of water for specific uses.

2.3 Phoenix

Before the modern city of Phoenix, the Hohokam Indians lived in the area for a thousand years. They sustained their civilization through a network of canals from the Salt, Gila, and Verde rivers[14]. Their canal building was far ahead of their time; they engineered their canals with the exact slope required to flush away all the salt from the water[15]. However, some evidence exists that the climate was wetter when the Hohokam lived in the Phoenix area because fish bones from the Gila River

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[14] http://www.waterhistory.org/histories/hohokam2/

[15] Las Vegas Master Plan 2020. City of Las Vegas. http://www.lasvegasnevada.gov/files/Population_Element.pdf

were found[16]. This wetter climate contrasts with the much drier climate experienced in more recent times. Today the Gila often flows underground or does not flow for months on end[17].

The average temperature of the Phoenix area in the summer is 94 degrees, and it receives 19 cm of rainfall each year (Walton, 2010). The City of Phoenix is the governing body in charge of the supply of municipal water for the Phoenix area. Phoenix is the only city in the U.S. with a uniform price structure that increases during the summer months (Walton, 2010). Water is less expensive in Phoenix than in almost any other city in the U.S., which seems counterintuitive because water is scarce in Phoenix (Walton, 2010). For example, "A family of four using 100 gallons per person each day will pay on average $34.29 a month in Phoenix compared to $65.47 for the same amount in Boston" (Walton, 2010)

Phoenix has four sources for its municipal water. These include the Colorado River, water from the Salt and Verde water system, groundwater, and reclaimed water. According to Phoenix's official website, they recycle 90% of their wastewater to use as non-potable water, which is water that is used primarily for outdoor uses such as landscaping and filling pools (City of Phoenix, 2005). About 60% of Phoenix's water is used to serve residential customers, while the remaining water is used for commercial and industrial users (City of Phoenix, 2005). Also, 60% of Phoenix's water is used for landscape irrigation[18].

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[16] Las Vegas Master Plan 2020. City of Las Vegas.
http://www.lasvegasnevada.gov/files/Population_Element.pdf
[17] http://www.srpnet.com/about/history/legacy.aspx
[18] http://phoenix.gov/WATER/drpers04.html

The City of Phoenix has several conservation requirements. These requirements include complying with state and federal laws. There are also a few city requirements such as the prohibition of private lakes. However many of these programs are recommendations rather than requirements, or goals set for a certain year. For example, they state that increasing and seasonal price structures promote conservation, but there are a few conservation requirements or conservation goals[19]. Other recommendations include retrofitting plumbing fixtures and fixing leaks. However, the city does have a comprehensive sustainability report, to improve sustainability throughout the city, including water resources (City of Phoenix, 2008).

2.4 Los Angeles

Los Angeles was first settled by the Spanish, who relied on the Los Angeles River for their water supply (Reisner, 1993). In the early 20th century Los Angeles experienced rapid population growth, and with this population growth came water shortages (Reisner, 1993). To fix these water problems, and allow for the continued growth of Los Angeles, water from the Owens Valley was brought to Los Angeles through construction of the Los Angeles Aqueduct (LA aqueduct). The aqueduct brings water from the eastern Sierra Nevada down to Los Angeles.

Los Angeles, the second largest city in the United States, is less arid than Phoenix and Las Vegas; it receives 39 cm of rain annually[20], compared to 19 cm in Phoenix and 10 cm in Las Vegas. The average temperature throughout the year in

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[19] http://www.srpnet.com/about/history/legacy.aspx
[20] http://www.vegas.com/weather/averages.html

Los Angeles is 66.2 degrees[21]. Los Angeles experienced a severe drought from 1989 to 1992 that effected water policies and use in the city. Due to this drought, a two-tier price structure with seasonal variance was implemented (Hanemann, 1993).

Los Angeles water is under the jurisdiction of the Los Angeles Department of Water and Power as well as the Metropolitan Water District. The LADWP is one of the 26 member agencies of the MWD[22]. The MWD is responsible for distributing water to these agencies, but the LADWP receives much of its water independently of the MWD. For example, the city of Los Angeles relies on the LA aqueduct for about half of its water needs, and this water is independent from the MWD[23]. The LA aqueduct and the MWD water are just two of the water sources that are available to Los Angeles. Others include the Colorado River aqueduct, water from the California State aqueduct, and groundwater and recycled water[24]. However, the MWD provides around 53% of Los Angeles' water, which includes Colorado River water and water from the San-Joaquin delta (Villaraigosa, 2008).

A smaller percentage of water in Los Angeles is used outdoors than in Phoenix or Las Vegas[25]. Outdoor water use is only 30% of the total water use in Los Angeles (Villaraigosa, 2008). Residential users make up 68% of water users in Los Angeles, which is slightly more than in Phoenix and Las Vegas (Villaraigosa, 2008). Los Angeles has numerous conservation efforts in all sectors of its economy and has

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[21] http://www.weather.com/weather/wxclimatology/monthly/graph/90089
[22] http://www.mwdh2o.com/mwdh2o/pages/about/about01.html
[23] http://www.mwdh2o.com/mwdh2o/pages/about/about01.html
[24] http://www.ladwp.com/ladwp/cms/ladwp010587.pdf
[25] http://www.ladwp.com/ladwp/cms/ladwp010587.pdf

a sustainability plan, a long-term resource plan, and many other plans to ensure the long-term viability of water in Los Angeles (Villaraigosa, 2008).

Chapter 3

Literature Review

3.1 Economics and how it pertains to water

Basic economics help explain and uncover the most efficient outcome for the management of municipal water. Water policy makers are most concerned with the elasticity of demand for water, which explains the change in demand for a given price reduction or increase (Hanemann, 2005). For example, demands for inelastic goods change very little even if the price of a good increases. Goods with inelastic demand are generally necessities or goods that cannot be substantially differentiated by the manufacturer, such as salt, water, and soap. On the other hand, goods with an elastic demand, such as luxury or more expensive goods, are more price-sensitive (Hanemann, 2005). If the price of an elastic good increased substantially many consumers would probably no longer buy the good. Examples of these are fancy cars, computers, or steak. Figure 3.1 shows how when the price of water is increased, the consumer with the inelastic demand will decrease consumption very little, while the consumer with more elastic demand will reduce consumption much more.

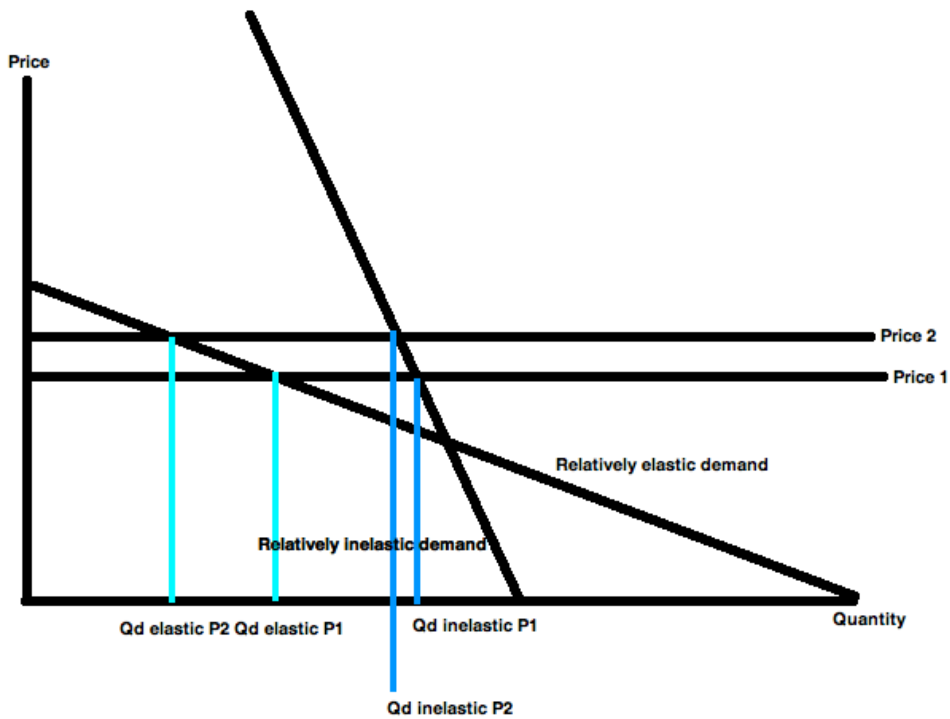

Figure 3.1 Elasticity of Demand[26]

Two demand curves are shown in Figure 3.1, the steeper inelastic curve, and the flatter elastic curve. Notice how when the price increases slightly from Price 1 to Price 2, the quantity demanded on the X-axis falls much more for the consumer with elastic demand than the consumer with inelastic demand. This figure shows that consumers with an elastic demand will reduce their demand much more if there is a price increase than consumers with inelastic demands.

The elasticity of demand is important for water conservation because different uses of water have different elasticities. Indoor uses, such as cooking and cleaning, are generally inelastic, reflecting the necessities of these uses, while

[26] Figure courtesy of Deborah Pierce

outdoor uses, such as watering lawns and filling pools, are relatively elastic, in a sense luxury uses. This is important to note, because in Las Vegas historically 60% of residential water demand was for outdoor water uses (Stave, 2003). Therefore, if the price of water used outdoors were to increase, many water users would likely reduce their use. If the goal is to decrease water use as much as possible, then the best strategy is to increase the price of water for elastic uses.

The economics of water is also important from a policy standpoint. Municipal water is often priced below marginal cost (see Figure 3.2), which means it costs water utilities more to treat and distribute water than they receive in payment for that water (Hanemann, 2005). This situation arises because Americans are used to paying virtually nothing for their tap water, and because it is politically unpopular to raise municipal water prices. Furthermore, municipalities have found it difficult to remedy the pricing situation with a simple flat rate price increase. When municipalities raise water prices, many actually lose revenue, because people decrease their water use substantially. However, when prices are only increased at high levels of consumption, such as in a tiered price system, municipalities can maintain revenue while still promoting water conservation. An example of a tiered water price structure is shown in Figure 3.2.

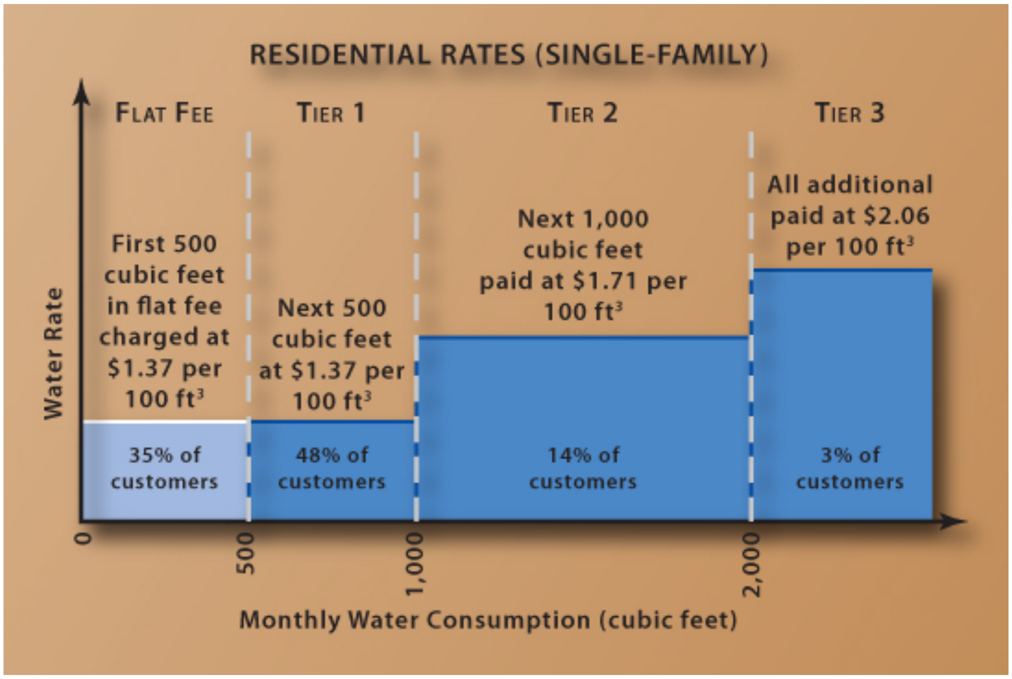

Figure 3.2 Example of tiered rate structure for residential water use[27]

Figure 3.2 illustrates many important aspects of tiered water pricing. First, it shows that for each tier, the price goes up substantially, based on quantity. Second, the figure shows the percentage of consumers in each tier. Only 14% and 3% of consumers are in tiers 2 and 3, respectively but these consumers make up for the revenue loss that the water department has from their conservation minded water structure.

The marginal cost of water treatment and distribution is expensive particularly when the treatment and distribution of the water is energy intensive. This pertains to Los Angeles, Phoenix, and Las Vegas, cities that all face high marginal costs because the water has to be transported for many miles before it reaches the city, often from a lower elevation to a higher one. Also, adding to the costs of water treatment and distribution are the fixed costs, or capital costs for the

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[27] ci.northfield.mn.us

treatment plants, pump stations, and other infrastructure required in municipal water supply systems. According to Hanemann (1993), supplying water is 3 or 4 times more capital intensive than the telephone industry, and 5 or 6 times more than the railroad industry. Given the cost intensive nature of municipal water systems, many stress the costs of new water infrastructure should be incorporated in the price of municipal water.

3.2 Water as a "Commons"

Water is truly unique in terms of distribution, ownership, and price. It's uniqueness stems from the fact that it is considered to be both a private good and a public good (Hanemann, 2005). The term "the commons" was coined by Garrett Hardin in 1968 in "The Tragedy of the Commons" to describe a public space or resource that everyone can enjoy and use, but no one can be excluded from that use (i.e., non-excludable). These characteristics of a non-excludable public resource mean that if too many people use the resource it can be exhausted. This concept can be applied to many public goods, but here I apply it to water. Although water is necessary to life, it is still both an economic commodity and a part of the commons, depending on where it is located, and how it is managed.

As a commons resource, in many ways water is available for the enjoyment and use of everyone who wishes to use it. So long as this commons resource serves everyone's needs, the commons will serve its purpose. However, if too many people enjoy a body of water, the water may become dirty and unfit for use. Or, if too many people withdraw water, the water could simply run out, leaving future generations with none. Although Lake Mead is not a commons resource in terms of extraction, too many users may have the right to extract water from it. This problem is exemplified by the current capacity of Lake Mead, which sits at about 40% (Quinlan, 2010). There are also issues with water as a commons because although a body of water may be a commons, water can still be extracted from this body and sold to consumers, as many municipal water departments do. This creates concerns from users who care about this water as a commons and as a source for municipal water.

