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A Comparative Analysis of Water Districts Strategies Against Drought in Western Municipal Water District of California, East Bay Municipal Utilities District of California and Denver Water

Megan A. Paliwoda
University of Colorado, Boulder, megan.paliwoda@colorado.edu

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By
Megan Paliwoda
Department of Environmental Studies
University of Colorado at Boulder

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Thesis Advisors:

Paul Lander, Department of Geography, Main Advisor
Dale Miller, Environmental Studies Program
Deserai Crow, Environmental Studies Program

ABSTRACT

This thesis looks at water management strategies for conservation of residential water use in the midst of drought, and the effectiveness of these strategies. There is a lot to be learned from past mistakes and successes in the way that water managers and states approach the problem of drought. Water is a vital resource that needs to be properly handled, and the current drought in California is leaving many districts struggling to find ways to conserve water. In this document three districts are looked at, two in California (Western Municipal Water District in southern California and East Bay Municipal Water District in northern California) and one in Colorado (Denver Water). Denver Water's management plan saw success during their early 2000's drought, and much can be learned from the comparison of these districts. In order to see what their plans were and how effective they were, water use patterns are analyzed as well as policies implemented by the districts. Their budgets were also looked at to see if there were any significant changes because of drought. Many similarities were seen between the districts, such as strict lawn watering hours, surcharges, and rebates for efficient appliances. For Western Municipal Water District of southern California, their flexibility in terms of supply helped them to be less water stressed, but their reductions did not meet state mandated goals. East Bay MUD saw the highest reduction and had the most success in lowering water use. This may be attributed to their successful lawn conversion program as well as the willingness of constituents to conserve—possibly due to the competition imposed on them. Denver Water had a huge advertising campaign that helped get the word out about conservation, and their lawn watering restrictions were very successful. Reducing water consumption in residential areas has many factors to it, and monitoring drought is extremely difficult.

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PREFACE

This thesis was brought on by my fascination with western US water law. My classes at the University of Colorado have taught me a lot about it, but I wanted to delve deeper into the world of water management with this opportunity. I would like to express my extreme thanks to each of my thesis advisors—Paul Lander, Dale Miller, and Deserai Crow—for their help during this process. I would also like to thank the employees from each district as well as the University of Colorado professors who spoke with me regarding my project.

INTRODUCTION

With all of the issues surrounding water, it is important that we have management strategies and reduction goals that can be met based on regional water scarcity. While many are generally unaware of the fragile state of water, the recent droughts occurring in the western United States has forced many areas to implement strict reduction and conservation plans. Sustainable management plans have been important in western states, as ineffective management has caused increased issues with water accessibility and water use efficiency in the past. While water is a concern worldwide, the western United States has often been the source of controversy when it comes to water law and management. Not only are there immediate pressures to water sources, there are also more long term pressures to consider, especially currently in the western US.

In this honors thesis I will be looking at strategies that water managers have taken on in the midst of local drought. The areas of focus will be southern and northern California (Western Municipal Water District of Riverside and Easy Bay Municipal Utilities District, respectively) as well as the front range of Colorado (Denver Water). While California is in a severe drought right now, Colorado's most recent drought ended in about 2005. I believe it's important to look at how the very different southern and northern parts of the state of California are responding to changes in policy by the state, as well as environmental stresses. Colorado can add an interesting point of comparison as they are a state that has gone through drought and can add perspective to California's current problem. Denver ran a very successful water conservation program during their drought and it would be interesting to see how it compares to the California districts plans.

California is an important area to look at because of how extremely water stressed they are at the moment. Not only is it my home state but it houses over 35 million people, and how

they handle their water while going through this can be an important lesson for other states in the future. They can also learn a lot from past experiences, not only within California but from other states and countries which have gone through extreme drought, including Colorado and other areas of the world such as Australia. With that being said it is also can be helpful to look at different portions of the state to see if they have different interests that cause them to make different decisions when it comes to water management. How certain portions of the state react to this drought can serve to answer questions like what works when it comes to water reduction strategies and help others conduct themselves during drought times in the future.

What I hope to see in this study is water managers within different agencies or districts working to reduce water use in the face of drought, and to compare their strategies in order to find out what works best. It's important to note that different areas have different priorities, which will be researched and discussed. By looking at what the districts are doing the same and what they're doing different and comparing this to Denver, it can help to see what was learned from past drought management strategies. Australia went through a harsh drought and many are comparing the two and trying to learn from Australia's successes. While California will be the main area of focus, Denver Water will also be researched in order to take into account to another state, where although there are differences within laws, there is a lot to be learned from this comparison.

This question is important to look into for many reasons. Water is vital to sustaining human life. Protection of this resource is especially important in times of drought, and because droughts are a natural phenomena they will always be something to consider when discussing water management. In order to make informed decisions in the future regarding this, looking at

past and current strategies can be helpful. Also in order to meet reduction goals set by water agencies, citizens need to be made aware of the stress that we put on our water sources. In this sense, education is essential.

Examined in this thesis will be several types of data. First, numbers such as gallons per capita per day (gpcd) are considered. For this California drought, gpcd is the main measure of success. Water use patterns pre and post drought in California will be compared, before 2014 and after. In Colorado the same method and data will be used for their drought that ended in 2005. California has an overall reduction goal and plan as of 2015 mandated by Governor Jerry Brown, where each of the 411 urban water agencies in the state were given a reduction goal which is based on existing water use (Siders and Kasler, 2015). Along with this, districts have local goals and restrictions that aim to further decrease water use. Then, it will be important to look at restrictions made by the three different areas of research. In the two California regions, policies which were enacted both before and after the Governor's mandate will be examined to see what water mangers were doing before the official drought confirmation and if there were any changes made after. Other data will be if and how the budget of water agencies changed because of the drought.

Agriculture is the largest water user. Agriculture and urban water use are two