3.3 Water as a "Commodity"

"Only what is rare is valuable, and water, which is the best of all things ... is also the cheapest" (Plato, Hanemann, 2005, p. 3). The price of a good sold on the free market is determined by supply and demand of the good. Plato implicitly said that it is important to distinguish between supply and demand. Although something may be in high demand, if it is very plentiful then the supply and demand model predicts that it will be inexpensive. The opposite is true as well. Water is the first type of good—it is relatively abundant in many areas and relatively easy to obtain and distribute in large quantities. Pricing water so that its availability is ensured to everyone is an obstacle in creating conservation minded price structures. Other than this obstacle, water prices are often influenced by elected officials aiming to please their voters, and many people do not want to pay higher water prices, even if they can afford it.

Water is a unique good in that while the supplier is generally a monopolist, it is often the city government. In the United States water is viewed as a necessity that everyone should have access to, and because of that the price of water is highly regulated, and often kept low enough so that everyone can afford it. Monopolists usually have the market power to charge prices that are substantially above cost, but in the case of water, price is often below cost (Pacific Institute, 2007). This is good news for the consumer but in terms of conservation and the actual supply of the water, the price often does not reflect the true scarcity of some water supplies. According to the UN, GWP, and EU (2008) "potable water provision is often supplied directly or regulated by the state, and the price formation will not be an automatic result of supply"(p. 31). Figure 3.3 illustrates municipal water pricing when the supplier has monopoly power and is unregulated.

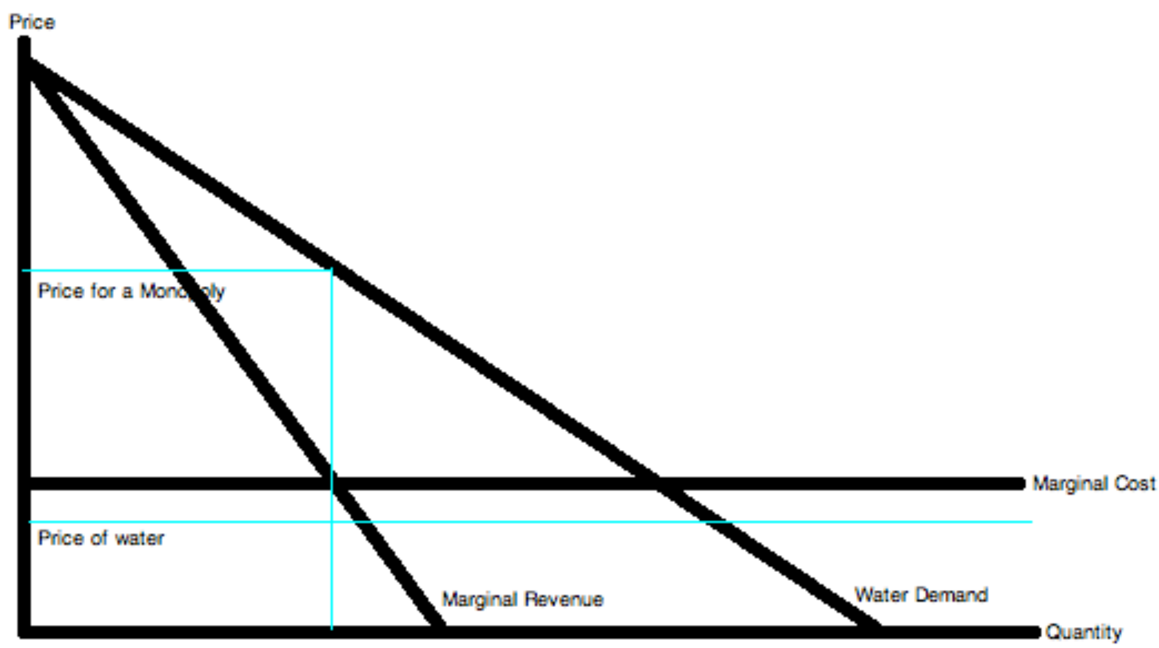

Figure 3.3 Monopoly Pricing in Municipal Water Supply[28].

The lower turquoise line in Figure 3.3 represents the common price of water in US cities. Notice that it is below the line depicting the marginal cost, which means that the supplier is not charging enough to cover their costs. To maximize profits, monopolists charge consumers a price where marginal revenue equals marginal

28 Image courtesy of Deborah Pierce using data collected from this research.

cost, and then where this equals market demand, shown in the figure as the turquoise line labeled "Price for a Monopoly" (the price line is drawn horizontally across to where the lines depicting marginal costs and marginal revenue intersect). Notice that this monopolist's price is much higher than the price of water in most American cities, shown in the figure as the turquoise line labeled "Price of water".

How does pricing relate to sustainability? The low price of water in our society facilitates many uses that are unnecessary and wasteful, especially when the water is not reused. There are many ways to use water pricing to induce consumers to change their behavior, especially when they are using water in ways that are not essential. One example is offering rebates to consumers who buy water-efficient appliances, or who cover their pools to reduce evaporative water losses (The City of Phoenix, 2008). Both activities reduce water use. Another example is water pricing based on quantity of water used, timing of water use, type of use, or quality of water used (Hanemann, 1993). Another example is to meter water use. Pricing and incentives can be used in conjunction with water meters to monitor water use, analyze trends in water use, and for billing purposes.

Understanding how water functions as an economic commodity is important given the implications for policy and management. For example, an important aspect of municipal water use is that consumers have a different elasticity of demand for different uses of water. Consumers using water for drinking, cooking, cleaning, or other basic uses have a very inelastic demand for this water (Hanemann, 2005). An inelastic demand means that if there is a rise in the price of water for these uses (or for the quantities encompassing these uses) then consumers will change their consumption very little (Hanemann, 2005). Consumers using water for watering their lawn, or filling their swimming pools have a more elastic demand for water. These examples illustrate how consumers respond differently to price increases depending on their demand for particular water uses.

Other properties of water as an economic commodity figure into its price as well. These other qualities include location of the water, timing of the distribution, and quality of the water. Water is also important for its intrinsic value, for just existing in nature for future generations. It is hard to place a monetary value on goods that are not sold in the market. Water in lakes, river, and ponds can be thought of in this way.

3.4 Marginal Cost Pricing and the new LADWP water rates

In 1993, Los Angeles was experiencing a severe drought, which induced them to change the way they priced water. The city hired Michael Hanemann at the University of California Berkeley, and his coworkers to devise a new water price system incorporating all facets of supply and demand of municipal water. Hanemann (1993) found that there are many types of demand for water, some with much higher elasticity than others. For example, water used for landscaping and other outdoor uses was much more elastic than indoor uses, such as cooking and cleaning. Outdoor water use was also variable, ranging from 25 gallons per capita per day to over 100 depending on the user and the season. Hanemann (1993) concluded that this elasticity of demand was an important factor in determining the price of water.

A distinguishing feature of Hanemann's rate schedule is that there are only two price blocks. Many other cities throughout the west have four or five rate blocks, which seems like they could be more conservation oriented on the surface. Often however, this multi-tiered rate structure weakens the incentive to reduce water use, especially at very high levels of water consumption (Hanemann, 1993). The strategy underpinning the development of the Los Angeles rate schedule was to reduce water use of the highest users. To effectuate this reduction, Hanemann, (1993) proposed using switchpoints at 175-200% of the median household water consumption. The idea was that if a switchpoint was high enough, it would induce high water users to change their consumption resulting in consumers reducing water use willingly. This strategy targeted the highest users where the city might achieve the greatest impact in reduction, rather than attempting to make almost half of Los Angeles' water users alter their consumption patterns.

Switchpoints changed seasonally and were adjusted as needed based on water availability. In the winter, the switchpoint is 575 gallons/account/day, and 725 gallons/account/day in the summer. During drought years, the switchpoints are reduced in accordance with the severity of the drought (Hanemann, 1993). Adjusting switchpoints in this way meant that water pricing would better reflect marginal costs. Marginal costs are higher during the summer months, which translate to a higher price for water during the summer months. Before the price reform, the price of water was 25% higher in summer months than in winter months, but afterwards, it was 50-70% higher.

3.5 Water pricing and water use in U.S. cities

Walton (2010) undertook a survey across 30 municipalities[29] in the US to compare water rates. Regardless of price, use differs drastically from city to city. Results showed water use varied regionally with water use, with much higher use in dry areas where a lack of rainfall motivated increased use of water for landscape irrigation (Walton, 2010). Water rates were found to be low in the Great Lakes region because cities are located close to their water sources, and water is expensive to transport relative to its value.

In some cities where water use was found to be decreasing, water rates were rising, to make up for the revenue loss. According to Peter Gleick in the Circle of Blue article (2010), this situation represents "a failure of the rate design"(p. 3). Many municipalities operate on a flat budget, which means that if use declines, they will need to offset costs by raising prices. This phenomenon is called the "death spiral", because residents become disenchanted when they use less water yet pay more because of the higher water prices (Walton, 2010). This results in consumers who are less willing to conserve.

The study compares cities in the southwest, such as Phoenix, Las Vegas, and Santa Fe. Santa Fe has reduced per capita water use by 42% since 1995, and has reduced total use by 30%. This reduction is likely a result of a combination of water prices—Santa Fe's water rates are among the highest in the country—and aggressive water conservation and efficiency policies (Walton, 2010). Interestingly, unlike most western cities Santa Fe is building a self-financed water project while

[29] In order to capture all the regional differences, the survey questioned the 20 largest cities in the US, and the remaining 10 were spread out across regions.

pursuing aggressive conservation efforts (Coss et al., 2010). Phoenix on the other hand has some of the lowest rates in the country, and has not reduced total use at all in the last 10 years (Walton, 2010).

According to Reisner (1993) most cities in the West have been spoiled by the federal government's investments in large water projects. Pricing water lower than costs can have serious implications, beyond being detrimental to conservation. For example, Las Vegas' fixed water fee only covers 18% of their fixed costs (Walton, 2010). Selling water at such low rates poses a problem when the city needs to pay for infrastructure maintenance. Unfortunately, much of this infrastructure maintenance does not happen, which leads to other challenges such as deteriorating infrastructure. But, raising the price of water is not a simple undertaking. Water rates are kept low for political reasons because many officials are elected and higher water prices are politically unpopular (Walton, 2010).

Other cities in the west have taken varying approaches to conserve water. Tucson introduced a tiered water system earlier than Las Vegas or Phoenix to increase water conservation and pay for the infrastructure maintenance needed (Walton, 2010). At first this increase was met with a stinging backlash from residents and businesses (Walton, 2010). However, this started a wave of tiered and seasonal water pricing across the country. The Irvine Ranch Water District (District) in California is used as model for many western water agencies. The water rates are very low, but the water use is very low as well. This is possible because of the situation in the District. Using more water is very expensive because the water must be imported from the Colorado River (Walton, 2010). The Irvine Ranch Water

District model does not work for all western cities, especially those who rely primarily on expensive sources of water.

3.6 Hidden Oasis

A study undertaken by the Pacific Institute and Western Resource Advocates (2007) found that in Las Vegas outdoor and indoor water use can be reduced by 40% each by installing water efficient appliances, and using water efficient landscape practices. These findings suggest that Las Vegas should be focusing its conservation efforts on both outdoor and indoor use. In reality, Las Vegas is concentrating much more on outdoor use, because outdoor use in the summer can be very wasteful. The Pacific Institute (2007) also suggested that Las Vegas should focus on reducing demand instead of increasing supply.

According to the Pacific Institute (2007), the water price structure used by Las Vegas does not encourage conservation because it has high fixed rates with small increases in per unit costs. Instead, Las Vegas should implement a tiered price structure with very low flat rates and sharply increasing rates for higher levels of consumption, especially for very large quantities (Hanemann, 1993). A key limitation to the study was that it lacked data for non-residential and multi-family users.

3.7 Sustainability Definition

According to "Economics in Sustainable Water Management", a joint study between the United Nation (UN), Global Water Partnership (GWP), and European Union (EU) Water initiative, a multi-sector approach is the best method for moving towards sustainable water management (2008). The UN, GWP, and EU Water

Initiative (2008) also stress the importance of working with diverse interest groups that have a stake in the water issue and of looking at the watershed of a river or river system, instead of using political boundaries. According to the UN, GWP, and EU Water Initiative (2008), sustainability cannot be achieved using a siloed approach. Rather, all sectors and levels of governance must be integrated: environmental, political, social, cultural, economic, financial, and legal sectors.

The UN, GWP, and EU Water Initiative (2008) take a global view and in doing so the guidebook is meant to be broadly applicable. Still, many of the ideas from this guide can be applied to a more regionally specific sustainability context with a few exceptions. For example, the sustainability criterion for the involvement of women in decision-making is a more important criterion in developing countries than in the U.S. But, other criteria such as the involvement of all relevant stakeholders, seemed applicable and important for this regional context. By combining portions of the study by the UN, GWP, and EU Water Initiative (2008) with economic concepts of water management, I crafted a set of sustainability criteria. These criteria focus on water pricing as a means of reaching sustainability.

1. **Rivers must flow, if not naturally, then enough to support a healthy ecosystem of plants and animals. Other natural bodies of water must also be maintained to ecologically healthy levels.**
2. **The water management must be economically efficient. This means that social surplus must be maximized.**

3. The water management must be socially equitable. All stakeholder groups should be involved in decision making, regardless of their size or importance.

4. The price of the water should reflect both the costs involved in distributing the water as well as the scarcity of the water supply. A diverse water resource portfolio results in an improved score. All improvements in infrastructure should be considered in the price of water.

5. The distribution and pricing of water should consider climate change projections for the region, and included in all decision-making. If climate change is not mentioned specifically, there should be a good effort towards reducing demand, with rigorous conservation policies.

6. The price structure of the city and the policies of the city in question must show that GPCD decreased due to its implementation.

The first criterion is based on the importance of the intrinsic value of ecosystem services. Ecosystem services can be defined as the natural benefits that humans and other animals receive from a healthy ecosystem. Not only should rivers flow naturally, all natural aquatic ecosystems should be maintained at a healthy level. Ecosystems can be thought of as a commons, that everyone should have access to without being degraded. Criterion 2 is based on the theory that policies should be economically efficient. Dead weight loss is an economic benefit that is lost due to inefficient policies (Hanemann, 1993). However, sometimes policies aim to minimize the dead weight loss, because sometimes dead weight loss is necessary for equity reasons. For example, with all taxes and subsidies there is some dead weight loss involved, but sometimes taxes and subsidies are necessary for equity and other public policy reasons. Social surplus is the total benefits to society from a policy. I consider Criterion 2 to be met if the policy addresses social surplus.

Criterion 3 addresses issues of equity in a policy. A policy must target everyone in society equally, without widening any gaps in income, education, or awareness. Different price structures have different implications for equity. Tiered structures, with low fixed costs, and increasing gaps in tiers are good for equity because it allows users to purchase water for a very low price at low quantities of consumption. If every consumer is faced with the same price for each unit of water, then those who can easily afford to pay for water can use as much as they want, and only pay slightly more than those who have a harder time paying for their water.

Criteria 4 and 5 connect the importance of price with sustainability. Criterion 4 discusses how water prices are determined and whether the city has a diverse water source portfolio. Criterion 5 discusses the importance of climate change in water policy-making. Climate change is difficult to define and incorporate in policy-making. When policy-makers are aware of the possible effects of climate change on precipitation, and therefore water supplies, this is an important step in incorporating climate change into policy and planning.. Criterion 6 ensures that there is direct evidence that the price structure caused GPCD to decrease.

Chapter 4

Materials and Methods

This section describes data collection, data sources, and analytical approaches. First, I describe data collection on the price of water in Phoenix, Las Vegas, and Los Angeles and average GPCD water use in each city over the last 20 years. Next, I describe how I obtained information about the major conservation policies implemented in Phoenix and Las Vegas in the past 20 years. Then, I discuss the development and administration of a survey via email to water departments in Phoenix, Las Vegas, and Los Angeles. Finally, I describe the analytical approaches—evaluating conservation policies with water use trends and evaluating current pricing, consumption, and policies in Phoenix and Las Vegas to determine their relative sustainability score using my sustainability criteria.

4.1 Data Collection

I collected data on water price systems using a combination of surveys of water department employees, city website information, and data collected from various studies. City websites and previous studies provided most of the data. City websites were an integral source of information for both quantitative and qualitative data. In addition to information about water pricing and water use, city websites provided accessible information about population size, average income, water sources, and population growth. Furthermore, I collected qualitative data such as policies implemented in the last 20 years, conservation plans, sustainability plans, and phone numbers and email addresses of water department employees for use in survey administration. Information from sustainability plans was particularly important because these plans contained information that was not easily accessible elsewhere on the city websites. The plans also contained quantitative data such as a breakdown of the amount of water used for different purposes, such as indoors versus outdoors, and additional information about how many of each type of users there were in each city.

Besides websites, another important source of data on current water pricing schemes and per capita use for Los Angeles, Phoenix, and Las Vegas and other U.S. cities were peer-reviewed and other published literature. Although city websites were an important resource, I had concerns that the websites would be biased whereas independent research might provide a more objective view of each city and cross-city analysis. For example, I obtained data on the average water price in each city for a family of four consuming 50, 100, and 150 GPCD from Walton (2010) at the Circle of Blue. The Circle of Blue is a non-profit network of journalists and scientists, and is an affiliate of the Pacific Institute. This data was helpful because it gave me a sense of how water is priced differently in the three cities that are the focus of this thesis.

Independent research articles and reports also provided a different perspective for the rationale underlying certain policies that differed from that stated by representatives working for the city. Furthermore, independent research often offered critiques of existing policies or arguments for a different policy. For example, Hanemann (1993) was useful because the author provided sound justification for a new price structure for Los Angeles that encouraged conservation.

In addition, I gained a better understanding of why the Blue Ribbon Committee was helpful to Los Angeles, why the water rate was beneficial, and some of the economic conditions behind municipal water rate setting. The Pacific Institute (2007) was useful because the authors provided an independent analysis and critique of water management in Las Vegas and usefully compared management in Las Vegas to other cities. In addition, I found Walton (2010) useful because it provided background on the tough choices that municipalities are faced with when choosing water rates. In addition, the articles helped formulate the development of the questions of the survey that pertained to profits and how water rates are set.

Survey data supplemented the publicly available data. Surveys were administered by email to individuals at water departments of each city. Besides providing supplementary information not otherwise obtainable, survey questions were aimed at providing information for the sustainability criteria analysis. Survey questions covered a number of topics including water pricing such as understanding costs incurred with the distribution of water, and how the price of water was determined. These survey questions are located in the appendix. Direct answers on how prices were set informed my decision on whether or not certain sustainability criteria were met. In addition to questions about water pricing, water departments were also queried about major policies implemented in the last 20 years, as well as the GPCD in the city over the past 20 years. If these data were not available, I used

GPCD for residential users[30]. In some cases, a combination of data obtained from survey respondents and data obtained from water department websites were used.

Average daily use per capita (GPCD) was used for a couple of reasons. First, the concept is relatively easy to understand while also being valuable for comparative purposes. Secondly, it is also a good statistic for tracking conservation, because other water use data such as total daily use do not capture changes in population. Understanding how water use changes with population is essential for conservation efforts, especially in many western cities that are experiencing rapid population growth. Although the total water consumed in a city can be a useful statistic when dealing with shortages in water supply, my interest was in understanding reduction in water demands. For reducing water demand, the total water consumed is not as meaningful a measure.

4.2 Data Analysis

Once I collected all the data, I compared current water price structures in Phoenix and Las Vegas to determine the conservation implications for specific parts of each of the price structures. I then analyzed the price structure in Los Angeles, to understand if that price structure was better for conservation than the price structure in either Las Vegas or Phoenix.

Once the analysis of the price structures was done, I compared average water use per capita in Phoenix, Las Vegas, and Los Angeles. I looked at GPCD over the past 20 years for each of the three cities. I decided to use GPCD in the past 20 years as a parameter because the change in pricing in Los Angeles occurred in 1993,

[30] This was appropriate because single-family residential users comprise the largest group of water consumers or the largest use of water in the three cities.

which was a little less than 20 years ago. Twenty years is also long enough to cover the changes that could have occurred due to understanding about conservation. For Las Vegas at least, changes in water use and/or pricing occurred 10 years or less ago, which means that the 20-year threshold should more than cover these changes.

After I determined the average per capita water use in each city over the last 20 years, I then looked at specific policies that have been implemented in Phoenix and Las Vegas to see if any of these could have potentially affected demand in the last 20 years. In the case Los Angeles, I am not looking at policies implemented in the last 20 years, because I only want to know the effect of the price structure on consumption. The framework for data collection and analysis is shown in Figure 4.1.

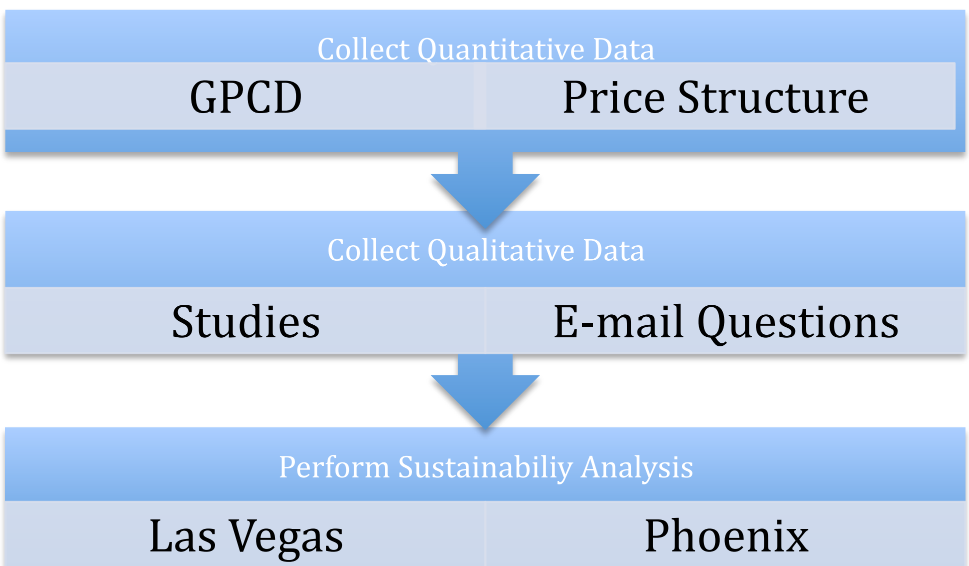

Figure 4.1 Framework for data collection and analysis

4.3 Sustainability Analysis

Once I analyzed my data and the relevant policies implemented in the last 20 years, I compared current per capita use, pricing, and policies to the five criteria for sustainability to determine to what extent the management and policy approaches met the criteria. This was a qualitative analysis based on information about the policy or pricing. If a specific policy or pricing scheme was found to be unsustainable, I provided several solutions to the problem. I also suggested possible obstacles to sustainable use and policies, such as political, technological, or monetary obstacles. I expected that none of the three cities will meet all my sustainability criteria, but I provided specific feedback on why a criterion was not meet and how to meet it.

The sustainability analysis is based on both quantitative and qualitative data on the use and management of water resources in each city. To obtain a quantitative measure of sustainability, I assigned each city a sustainability score, ranging from 1 to 10, with 1 being the least sustainable, and 10 being the most. I began with an analysis of each city's sustainability or conservation plan looking for key words or phrases such as "reducing demand", "pricing as a conservation tool", "ensuring future supply", "public input", "ecosystem health", "regional wide plans", and "climate change". These words of course do not have to be exact, but when I saw phrases and words that were similar, then this counted towards the sustainability score. In general, I considered policies to be more effective if they were especially specific and binding in their requirements. Then, I evaluated the water pricing and water use data and the analysis described in Section 4.2 along with analysis of other relevant water management information and assigned specific sustainability scores for each criterion. The sustainability score is based on the following analysis of sustainability criteria:

1. **Rivers must flow, if not naturally, then enough to support a healthy ecosystem of plants and animals. Other natural bodies of water must also be maintained to ecologically healthy levels.**

This criterion will be analyzed based on the amount of water that has historically been present in the water system. In other words, there should not be further depletion of bodies of water, or degradation of the quality of water. This is important for long-term ecological sustainability of freshwater systems. Satisfying this requirement earns a score of 1.5.

This criterion is receiving a score of 1.5 because it is very important to have water sources that are not being depleted, and that can support a healthy ecosystem.

2. **The water management must be economically efficient. This means that social surplus must be maximized.**

This was analyzed based on the water departments' profits. If I found that a city was pricing water below costs resulting in negative profits, this was considered economically unsustainable, and I recommended a new price structure. Satisfying social surplus means that the outcome that is best for society is chosen. Satisfying this requirement earns a score of 1.3.

This criterion received a score of 1.3, because while I considered it important, it is also possible for a city to be close to satisfying this requirement while having inefficiency in some aspects of its management. However, when I saw that the focus was on the social surplus, this improved a city's score.

3. The water management must be socially equitable. All stakeholder groups should be involved in decision making, regardless of their size or importance.

This was determined by language used in the sustainability plans of the cities. If a city discussed how policies are implemented with stakeholder involvement and other interest groups, then this criterion was satisfied. I considered this to be important even if including all interest groups can be difficult and sometimes less efficient in passing policies. Satisfying this requirement earns a score of 1.5.

This criterion received a score of 1.5 because I considered equity and ecological health to be of similar importance.

4. The price of the water should reflect both the costs involved in distributing the water as well as the scarcity of the water supply. A diverse water resource portfolio results in an improved score. All improvements in infrastructure should be considered in the price of water.

Survey data and information available on city websites were evaluated. All requirements have to be met to merit the full score. Satisfying this requirement earns a score of 2.

Because I am focusing on the importance of price in reducing demand and moving towards sustainable water management, I considered this to be vital to the sustainability definition.

5. The distribution and pricing of water should consider climate change projections for the region, and included in all decision-making. If climate change is not mentioned specifically, there should be a good effort towards reducing demand, with rigorous conservation policies.

This information was found in the sustainability plans for each city. Any mention of planning for climate change, and actual activities to implement plans satisfied this requirement. Satisfying this requirement earns a score of 1.5.

This received a score of 1.5 because I think reducing demand in ways other than pricing often happens. A focus on the importance of reducing demand, rather than solely increasing supply is important for this criterion. Methods of reducing demand include but are not limited to programs that provide incentives for the installation of water efficient appliances and education programs on water scarcity.

6. The price structure of the city and the policies of the city in question must show that GPCD decreased due to its implementation.

This will be determined by examining the data on GPCD in each city over the past 20 years, and lining this up with major policy and price changes in the past 20 years. Satisfying this requirement earns a score of 2.2.

I considered this criterion to be the most important, giving it a score of 2.2. If there has been evidence in the city of reduced GPCD due to policies or pricing, then this is an integral part of sustainability.

Each individual sustainability score adds up to 10. Each score was determined by understanding of what is most important in the sustainability of water management in this region. For example, criterion 6 has a full sustainability score of 2.2, because I believe that direct evidence of a price structure that encourages conservation is a very good sign of sustainability potential in water sources management, and ensuring water supplies for the future. Other criterion that are harder to determine, and may not be as important, such as criterion 2, which received a lower score. Also, there was the possibility that some cities would meet part of a criterion but not another. In this case, I used my discretion to award part of the score. Finally, I group obstacles into 3 groups, which are: social, political, and economic obstacles. I then analyze these obstacles and try to provide solutions.

4.4 Limitations

There were many limitations in this study, both in terms of the variables themselves, and how the data was collected. First, GPCD per year only covers the average use of everyone in the city, so in order to understand variations in use by season, use of water, and specific consumers we have to rely on other data. GPCD by month is a more specific measurement of GPCD that is very useful, but unfortunately I could only find this data for Phoenix. To capture the differences in uses of water, and the different elasticity of demand associated with these uses, we must rely on different data. This information came from previous studies.

Another limitation is that it was hard to determine the validity of all my data. Population of each city varied from websites, so I ultimately tried to retrieve all my data from the city websites to be consistent, and attempt to be as accurate as possible. However, there was other data that was not available on city websites, such as precipitation and average temperatures. GPCD values also varied quite a lot from the data in the Circle of Blue articles to the values on city websites. Circle of Blue values were much lower, but I determined that the reason for this was because these were purely residential values.

Chapter 5

Results and Discussion

"In a society in which water is really considered a scarce resource and water tariffs are set up to reflect the total economic value of water, it will be easier to generate financial resources for water management" (UN/GWP/EU, p. 20, 2008). It is this consideration of water as a scarce resource that leads to more appropriate pricing, which is exactly what should be occurring in water scarce cities such as Las Vegas and Phoenix. However, pricing water appropriately is merely one aspect of the sustainability definition. According to Udall in *Cadillac Desert* (1993),"We need to be making major policy changes to Western water, and a lot of people aren't willing to do it until you have a full-fledged crisis on your hands."(Reisner, 209). While crisis is often a motivator, it is the aim of this thesis to bring the importance of sustainable water management to the forefront today without a needing crisis to instigate it.

5.1 Water Pricing

Characterizing differences in price structures is important because certain pricing structures can be more successful than others in conserving water (Hanemann, 1993). Different factors affect the price of water in each city. The most common factors affecting price are time of year or season and quantity of water used. For example, Phoenix designates high use months, coinciding with the summer, when water is priced higher. Las Vegas does not use the seasonal approach. Instead, it has higher prices based on quantity used, so that the more water used, the higher the per-unit price. Los Angeles combines these approaches by setting prices for both high use months and for larger quantities of water consumed. Differences in pricing approaches are summarized in Table 5.1.

Table 5.1 Factors affecting water prices

City	Pricing Factors
Las Vegas	Increasing tiered based on quantity
Phoenix	Increasing based on season
Los Angeles	Increasing tiered based on season and quantity

5.1.1 Phoenix and Las Vegas

To illustrate the differences in pricing approaches and to facilitate a comparative analysis of pricing across the three cities, pricing data were collected from each city's respective website. These data include meter pricing and seasonal and tiered pricing. Meter pricing is a flat rate based on the capital requirements of supplying water to different sized meters (Walton, 2010). Different consumers have different sized meters, depending on their need for water and the size of the building where water is being supplied. Comparing meter pricing in Phoenix and Las Vegas it is clear that water is more expensive in Las Vegas. The flat price for metering across each size category is almost twice as much in Las Vegas compared to meter prices in Phoenix. Meter prices are summarized in Tables 5.2 and 5.3.

Table 5.2 Meter pricing in Phoenix[31].

Meter size	Price per Month(inside city)
5/8 inches	$4.36
¾ inches	$4.45
1 inch	$4.49
1.5 inches	$5.57
2 inches	$5.97
3 inches	$20.23
4 inches	$22.56
6 inches	$24.61

Table 5.3 Meter pricing in Las Vegas (SNWA, 2009)

Meter Size	Price per Month
5/8 inches	$10.06
¾ inches	$11.59
1 inch	$14.46
1.5 inches	$22.26
2 inches	$31.42

The situation is different in the comparing of seasonal pricing in Phoenix to tiered pricing in Las Vegas. The marginal rates (by month in Phoenix, and by volume in Las Vegas) are lower for the lowest tier in Las Vegas and higher for the highest tier than any of the monthly marginal prices in Phoenix. Another difference is the price range across seasons or tiers. The marginal prices in Phoenix are all very similar in price, while the marginal prices in Las Vegas have a wider range in price. Marginal prices by season or tier are summarized in Tables 5.4 and 5.5.

Table 5.4 Seasonal water pricing in Phoenix[32]

Season	Price
Low: December-March	$2.18
Medium: April, May, October, November	$2.69
High: June-September	$3.51

[31] This data is from the city of Phoenix website and does not include pricing outside the city of Phoenix. The prices here are added on to the price by meter in table 5.2.
[32] This data is from the city of Phoenix website and does not include pricing outside the city of Phoenix. The prices here are added on to the price by meter in table 5.2.

Table 5.5 Tiered pricing by volume of water consumed in Las Vegas (SNWA, 2009)

Tier[33]	Threshold in 1,000 gallons	Price/1,000 gallons
1	0-5	$1.16
2	5.01-10	$2.08
3	10.01-20	$3.09
4	20.01 and over	$4.48

[34]

According to Hanemann (1993), pricing can encourage water conservation by introducing a price signal strong enough to alter consumption patterns. Given the higher flat rate and tiered pricing observed in Las Vegas, its pricing structure is likely to exert a stronger pricing signal than the price structure used in Phoenix. Therefore, Las Vegas' price structure is likely more encouraging of water conservation than Phoenix. Las Vegas' stronger price signal is administered in two ways: first, through more extreme price differences in marginal prices and second, through higher price points for almost every meter and threshold of water consumption. Higher prices encourage conservation because people want to save money, and therefore will consume less water (Kenney et al., 2001). However, compared to other desert cities, such as Santa Fe and Los Angeles, these cities have relatively inefficient water price systems given the much higher level of water consumption. An example of relatively efficient water pricing in an arid, southwestern city can be found in Los Angeles.

[33] This data is from the city of Phoenix website and does not include pricing outside the city of Phoenix. The prices here are added on to the price by meter in the table above.
[34] http://www.lvvwd.com/

5.1.2 Los Angeles

The price structure of Los Angeles is more complex than the price structures employed in Phoenix and Las Vegas because Los Angeles' prices encompasses price changes by tier and by month. There are no fixed monthly costs in Los Angeles. At first glance, the price of water appears less expensive here than in Phoenix or Las Vegas. But, in fact, pricing in Los Angeles exerts a much stronger price signal on consumption than either Phoenix or Las Vegas. To see this, we need to dissect the price structure to better understand how pricing affects water consumption.

Hanemann (1993) developed Los Angeles' new tiered price structure, justifying the new system by stating that two tiers that are extreme reward low water users with low prices, and punish high water users with high prices. In theory, the very high prices for Tier 2 make up for the revenue loss from low Tier 1 prices. Tiers are determined by three factors: lot size categories, temperature zones, and lot size. Generally, an individual with a smaller house and lot and who resides in a cooler temperature zone relative to other households in Los Angeles, will have most of their water consumption in Tier 1.

Both Tier 1 and Tier 2 prices vary according to the season. Each season is further divided into three quartiles, with four quartiles total. The quartiles are based on months and water use during those months. For example, in both Tier 1 and Tier 2, the high season encompasses all of Quartile 1 (Q1), corresponding to July through September, Quartile 2 (Q2) corresponding to the month of October, and the month of June corresponding to Quartile 4 (Q4). Similarly for both tiers, the low season encompasses November and December of Quartile 2, all of Quartile 3 corresponding to January through March, and April and May of Quartile 4. Each quartile within a high and low season has its own designated price. The tiered pricing is summarized in Table 5.6.

Table 5.6, Tier 1 and Tier 2 Pricing[35]

Tier 1			
High Season	Q1: July-September	Q2: October	Q4: June
Price	$3.77	$3.74	$3.73
Low Season	Q2: November, December	Q3: January-March	Q4: April-May
Price	$3.74	$3.73	$3.73
Tier 2			
High Season	Q1: July-September	Q2: October	Q4: June
Price	$5.69	$5.83	$5.94
Low Season	Q2: November, December	Q3: January-March	Q4: April-May
Price	$5.83	$5.94	$5.94

A comparison of the tiered pricing summarized in Table 5.6 reveals Tier 2 is significantly more expensive than Tier 1. This difference in price exerts a strong price signal that discourages consumers from consuming water at high volumes that would cause them to enter into Tier 2 pricing. The switchpoint from Tier 1 to Tier 2 is 400-600[36] gallons per account per day, which is a reasonable volume of water sufficient for the core household uses plus some outdoor uses in an average household. Once the use of water goes above this core use threshold, the household faces Tier 2 pricing. The switchpoint used in Los Angeles' tiered pricing is higher than that used in many other city's increasing block rate structures. On average, Tier 2 is roughly $2 more per unit of water than Tier 1 making Tier 2 pricing

[35] Las Angeles Department of Water and Power, does not include prices for the 2009-2010 price year.
[36] This assumes that the average household has five people, and indoor use is between 70-80 gallons per day with basic outdoor use (Hanemann, 1993).

significantly more expensive than Tier 1 pricing. Interestingly, the high season prices in Tier 2 are less expensive than the low season prices in Tier 2, except for Q4 where it is the same. In contrast, in Tier 1, the high season prices match low season pricing except for Q1, the months corresponding to highest demand.

While Hanemann (1993) theorized Los Angeles' new price structure would encourage more water conservation, just because Los Angeles' pricing structure is set up to be more conservation oriented does not mean that this goal is achieved. To truly understand if the price structure of Los Angeles encourages more conservation than that of either Phoenix or Las Vegas, we must look at price in relation to per capita water consumption (GPCD) in each city today, and how price and water use have changed over the past 20 years.

5.2 Per Capita Water Use

An important first step is to establish a means to make an apples-to-apples comparison of the price of water in each city. To do this, I examine the average cost of water for a family of four in each city assuming 50, 100, and 150 GPCD rates of consumption. The data are summarized in Table 5.7.

Table 5.7, Per capita water use in Phoenix, Las Vegas, and Los Angeles (Walton, 2010)

City	Amount of water consumed (GPCD)	Average monthly bill for a family of four
Phoenix	50	$11.02
	100	$34.29
	150	$59.84
Las Vegas	50	$17.18
	100	$32.93
	150	$52.73
Los Angeles	50	$27.18
	100	$58.49
	150	$99.07

As shown in Table 5.7, the price of water in Las Vegas and Phoenix for a family of four is similar. Water is slightly more expensive in Las Vegas than in Phoenix at 50 GPCD. However, as consumption increases, prices in Phoenix increase at a faster rate than prices in Las Vegas. A family of four in Phoenix pays more for water at both 100 and 150 GPCD of monthly consumption than a family of four consuming the same amount in Las Vegas. Because Las Vegas has an increasing block structure based on volume, water actually becomes cheaper at larger consumption rates than water in Phoenix, which has a uniform price structure.

Water prices in Phoenix and Las Vegas are substantially cheaper than Los Angeles, across all consumption amounts. At the lowest level of consumption a Los Angeles family of four pays on average $13 more per month. At 100 and 150 GPCD, the average Los Angeles family pays on average $25 or $43 more per month, respectively. Over a year, the Los Angeles family consuming 100 GPCD spends over $700 for water or roughly $300 more than a family consuming the same amount in Phoenix or Las Vegas. When price structures are made comparable and more tangible, it is clear residential water use in Los Angeles is significantly more expensive than residential water use in either Phoenix or Las Vegas.

Residential water users are the largest group of water users in all three cities. An important difference to note here is how the residents in each city use their water. Residential water use in Los Angeles represents about 75% of the total water used in Los Angeles[37]. On the other hand, in Las Vegas single-family residential users make up only 40% of the total water use in Las Vegas, whereas multi-family residents contribute 14% of total demand (Pacific Institute, 2007). Commercial water use in Las Vegas—casinos and resorts—make up only 7% of total water demand[38]. In Phoenix, single-family residential and multi-family users comprise 51% and 17% of the demand, respectively. Non-residential users contribute 31% of water demand in Phoenix. Even with these differences in types of uses and use sectors, it makes sense to focus on single-family residential use because pricing for other uses is not available. Furthermore, the elasticity of demand of some residential uses (e.g. outdoor uses), supports the argument for focusing residential water demand. In Los Angeles, single-family residents use 40% of their water outdoors (Villaraigosa, 2008). According to the SNWA, 70% of residential water is used outdoors, while 20% of casino and resort water is used outdoors (2009). Because the elasticity of demand for water used outdoors is much higher than for indoor uses, outdoor water use should be targeted in policies. To

[37] http://www.ladwp.com/ladwp/cms/ladwp000509.jsp

[38] The reason for this low demand is because there are many regulations placed on water use by casinos and resorts in Las Vegas by the SNWA.

further understand differences in pricing requires a closer look into the policies of each city.

5.3 Policy Analysis

To understand the sustainability of water management in each city requires an examination of policies in each city aimed at either increasing municipal water supply or reducing water demands. First, it is important to understand the organizational structure involved in managing water resources noting how water is managed differently in these three cities. Water in Los Angeles is managed by the Los Angeles Department of Water and Power (LADWP), with some oversight from the Metropolitan Water Authority that oversees all water management in Southern California. Water in Las Vegas is managed in a similar way, with a regional overseer and then a city department. The Southern Nevada Water Authority (SNWA) oversees the region of Southern Nevada that includes Las Vegas, and controls much of the information sharing and conservation efforts. The Las Vegas Valley Water Authority (LVVWA) is the governing body for the city of Las Vegas and is responsible for setting water rates for the city. Water in Phoenix is managed somewhat differently than Los Angeles and Las Vegas in that there is no regional governing body. Water is managed only by the city of Phoenix.

5.3.1 Los Angeles

Los Angeles has a sustainability program that was released in 2009, and has 11 components. These components range from renewable energy and green jobs to air quality. However, the component that is the most relevant to water is the sustainable water supply component. This component was prompted by the drought that Los Angeles experienced in 2007 which caused many of Los Angeles' water supplies to decrease at the same time. For example, the drought reduced supplies that Los Angeles normally receives from northern California via the LA Aqueduct[39,40]. This situation caused Los Angeles to rethink the vulnerability of their water supplies across all water needs and resulted in the 2009 Sustainability Plan (LADWP, 2009).

There are five action area categories that the LADWP determined are necessary to take in order to reach a sustainable water supply[41]. Of most relevance here is increasing water conservation. Los Angeles began implementing conservation measures in 1986 when water use peaked in Los Angeles, and there was a severe drought (Villaraigosa, 2008). For example, Los Angeles reduced water use by increasing the installation of low flow fixtures, including low flow toilets and clothes washers in the residential high efficiency clothes washer rebate program. Measures like these helped the city to reduce per capita use so that the city residents now uses as much water as they did 25 years ago, with 1 million more people (Villaraigosa 2008). However, like many other western cities, Los Angeles has done about all they can to lower indoor water use given the saturation of the low flow appliance market. Now, Los Angeles plans to focus on increasing outdoor water efficiency because there is more reduction available due to the high outdoor

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[39] http://www.nbclosangeles.com/news/local/California-Delta-Smelt-111925459.html

[40] Water transfers to Los Angeles were reduced to protect the delta smelt.

[41] 1. Increase water conservation, 2. Maximize water recycling, 3. Enhance stormwater capture, 4. Accelerate clean-up of the San Fernando groundwater basin, 5. Expand groundwater storage.

water use. Los Angeles intends to implement an irrigation controller program to reduce outdoor water use.

Sustainability plans are an important step for a city, because they suggest cities are thinking about sustainability in a broad sense, they are developing their own definitions and interpretations of sustainability, and they are directing some resources towards achieving sustainability. In the case of Los Angeles, while they did define sustainability, they still discussed it in broad terms.

5.3.2 Phoenix

Phoenix also has a sustainability program. They have 10 components to their program[42], but as with Los Angles, my focus is on the water component. Within the water section there are many sub-components, but I focus my analysis on those that are most relevant to this thesis: the water utility and resource sustainability sections. The water utility section mentions Phoenix's successes, such as 100% metered connectivity since the mid 20th century, and implementing a seasonal water rate structure since 1990 (Personal Communication).

Many of the major conservation efforts in Phoenix in the past 20 years have focused on groundwater. These efforts began with the 1986 Groundwater Management Act (GMA), a statewide policy that required significantly decreasing groundwater use (City of Phoenix, 2008). At the time, Phoenix relied heavily on groundwater to supply 35% of municipal water. This reliance on groundwater resulted in the resource being mined unsustainably. A focus on reducing

[42] 1. Environmental leadership, 2. Climate Action, 3. Land use, 4. Parks and open space, 5. Pollution prevention and recycling, 6. Air quality and transportation, 7. Green buildings and energy, 8. Water, 9. Riparian area restoration and preservation projects, 10. Historic preservation.

unsustainable groundwater use (i.e., mining of groundwater) resulted in a substantial reduction in groundwater use from 35% of municipal water to 3% today (City of Phoenix, 2008).

The Central Arizona Project (CAP) was key to groundwater use reduction in Phoenix. CAP enabled the drastic reduction in the reliance on groundwater for water supply by making it easy to switch to greater reliance on surface water from the Colorado River. The CAP brought Colorado River water to Phoenix from near Lake Havasu through a canal. The first water deliveries reached Phoenix in 1993[43]. By 2005, Phoenix had accomplished a near full reversal using Colorado River water and other surface water for 90% of its water supply. This reduction in groundwater mining means Phoenix gained ground, moving towards improved water resources sustainability. Phoenix also has a long-term water resource plan that is updated regularly (City of Phoenix, 2008). Looking to the future, Phoenix plans to research ways to increase water supply.

Phoenix has had a conservation program since 1986, which includes education initiatives like Project WET, the retrofitting of water efficient appliances, and water efficiency requirements for new development. Project WET, an educational program for educators in Arizona, has been implemented in schools throughout Arizona[44]. Phoenix also employs innovative recharge and reclamation programs, which helps increase flexibility and water use efficiency (City of Phoenix, 2008). According to the city of Phoenix, per capita use has decreased by 20% over the last 20 years. This improvement in GPCD is commendable. However, it is

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[43] http://www.phoenix.gov/waterservices/wrc/yourwater/history/index.html
[44] http://phoenix.gov/waterservices/wrc/school/index.html

difficult to discern how much of the reduction is attributable to conservation programs and policies or is a result of other factors such as the current economic conditions. Another problem is that conservation of residential demand is not discussed.

The City of Phoenix plan does not discuss water pricing in much detail. The city uses a seasonal price structure to promote conservation through higher prices during summer months. On the other hand, the sustainability plan is explicit about supply side policies it has undertaken or will undertake, but demand side policies are not mentioned as frequently as in the sustainability plans of Los Angeles and Las Vegas. While there is a climate change and conservation section, the only conservation initiatives that are mentioned are education programs and retrofitting appliances. There is no mention of how demand will be reduced in the future to ensure sustainability. Water conservation is also discussed at the department level, for parks and recreation and other city departments (City of Phoenix, 2008). Phoenix does not mention planning for climate change explicitly, or any of the specific effects of climate change on the region.

5.3.3 Las Vegas

Las Vegas does not have a sustainability program, but it does have similar initiatives to both Phoenix and Los Angeles. The SNWA is responsible for the conservation efforts for water in Las Vegas. The conservation plan encompasses the seven water agencies in the Southern Nevada region and includes both strategies for reducing water demand and increasing supply, and addresses the problem of demand hardening. Demand hardens as consumers conserve more and more water and after a time it becomes increasingly hard to reduce demand further because there are fewer non-essential water uses in the system. This problem is especially acute in Southern Nevada, because almost all of Southern Nevada's water comes from the Colorado River (SNWA, 2009).

Starting in 1996, the SNWA set GPCD reduction goals for a given year. The first GPCD goal was a GPCD of 280 by 2010, and when this goal was met, the second goal was a GPCD of 250 by 2010. Both goals were met earlier than expected due to aggressive demand side policies, such as the highly successful landscape removal rebate that paid consumers to remove their lawns in return for monetary compensation. The current conservation goal is to reach 199 GPCD by 2035. The SNWA has a set of measures they are using to reach their conservation goal of 199 GPCD by 2035. Most of these measures are meant to reduce demand rather than increase supply. These include water rate setting, conservation incentives, regulation, and education. Taken together these four measures work to promote efficient water use.

Another important conservation strategy for the SNWA is return flow credits. Any water not used consumptively can be returned to the Colorado River resulting in a return flow credit that enables that amount of water to be diverted and used again by Las Vegas. If Las Vegas can increase the amount of return flow credits, they can drastically increase their water supply by recycling the water they use. Indoor water is already mostly recycled at the treatment plant, but expanding this would increase the amount of return flows for Las Vegas.

Las Vegas is the only city that equates water pricing with a conservation measure. On the other hand, both Phoenix and Los Angeles characterize their price structures as creating a situation that increases water use efficiency, but Las Vegas is the only city to use water pricing explicitly to conserve water in the future. The price structure in Los Angeles was implemented to protect against drought more than to conserve water, although it did a good job of both. The LVVWA has had an increasing block structure since 1994. According to the SNWA an increasing block rate structure is more effective than other conservation measures that could result in demand hardening over time.

5.4 History of Major Price Changes and Policies in the last 20 Years

5.4.1. Phoenix[45][46]

The majority of Phoenix's policies in the past 20 years have been supply oriented, in that they attempt to increase the sustainable supply of water to Phoenix. The supply focus is evidenced in the switch from an unsustainable reliance on groundwater to potentially more sustainable (or at least "renewable") surface water supplies from CAP. Even with this supply side focus, Phoenix has aggressively pursued reuse and has enacted numerous conservation-oriented policies over the years to manage demand. The effect of these policies on reducing per capita water use in Phoenix over the past 20 years is shown in Figure 5.1.

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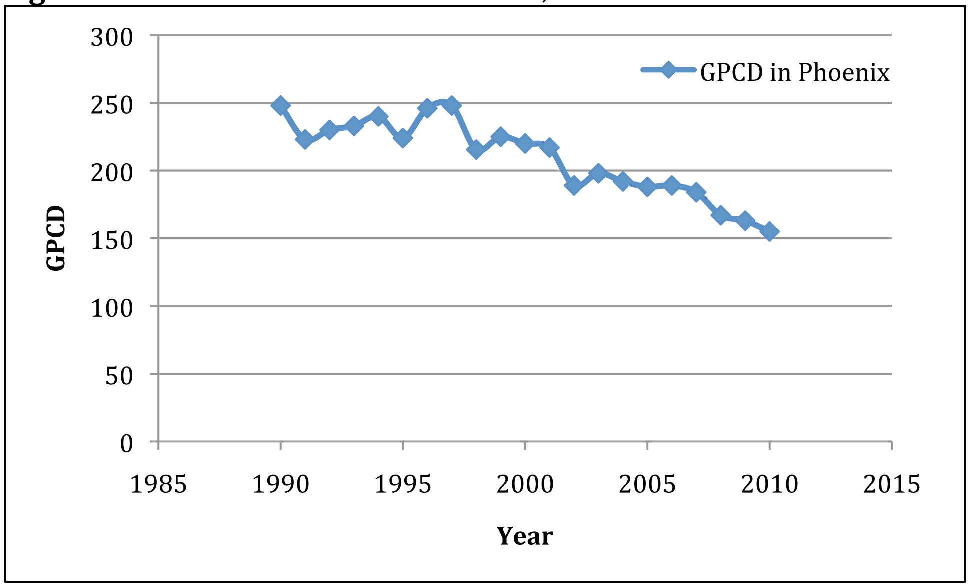
[45]http://phoenix.gov/webcms/groups/internet/@inter/@dept/@wsd/@wrc/documents/web_content/content_wrp_2005_update_final.pdf

[46] http://www.phoenix.gov/waterservices/wrc/yourwater/histuse.html

Figure 5.1 Water use trends in Phoenix, 1990-2010[47]

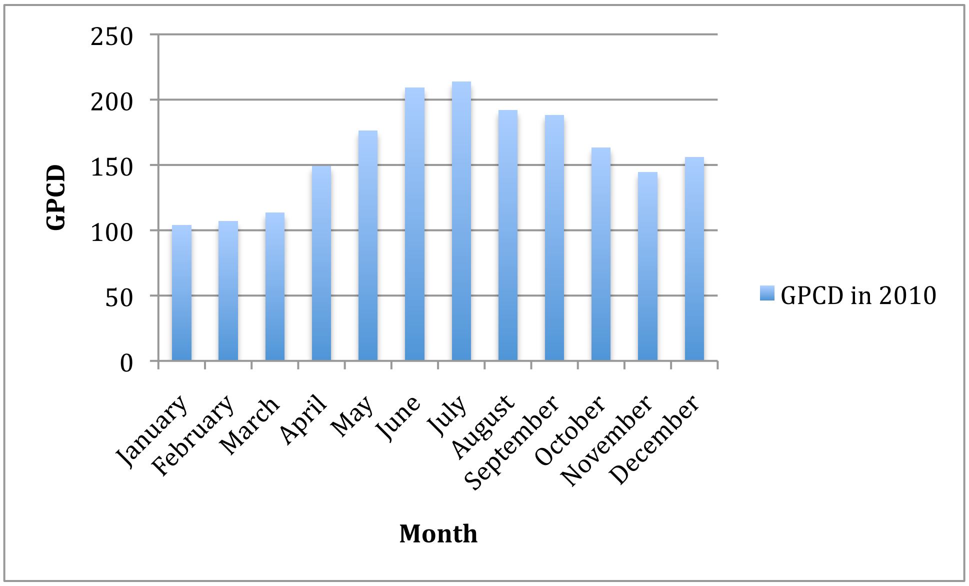


The trend of GPCD over the past 20 years is interesting, because GPCD increases slightly from the early-to mid 1990's and then begins to trend lower. It is difficult to explain the shift and subsequent rapid decline without understanding more about the implementation of demand side policies. It is clear water pricing has played a minor role in lowering GPCD given Phoenix has had the same price structure for over 20 years.

Phoenix, like all desert cities, uses far more water in the summer than in the winter. Figure 5.2 shows the GPCD used each month in 2010.

[47] Data obtained through survey of water managers in Phoenix.

Figure 5.2 GPCD water use in Phoenix for 2010[48]



Water use is lowest in January through March and increases steadily through the summer peaking in June and July. Water use decreases late in the summer with the onset of the summer monsoons and remains mostly low through the fall.

5.4.2 Las Vegas

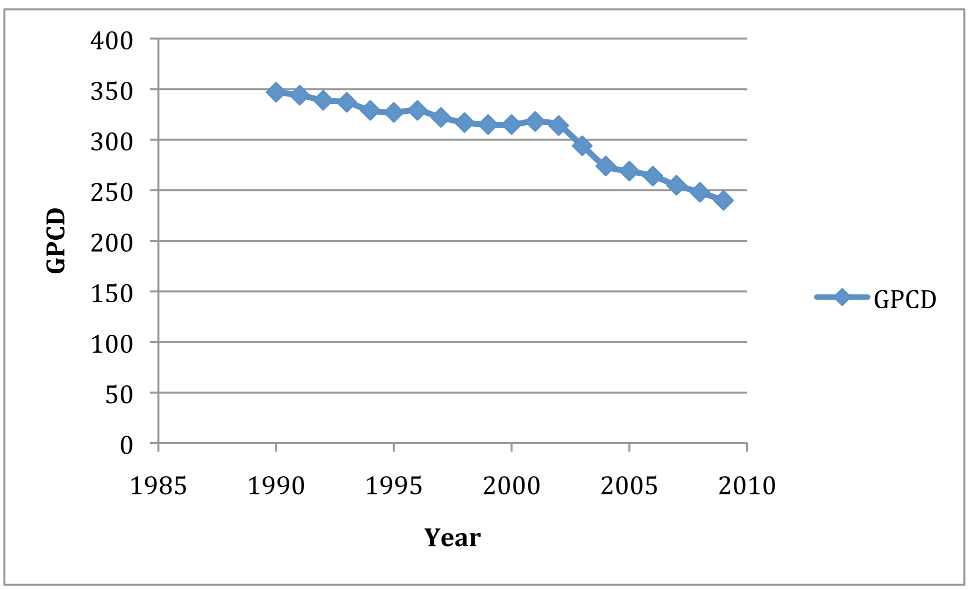
The Las Vegas Valley Water Authority (LVVWD) has had an increasing block rate since 1994. They modestly increased water prices in 1994, 1996, 2007, and dramatically increased the price in 2003 and in 2008. The most drastic price changes were in 2003 and in 2008. Water pricing likely had a strong effect on water consumption patterns. But before I examine the impact of pricing in more detail, it is important to mention other major policies that also likely affected per capita consumption in the past, which include the Water Smart Landscapes Rebates Program, started in 2002; the Water Efficient Technologies Program, started in 2001; and, the new drought plan implemented in 2003. In addition to pricing and

[48] Data obtained through survey of water managers in Phoenix.

major conservation efforts, Las Vegas undertook many other smaller policies and programs including advertising campaigns, educational programs, and partnerships with local businesses. These efforts likely contributed modestly to reducing GPCD water use while the larger policies and programs likely contributed to the more dramatic changes in water use evident over the past 20 years.

To examine the impacts of the major policies and pricing changes on per capita daily water use in the past 20 years, trends in water use over time must be examined. Figure 5.3 depicts GPCD for Las Vegas from 1990-2010, clearly showing a downward trend in GPCD over the 20-year period.

Figure 5.3 GPCD in Las Vegas, 1990-2010[49]



Interestingly, the curve has a major dip from 2002 to 2003. According to the Pacific Institute (2007), water deliveries fell by 20 billion gallons from 2002 to 2003. This reduction in water use coincides with two important policy changes initiated in 2002 and 2003: the Water Smart Landscape Rebates Program started in

[49] Data obtained through survey of water managers in Las Vegas.

2002 and, in 2003, a major price adjustment that increased each block in the price structure. The two programs combined drastically affected per capita daily use. Furthermore, after 2003 the decline in per capita in water use gets steeper. The reduction from 2003-2010 is larger than the reductions from 1990 to the early 2000's. This is a good sign for conservation, because even though there is not a drastic decrease in per capita use, it is decreasing at a higher rate than it was prior to 2003. This means that taken together conservation efforts undertaken by the SNWA are causing people to reduce their water consumption.

5.4.3 Los Angeles

The LADWP implemented an increasing seasonal rate structure in 1992 in response to a 3-year drought in the Los Angeles area. At the same time a blue-ribbon committee was established to ensure that conservation of water was being discussed. The blue-ribbon committee provided a way to involve different sectors of the Los Angeles economy in the decision-making process to alleviate the political obstacles that worked against raising water prices[50]. The impact of the change in water pricing on GPCD can be seen in Figure 5.5.

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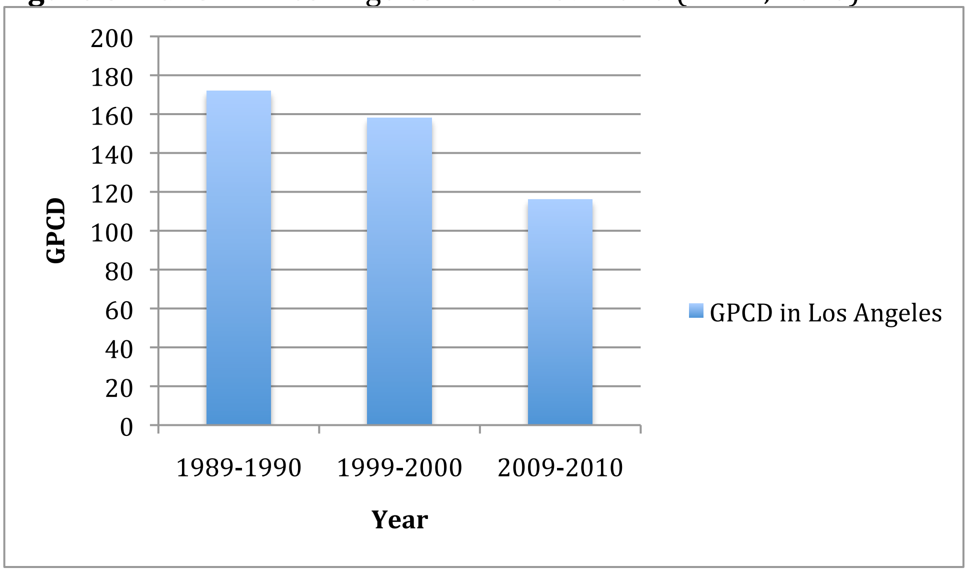
[50] The price increase was originally met with resistance, because LADWP initially asked consumers to voluntarily conserve water because of the drought. However, when consumers actually reduced their use, the LADWP experienced a revenue shortage and was forced to raise their prices. This loss of revenue problem is not unique to Los Angeles; rather, cities often experience revenue losses when consumers are asked to conserve voluntarily (Walton, 2010).

Figure 5.4 GPCD in Los Angeles from 1989-2010 (MWD, 2010).



Although available data does not facilitate an examination of GPCD trends at yearly increments[51] from 1990-2010 as was available in Phoenix and Las Vegas, the average GPCD calculated once per decade reveals a clear downward trend in water use. Data presented in Figure 5.5 clearly shows Los Angeles has lower GPCD than both Phoenix and Las Vegas. Next, I argue that GPCD in Los Angeles is lower due to an efficient price structure combined with other water conservation methods.

5.4.4 Comparing Conservation and Evaluating Relative Progress

Figure 5.6 represents GPCD in each city in 1990, 2000, and 2010. Regardless of the starting GPCD in 1990, one can see how some cities made more progress in reducing GPCD than others.

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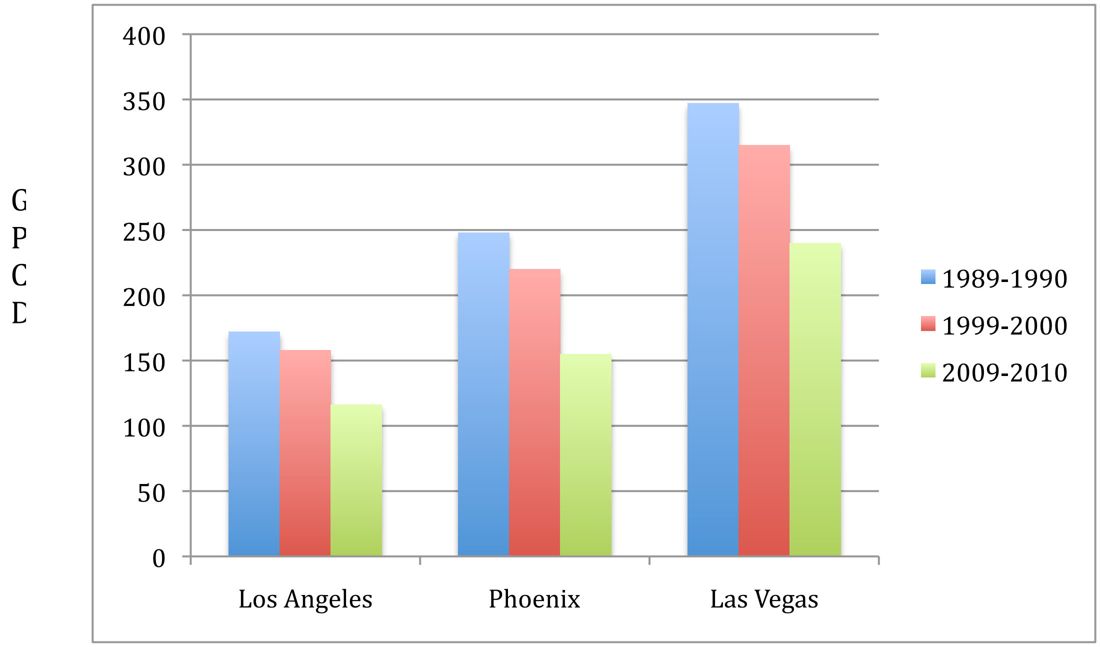
[51] There is little data on GPCD in Los Angeles in particular, but there is data for average GPCD in one year that is calculated every 10 years.

Figure 5.5 Comparing Conservation: Phoenix, Las Vegas, and Los Angeles



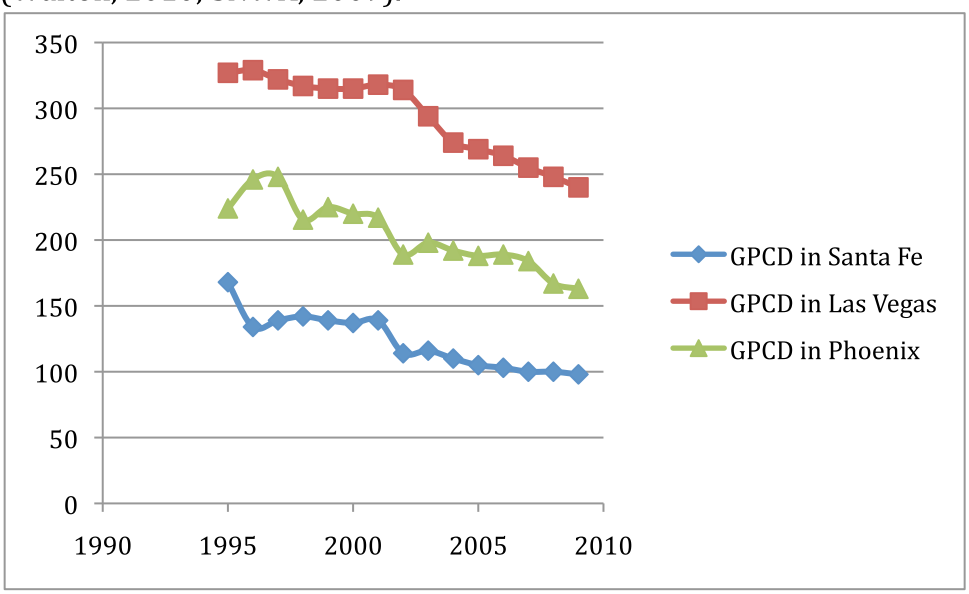
Los Angeles has by far the lowest GPCD in 1990[52]. Las Vegas reduces the most in absolute terms, reducing 107 GPCD from 1990 to 2010. All three cities made their most drastic reductions from 2000-2010, which makes sense because it was in this decade that conservation policies were implemented in each city (or implemented aggressively in the case of Los Angeles). The reduction in GPCD between 2000-2010 for Las Vegas is considerable and coincides with the implementation of many successful policies, and drastic price increases furthering its tiered block structure. However, marginal reductions in GPCD are only part of sustainability calculus. For example, Los Angeles has the most innovative price structure of any of the three cities, but its reductions in GPCD are the smallest in absolute terms. It is important to note that as GPCD decreases, it is harder and

[52] In 1990, Los Angeles was experiencing a severe drought that would last three more years, which means that GPCD was unusually low in this year.

harder to reduce GPCD further. This phenomenon is represented in all three cities, with Las Vegas reducing GPCD drastically but starting with the highest GPCD, Phoenix in the middle for both, and Los Angeles having the lowest starting GPCD and lowest absolute reduction. Therefore, sustainability must be measured in multiple ways, as we will see.

Although reductions in per capita water use in both Phoenix and Las Vegas are commendable, both Phoenix and Las Vegas have room for further improvement. This room for improvement is obvious when we compare Las Vegas and Phoenix to Los Angeles (Figure 5.6) and to other western cities, such as Santa Fe, which has much lower per capita use. The change in GPCD for Santa Fe, Las Vegas, and Phoenix since 1995 is shown in Figure 5.7.

Figure 5.6 Comparing GPCD of Santa Fe, Las Vegas and Phoenix from 1995-2010 (Walton, 2010; SNWA, 2009).



As indicated in Figure 5.7, Santa Fe reduced GPCD from 175 to 100 since 1995, a 43% reduction in GPCD, Las Vegas reduced their GPCD from 325 to 240 over the same period, only a 26% reduction. However, Las Vegas reduced water more drastically than Phoenix in the past 10 years. In comparison, Phoenix reduced their GPCD by 40% (from 250 to 150) nearly as much as Santa Fe over the fifteen-year period. Still, Santa Fe has a much lower GPCD than Phoenix or Las Vegas. So, by comparison, Las Vegas and Phoenix have considerable room for improvement. Los Angeles could also further reduce GPCD. Santa Fe has a lower GPCD than Los Angeles. In 2010, GPCD in Los Angeles was 116, while it was only 98 in Santa Fe. This comparison shows that lower GPCD is possible in Los Angeles without drastic increases in prices (though prices are higher in Santa Fe), as long as the proper price structure remains in place and aggressive conservation policies continue.

There are a couple of reasons for Santa Fe's relative low GPCD in comparison to Phoenix, Las Vegas, and Los Angeles. First, Santa Fe has some of the most expensive water in the United States, which helps reduce GPCD (Walton, 2010). Secondly, Santa Fe receives more rainfall in comparison to either Las Vegas or Phoenix, which likely reduces demands for outdoor water use, which can lower GPCD. While it is useful to compare Las Vegas and Phoenix to Santa Fe to illustrate the GPCD reduction that may be possible over time, Los Angeles may provide a better comparison in the near term given it is more similar to Las Vegas and Phoenix.

5.5 Sustainability Analysis

A study on the sustainability of Los Angeles' waste system suggests: "…it is important to have indicators that can be applied periodically to gauge progress and to assess planning options for the future" (Boyle et al, 2005, p. 5662). The study proposes social, economic development, and environmental pollution indicators to determine the sustainability of waste management in Los Angeles. This study did not suggest solutions, but merely showed where there were gaps in data. While this study was measuring a completely different facet of water management than what I am measuring, I apply a similar method to assess relative sustainability of water management in Phoenix, Las Vegas, and Los Angeles using a qualitative analysis. Besides helping to evaluate and compare relative sustainability levels across the three cities, this approach facilitates the identification of areas where and how each city could improve sustainability.

In order to effectively compare each city against each sustainability criterion, I have compiled six tables of specific scorings under each criterion for possible outcomes in each city. The total score is listed in the top right corner, while additions or subtractions are listed in the rows below.

Table 5.8

Criterion 1	**1.5**
Diverse sources, ecosystem is fully maintained in both.	+1.5
Diverse sources, ecosystems not fully maintained in all.	+0.5
One large source, not effecting substantially.	+1

Table 5.9

Criterion 2	**1.3**
If costs are not met, without any societal benefits.	-0.3
Not capturing consumers willingness to pay	-0.3
Shocks in supply are not offset	-0.3
No or few specific conservation policies	-0.3

Table 5.10

Criterion 3	**1.5**
Little to no stakeholder involvement	+0
Some stakeholder involvement	+0.75
Significant stakeholder involvement	+1.5

Table 5.11

Criterion 4	**2**
Past, current, and future costs are covered.	+1
Infrastructure costs are included	+0.5
Diverse water source portfolio	+0.5
No scarcity costs included	-0.5

Table 5.12

Criterion 5	**1.5**
Climate change mentioned	+0.5
Conservation policies	+1
Climate change projections connected to conservation policies	+1.5

Table 5.13

Criterion 6	**2.2**
A decrease in GPCD from another factor besides price or direct conservation policies	1.1
A decrease in GPCD from price and/or direct conservation policies	2.2

5.5.1 Phoenix

To determine whether Phoenix's water management meets the sustainability criteria, I evaluate policies, approaches, and performance for each sustainability criterion. Recall, the sustainability criteria were introduced in Section 4.3.

1. **Rivers must flow, if not naturally, then enough to support a healthy ecosystem of plants and animals. Other natural bodies of water must also be maintained to ecologically healthy levels.**

This criterion is based on the sources of water that the city relies on, and how much water it takes from each source. Phoenix relies on the Colorado River, the Salt and Verde Rivers, groundwater, and reclaimed water. Phoenix takes so much water from the Salt and Verde rivers that these rivers now mostly flow underground. When the Hohokam used to live in the region, these rivers supported fish, and other aquatic animals. The Colorado River is more difficult to analyze, because so many cities and farmers rely on it. Therefore, I will assume that Phoenix contributes to the depletion of the Colorado River in a small way. On the positive side, Phoenix has made strides in reducing groundwater use so that groundwater use is more sustainable. However, reducing groundwater use is just one small part. Due to the fact that the Salt and Verde rivers flow underground, Phoenix qualifies as diverse sources, but taking too much water from some of these sources, and therefore receives a score of 0.5 out of 1.5 for this criterion.

2. **The water management must be economically efficient. This means that social surplus must be maximized.**

Staff at the Phoenix Water Service Department set water rates high enough to cover their costs but not so high as to earn a profit (Personal Communication). However, because Phoenix charges flat rates for their water, consumers' differing willingness to pay for water is not captured. Phoenix stores extra water for the future, because there is no demand for it at the time. This activity is considered a means of safeguarding water supplies for the future, especially in the face of climate change and drought. This also includes uses of water with a high elasticity of demand. This means that water used outdoors should be targeted, for this reason as well as the fact that all desert cities use a major portion of the water for watering their lawns and filling their pools. There are no specific policies in Phoenix to target this use of water. Phoenix did not capture all consumers' willingness to pay, and they did not have many specific conservation policies, subtracting 0.6 from their total score. Therefore, I award Phoenix with a score of 0.7 out of 1.3 for this criterion, because their water pricing is not completely efficient.

3. **The water management must be socially equitable. All stakeholder groups should be involved in decision-making, regardless of their size or importance.**

Qualitative analysis of the sustainability plan was undertaken to discern the level of interest group involvement in water management. The analysis revealed little involvement in a few very specific aspects of water management. For example, the only other sectors of Phoenix's economy that are engaged in water conservation are the airport, the Ed Pastor Transit Center, and the Neighborhood Service Department (City of Phoenix, 2005). However, the plan did not present any direct evidence of this involvement. Also, the management of water in Phoenix is only under the jurisdiction of the city of Phoenix instead of multiple authorities as in Los Angeles and Las Vegas. This is worse for equity, which lowers Phoenix's score for this criterion. Therefore, I awarded Phoenix with a score of 0 out of a possible score of 1.5 points for this criterion.

4. **The price of the water should reflect both the costs involved in distributing the water as well as the scarcity of the water supply. A diverse water resource portfolio results in an improved score. All improvements in infrastructure should be considered in the price of water.**

According to staff at the Phoenix Water Service Department, Phoenix includes production, distribution capacity, and "meeting standards related to pollution control and compliance with regulations that meet current and expected future requirements" in setting water prices (Personal Communication). The recognition of the need to set a price that facilitates meeting future requirements is important. However, it is unclear if the price is fully inclusive of the likely substantial costs of future infrastructure projects. Phoenix satisfies the diverse water source sector, and receives 0.5 points for this, and it satisfies the current, past and future costs sector gaining 1 point. However, there are no infrastructure or scarcity costs included in the price of water. Therefore, I awarded Phoenix with a score of 1 out of a possible 2 points for this criterion.

5. **The distribution and pricing of water should consider climate change projections for the region, and be included in all decision-making. If climate change is not mentioned specifically, there should be a good effort towards reducing demand, with rigorous conservation policies.**

A review of the survey data and the sustainability plan found no indication of substantial planning for climate change. Phoenix mentioned planning for climate change, but there were no climate change projections or specific plans to deal with water scarcity under climate change. The City of Phoenix did mention storing water for the future as means to safeguard against the potential effects of climate change. Unfortunately, Phoenix does not have any explicit goals for reducing GPCD, or water demand other than educational programs. Phoenix only mentions climate change, which awards it 0.5 points. Therefore, I awarded Phoenix with a score of 0.5 out of a possible 1.5 points for this criterion.

6. **The price structure of the city and the policies of the city in question must show that GPCD decreased due to its implementation.**

Phoenix has not changed its price structure in over 20 years (Personal Communication). Although GPCD in Phoenix has been decreasing over the past 20 years, it is not because of the changes in price structure. Decreasing GPCD in Phoenix is most likely attributable to conservation policies or consumers' conservation oriented behavior. However, I considered other policies that Phoenix has implemented towards reducing demand to count towards this criterion. Therefore, I awarded Phoenix a score of 1.1 out of 2.2 points for this criterion.

Summing across all six criteria yields a total sustainability score of **3.8** out of 10 for Phoenix.

5.5.2 Las Vegas

1. **Rivers must flow, if not naturally, then enough to support a healthy ecosystem of plants and animals. Other natural bodies of water must also be maintained to ecologically healthy levels.**

Las Vegas relies on the Colorado River for around 90% of their municipal water (Pacific Institute, 2007). However, this does not mean that they are degrading the Colorado River any more than other cities. In fact, according to the Colorado River Compact, Nevada only received 300,000 cubic feet (CF) of Colorado River water, which is much less than Arizona's 2.8 million CF (1922). Of course, virtually all of the 300,000 CF is going to Las Vegas, but 36% of Phoenix's water is from CAP. This translates to about 185,000 cubic feet (CF) of Colorado River water going to Phoenix every year (City of Phoenix, 2005). While Las Vegas is taking slightly more water from the Colorado River, this is not considered enough to restrict the flow of the River, leaving Las Vegas with a score of 1. Therefore, I awarded Las Vegas with a score of 1 out of 1.5 possible points.

2. **The water management must be economically efficient. This means that social surplus must be maximized.**

The LVVWA generally operates on zero profit, but recently they have allowed for a deficit (negative profits) to help consumers who are suffering due to the economic crisis (Personal Communication). This action taken to lower the price of water is effectively a subsidy. If the water price was lowered only for those who could not afford it, this action would not be overly harmful and, in fact would help in achieving social equity (Criterion 4). On the other hand, if the reduction is an across-the-board subsidy, then water pricing is made less efficient. Las Vegas has an innovative addendum to their budget: profits are allowed when there are water rate increases to encourage conservation. Even so, there are still a few flaws in the management, such as no seasonal price differences. However, this criterion includes policies targeting outdoor water use, and Las Vegas has one of the most innovative policies to target this use of water. Las Vegas did not capture all the willingness to pay from their consumers, and they did offset supply shocks by storing water, subtracting 0.6 from their total score. For these reasons, I awarded Las Vegas 0.7 out of 1.3 points for this criterion.

3. **The water management must be socially equitable. All stakeholder groups should be involved in decision-making, regardless of their size or importance.**

Las Vegas has made strides in involving more interest groups in water management (SNWA, 2009). With the start of the SNWA in 1991, all the water departments in the region have been working together (SNWA, 2009). Water departments have also been working with builders and other city workers, but other than this there are no other interest groups involved (SNWA, 2009). Las Vegas water is also governed by both the Southern Nevada Water Authority and the Las Vegas Valley Water Authority. It is also a better method is management for equity and innovation to have multiple governing bodies working together. Therefore, I awarded Las Vegas a score of 0.75 out of 1.5 possible points.

4. **The price of the water should reflect both the costs involved in distributing the water as well as the scarcity of the water supply. A diverse water resource portfolio results in an improved score. All improvements in infrastructure should be considered in the price of water.**

Water prices are based on estimates for the projected use in the next year and to recover previous costs incurred (Personal Communication). Also, costs of transporting the water are included in the price (Personal Communication). While this is more specific than the information I received from Phoenix, it is still not specific enough to satisfy this criterion. First, setting prices only based on past expenses and projected demand for the following year does not incorporate a long enough time scale to be considered sustainable. Second, there was no mention of how the supply of water is factored into price (Personal Communication). Third, Doug Bennett from the SNWA said: “There’s not a lot of infrastructure dollars in the water rate” (Walton, 2010). However, the other part of this criterion is that the city must have a diverse water source portfolio, and Las Vegas relies almost exclusively on the Colorado River. Therefore, Las Vegas receives 1 point for including past, current, and future costs. However, because it does not have a diverse water source portfolio, 0.5 is subtracted, leaving it with a score of 0.5 out of 2 possible points.

5. **The distribution and pricing of water should consider climate change projections for the region, and account this into all decision-making. If climate change is not mentioned specifically, there should be a good effort towards reducing demand, with rigorous conservation policies.**

While climate change was not specifically mentioned in the conservation plan for the SNWA, the SNWA is very focused on reducing water demand in various ways. For example, the SNWA uses financial incentives such as pricing, rebates, and educational programs. In addition, the SNWA conducts extensive research to inform conservation efforts. While Las Vegas does not explicitly mention climate change, it does have rigorous conservation policies, awarding it 1 point. Because of this commitment to conservation, I awarded Las Vegas a score of 1 out of 1.5 possible points.

6. **The price structure of the city and the policies of the city in question must show that GPCD decreased due to its implementation.**

Las Vegas has implemented many water price increases in the past 20 years, which have likely contributed to the sharp decrease in GPCD, especially in the past 10 years. One of the steepest decreases in GPCD was when the water smart landscape program was initiated in 2002. Some policies implemented around the same time could have also contributed to this decrease, such as the water smart landscape rebate program. The combination of this and other policies, and the direct evidence of decreasing GPCD every year have illustrated that the price structure and conservation policies have been relatively successful in reducing use. I awarded Las Vegas a score of 2.2 out of 2.2 possible points.

Summing across all six criteria yields a total sustainability score of **6.15** out of 10 for Las Vegas.

5.5.3 Los Angeles

1. **Rivers must flow, if not naturally, then enough to support a healthy ecosystem of plants and animals. Other natural bodies of water must also be maintained to ecologically healthy levels.**

Los Angeles has a diverse water source portfolio. Los Angeles gets 36% of its water from the Los Angeles Aqueduct, which diverts water from the Owens valley. 52% of water is from the MWD, which includes water from the Colorado River, and the San Joaquin River Delta. Both the Colorado River and the San Joaquin are below normal levels. Los Angeles receives a substantial portion of California's Colorado River allocation (4.4 million CF) (MWD, 2010). The delta region is even more stressed, with the legal issues over the delta smelt that are preventing the state from extracting water from the delta. Also, almost 100 years ago, Los Angeles diverted water from the Owens Valley to Los Angeles. Residents in the Owens Valley relied on the water for their agriculture, but after this diversion, the farmers could no longer subsist there. Los Angeles falls into the same category as Phoenix, but is a bit more extreme in terms of ecological damage due to its size. Because of the issues with the Colorado River and the San Joaquin River Delta, as well as the past issues with the Owens Valley, I awarded Los Angeles a score of 0.5 out of 1.5.

2. **The water management must be economically efficient. This means that social surplus must be maximized.**

The LADWP operates on a zero profit budget. Los Angeles also has a water price structure that captures each customers willingness to pay, and is therefore maximizing social surplus. Their price structure changes based on quantity and season. They also have subsidies for the poor who cannot afford their water bill. Los Angeles does not have specific policies targeting outdoor water use, but they do include higher prices in the summer in their price structure. They also have certain days of the week where use of a sprinkler is prohibited. Los Angeles satisfies all the criteria for the full score, even safeguarding during droughts. For these reasons, I awarded Los Angeles with a score of 1.3 points out of 1.3 possible points.

3. **The water management must be socially equitable. All stakeholder groups should be involved in decision-making, regardless of their size or importance.**

Water in Los Angeles is also governed by the Metropolitan Water District and the Los Angeles Department of Water and Power. As I mentioned, this joint management is good for equity, and fair decision-making. Los Angeles is a champion of socially equitable water management with their Blue Ribbon committee that involves all interest groups in the management of water in Los Angeles. The Blue Ribbon Committee has been in existence since 1977, and works closely with the mayor of Los Angeles[53]. The Blue Ribbon Committee has made recommendations such as the switchpoint from Tier 1 to Tier 2 in Los Angeles' price structure (Hanemann, 1993). I awarded Los Angeles with a score of 1.5 out of 1.5 possible points.

4. **The price of the water should reflect both the costs involved in distributing the water as well as the scarcity of the water supply. A diverse water resource portfolio results in an improved score. All improvements in infrastructure should be considered in the price of water.**

The LADWP includes infrastructure costs, and costs of incurring water in their pricing (Personal Communication). However, there was no mention of water scarcity factoring into the price of water. Los Angeles is very successful at using price as an indicator to consumers of scarcity. Los Angeles also has a very diverse

[53] http://www.ladwp.com/ladwp/cms/ladwp000548.jsp

water source portfolio, with sources including the Owens Valley, the Colorado River, the San Joaquin River Delta, the Sierra Nevada Mountains, and local surface and groundwater. Not only was there no mention of including the scarcity of the water supply, but environmental and social costs were not discussed either. Los Angeles has retrieved water in many unsustainable ways as I have discussed, and this should be counted against them if they are not including these issues explicitly in their pricing. Because Los Angeles includes past and future costs, as well as having a diverse water supply, it receives 1.5 points. However, like the Phoenix and Las Vegas it does not include scarcity costs, which subtracts 0.5 from its score. For these reasons, I awarded Los Angeles with a score of 1 out of 2 possible points.

5. **The distribution and pricing of water should consider climate change projections for the region, and account this into all decision-making. If climate change is not mentioned specifically, there should be a good effort towards reducing demand, with rigorous conservation policies.**

Los Angeles mentions climate change specifically in their water management plan (2010), and they have projections for their water sources based on the potential impacts of climate change. These changes include a 10% decrease in precipitation, and an average increase of 6.3 degrees Fahrenheit. Los Angeles mentions climate change, and connects these climate change projections to conservation policies. Therefore, I awarded Los Angeles with a score of 1.5 out of 1.5 possible points.

6. **The price structure of the city and the policies of the city in question must show that GPCD decreased due to its implementation.**

Unfortunately, Los Angeles does not have data on GPCD every year because the MWD has jurisdiction. Los Angeles does have data every ten years, and there is a definite downward trend in GPCD. Also, Los Angeles has a much lower GPCD than either Las Vegas or Phoenix. Also, according to the LADWP, the price structure implemented in 1993 has been successful (Personal Communication). Hanemann (1993) justifies the price structure in Los Angeles in many ways, which I have already discussed. The features of Los Angeles' price structure are the most innovative and conservation oriented out of the three cities. Therefore, I awarded Los Angeles with a score of 2.2 out of 2.2 possible points.

Summing across all six criteria yields a total sustainability score of **8** out of 10 for Los Angeles.

The individual and composite scores are summarized in Table 5.

Table 5.14 Sustainability Scores

Scores	Phoenix	Las Vegas	Los Angeles
Criterion 1	0.5	1	0.5
Criterion 2	0.7	0.7	1.3
Criterion 3	0	0.75	1.5
Criterion 4	1	0.5	1
Criterion 5	0.5	1	1.5
Criterion 6	1	2.2	2.2
Total	**3.7**	**6.15**	**8**

5.5.4 Sustainability Comparison

Comparing these three cities by composite sustainability score it is easy to see that Phoenix's water management is the least sustainable, while Los Angeles' is the most, and Las Vegas' is in the middle but slightly closer to Los Angeles. For criterion 1, it was very difficult to get a full score, and none of the cities did. These are all large cities, and they are all taking enough water from at least one of their sources to effect the flow of that source. I deemed Phoenix to be the worst because two of its rivers now flow underground, and Las Vegas to be the best because it is just taking a relative small amount from a huge river. Also, it should be noted that Los Angeles retrieved water from the Owens Valley in a very unfair and environmentally degrading way. However, this is still counted against Los Angeles. Of course, there is also a bias here against larger cities, because larger cities will need to extract more water. Los Angeles and Phoenix are both much larger than Las Vegas.

Criterion 2 did not differ substantially across cities. Small changes in management here yielded large changes in scores, for example subsidies and help for poor people helped both Los Angeles and Las Vegas, but the fact that Phoenix stores water helped their score. The outdoor water use policies in Los Angeles and Las Vegas boosted their scores as well. Criterion 3 is representative of total sustainability with Los Angeles receiving full points, Phoenix receiving zero, and Las Vegas receiving in the middle. However, the involvement of interest groups is an easy problem to fix in the management of water.

Criterion 4 was not met in either Phoenix or Las Vegas because both these cities are more focused on keeping water prices low than on including costs in the price of water. Phoenix does this less so than Las Vegas, but they have a much more diverse water supply than Las Vegas so their scores balance out. Los Angeles received a full score, because it has a diverse water supply, and costs are included in price.

Criterion 5 was also ranked in the same way that composite sustainability score was. Phoenix received the lowest score because they did not mention climate change, and had few policies towards reducing demand. Las Vegas had more mention of climate change, and more policies and goals towards reducing demand, but still not actual projection and plans for the effects of climate change. Los Angeles had specific effects of climate change and how to combat them, as well as demand reducing policies.

Criterion 6 was fully met in both Las Vegas and Los Angeles. It was not met in Phoenix because Phoenix has not changed their water prices in over 20 years (Personal Communication), and therefore does not have any reductions in GPCD because of changes in price. However, Phoenix has reduced GPCD through other policies, which is why they did not receive a score of 0. However, their reduction in GPCD has been slower than in Las Vegas and Los Angeles. However, a major cost that each city should include in its water pricing is the actual scarcity of water.

5.6 Obstacles and Solutions

There are a number of obstacles that could inhibit improved water management in Phoenix, Las Vegas, and Los Angeles. These obstacles can be categorized into three types: social, political, and economic.

5.6.1 Social Obstacles

Social obstacles include problems like the difficulty of involving stakeholder groups, and people not wanting to conserve because it is looked down upon in society or among friends. Another social obstacle that is specific to Las Vegas is that many people come to Las Vegas with the idea of letting loose and not worrying about anything, both those who visit and settle there. This kind of behavior could potentially lead to wasteful uses of water.

Social obstacles to conservation can be difficult to overcome. Mitigating social obstacles must be addressed on both an individual basis through cultural behavioral changes, and through water department policies to provide consumers with the proper incentives that promote conservation behavior. In the example of Las Vegas, it was popular to have green lawns, but with enough of a financial incentive from the SNWA, people started to remove their lawns, which lowered water use substantially.

In the case of involving stakeholders, this must be a government requirement, or there must be a financial or other incentive for water departments to involve other interest groups. Incentives can arise from stakeholder groups themselves. For example, when stakeholders can show a benefit from their involvement, or on the opposite side, express their anger at being shut out of the process, then their efforts can help increase stakeholder involvement. In Los Angeles, stakeholders protested water rate increases. To pacify these interest groups, the LADWP formed the blue ribbon committee to discuss water rates and other conservation issues including stakeholder groups in the process.

5.6.2 Political Obstacles

Like social obstacles, overcoming political obstacles can be difficult. For example, in general, politicians want to keep their most influential voters happy. Politicians who are successful at keeping voters happy are elected and this is what they continue to do if they want to be reelected. Some of their most influential voters, especially in the west, are farmers. Farmers want to continue to receive as much water as they can for as little cost as possible. In water scarce areas, this often leads to conflict between the people in urban and rural areas. Often these conflicts are focused around cities taking water from the country, or the fact that cities are willing to pay much more for their water than farmers.

There are many other political obstacles; some of which include the fact that people do not want to pay more for their water than they have to. Politicians will want to keep water prices low in order to keep people happy. Many citizens may not be very concerned about water conservation, or they would like to leave the problem to someone else in the future. In general, politicians need to focus on the present and immediate future, to apply their policies to people's lives. Many conservation programs are long-term policies, with benefits not being realized for many years. Therefore conservation programs may be difficult to initiate, along with other research relating to conservation.

There are other logistical obstacles involved in politics that could be detrimental to sustainable water management. Some politicians may not have the legal jurisdiction to allow a policy or to provide funding for the water department. Some other level of government, such as the state government or even the federal government may have jurisdiction. Unfortunately, as the governmental body becomes larger, it takes longer for policies to get passed and for funding to be acquired. This could cause a problem of funding for local departments.

5.6.3 Economic Obstacles

Economic obstacles are often related to one of the other categories of obstacles, but they have important issues of their own. A general problem that water departments face is the problem with the undervaluation of water, which creates uncertainty, external problems, and imperfect market conditions (Colby et al, 1987). One specific economic obstacle that many water departments face is the problem with falling revenues when people conserve. There must be the proper price structure in place to prevent this, prior to initiation of a conservation program. According to Gleick (2010) "There's no reason why municipalities who implement conservation programs should have to raise their rates, if that happens it's a failure of rate design"(Walton, 2010). For example, this occurred in Los Angeles before the implementation of the new water rates in 1993.

Water departments in general may not receive enough support to do all the work they would like to do. Especially recently, many government jobs at the state and local level are being cut, possibly at the expense of conservation and sustainable water management. There are many economic incentives working against water conservation, and in order to reverse these, water departments must work towards finding economic incentives that encourage conservation. There are no economic incentives towards monitoring water use and collecting data on water consumption.

Another economic problem is that water departments want to keep water priced low enough so that everyone can afford it. Although water bills are not a substantial part of most households, for poorer people living in a city, the water bill may be something that factors into their budget. Cities like Los Angeles have come up with ways of dealing with this problem while still raising water prices. Los

Angeles has subsidies for people who cannot afford water as it priced (Villaraigosa, 2008). This solves the problem of keeping water inexpensive just to protect the poor, as is happening in Las Vegas.

Chapter 6

Conclusion

Water resources in the United States face challenges such as degrading infrastructure, conflicts over resources, and increasing water scarcity. It is hard for many people to think about issues that are difficult to solve, but we must not leave these problems to grow. We must change some of our lifestyle choices. Things we have been accustomed to for decades have come into question and we must act accordingly. Water is only one part of this struggle, but in order to solve the environmental problems in our country and others a step-by-step approach must be taken. Always keeping the Brundtland Report (1987) definition of sustainability in mind: "development that meets the needs of the present without compromising the ability of future generations to meet their own needs", we embarked on a journey to evaluate the water issues in the American Southwest. The American Southwest faces both explosive population growth as well as increasing water scarcity, which makes it an ideal case study of water management problem (Loomis et al, 2003).

6.1 Policies

My findings can be categorized into four major themes: policies, pricing, water sources, and history. Policies that I found to be conservation oriented are policies aimed to reduce demand, such as educational programs, and policies aimed to reduce water used outdoors. Also, Los Angeles has many prohibited uses of water, or certain days that outdoor water use is not allowed. Los Angeles has had a blue ribbon committee, which ensures that all interested stakeholders are involved in decision making. These kinds of policies are important for equity in water management, and should be implemented in Las Vegas and Phoenix. Las Vegas also has some innovative conservation policies such as the rebate program to remove landscape, and ultimately to reduce outdoor water use. Policies that were based on sound economic and scientific analysis are considered the most sustainable. For example, policies targeting uses of water with a relatively elastic demand are better than those that ignore elasticity of demand. Also, policies targeting where water is wasted the most were considered more sustainable. For example, much of the water used outdoors evaporates quickly, or is wasted as runoff. These types of policies should be used as models for sustainable water management. Los Angeles' polices could be used in both Las Vegas and Phoenix, and Las Vegas' policies could be used in Los Angeles and Phoenix.

6.2 Pricing

The best price structures for conservation are tiered price structures with increasing prices as quantity increases. Combining this with higher prices in the summer months is the optimal price structure for conservation. Los Angeles incorporates both of these features, as well as having only two tiers of water pricing with a high threshold between Tier 1 and Tier 2. Within each of the tiers, water becomes more expensive as consumption increases, as well as during the summer months. Los Angeles' price structure is used as a model for other western cities' price structures. Besides the importance of price structure, pricing should also include the scarcity of the water supply, the costs incurred with the distribution of water, and given climate change and population growth projections. No city has done this completely, but Los Angeles was close with climate change and population projections. However, no city includes scarcity of the water supply explicitly in their pricing. Phoenix and Las Vegas can also learn from each other, in that Phoenix's price structure is based on season and Las Vegas' is based on quantity, but combining these features would be optimal.

6.3 Water Sources

The next category of my findings is the source of water that each city uses. These sources should be used in a sustainable and environmentally friendly way. The cities should not extract enough water to slowly deplete the water source, and the source of water should be a healthy ecosystem. This includes sources such as groundwater, rivers, aquifers, and lakes. Both Phoenix and Los Angeles have extracted water from sources in a very environmentally degrading way in the past. Phoenix has caused two of their rivers to retreat underground, and Los Angeles virtually stole water from the Owens Valley, which relied on the water for agriculture.

6.4 History

I also wanted to highlight the importance of history in sustainable water management. When defining sustainability, the trends in GPCD were more important to me than the absolute GPCD values. The same idea follows for policy implementation as well, so that even though Phoenix may have started implementing more conservation policies earlier than Las Vegas, Las Vegas started many more in the past decade than Phoenix, many of them very effective and innovative. Many state laws have also affected the way water has been managed in each of the three cities. For example, Phoenix was required by the state of Arizona to eliminate its groundwater use. Federal projects have also helped certain cities diversify their water sources. The CAP made Colorado River water available to Phoenix, and the aqueduct running from the Colorado River to Los Angeles was also federally funded. However, the only federally funded project that aided Las Vegas in extracting Colorado River water was the Hoover Dam, which was helpful but did not help in diversifying Las Vegas' water supply.

6.5 Suggestions

The ideal management of municipal water would include both sustainable pricing structures and conservation-oriented policies. Included in these policies are clean and diversified water sources, with an aim to try to mend past unjust actions. Las Vegas and Phoenix should have a price structure that is more similar to Los Angeles'. Phoenix also needs to focus on implementing conservation-oriented policies, and they need to set goals for reducing GPCD. Las Vegas needs to diversify its water supply, which they are attempting to do, but they need to make sure that they are not doing this at the expense of the environment or social equity. Both cities should make reduction in GPCD the ultimate goal, and this goal should be reached through pricing and policies. However, all three cities need to price water so that it incorporates the necessary economic, social, and environmental costs associated with the distribution of this water.

6.6 Goals

Ultimately, my goal was to come to a conclusion on whether the water management in Phoenix and Las Vegas is currently sustainable and relate the analysis of these cities to Los Angeles' relative sustainability. I used quantitative and qualitative methods to analyze the sustainability in each city. Clearly there were going to be aspects of each city's water management that were not sustainable, but I wanted to quantify these differences, and be specific about what each city could do better. I awarded Phoenix a score of 4 out of 10, and Las Vegas a score of 7.05 out of 10. My example of a city with relatively sustainable water management was Los Angeles, which received a score of 8.75 out of 10. This shows that all these cities can improve the sustainability of their water management. What I hope to contribute to the literature on sustainable water management is this sustainability score that quantifies how sustainable a city's water management is.

The main reason that Las Vegas scored much higher than Phoenix was because of the SNWA's innovative policies and pricing in the past 10 years, which have led to rapid decreases in GPCD. Even though Phoenix currently has a lower GPCD than Las Vegas, Las Vegas' GPCD has been decreasing faster. I argue that Los Angeles has a better price structure to encourage conservation than either Las Vegas or Phoenix. This can be seen by evidence from GPCD in each city over the past 20 years, as well as the policies implemented in the past 20 years.

Price is an important tool in reducing demand and conserving municipal water. If obstacles to setting new price structures are abolished, then a new price structure can be implemented in Las Vegas and Phoenix to meet the specific needs of the particular city. Phoenix and Las Vegas were chosen to represent the problem of wasteful water practices in an arid region and the consequences of these practices. I believe that price is an easy indicator of social, economic, and environmental sustainability. When price structures are set up in a way to encourage conservation willingly, then social, and economic sustainability are satisfied. Of course, an analysis of use must be done in order to ensure environmental sustainability. However, using the parameters of GPCD and price structures, all three overarching components of sustainability are satisfied. "Despite the abundance of water on the Earth, it is becoming clear that the relatively small proportion that is fresh and accessible is coming under increasing pressure as the world population rises" (Wallace, 2003).

6.7 Concluding Remarks

Sustainability is difficult to define, but sustainability indicators are a good way to aid in this. With a quantitative analysis of sustainability, cities can understand better where they stand in relation to other cities and how they can improve their water management. It is important to look at the past when determining sustainability. In order to have a full understanding of the issues facing water management and what sustainable water management is, we must delve into the history of water and the economics of water.

While change may not be immediate or drastic, there is a water crisis on our hands. This crisis is not limited to the American Southwest, and every region has unique water problems. Tackling the sustainability of water management can often seem like a lofty and unobtainable goal, but if sustainability is broken down into parts that are easy to define then reaching sustainable water management can seem like a reasonable goal.

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Appendix

Survey Questions:

1. How is the price of water determined? Is the price of water determined in part by the supply of water available? Or by potential population growth?
2. Are your profits negative or positive?
3. Do your current prices reflect future costs of distribution, purification, or monitoring?
4. Do you have data on average per capita water use for the last 20 years, as well as major pricing and policy changes?
5. Do you have any tiered water pricing schemes, such as peak load pricing, or different prices over a certain quantity of water consumption?

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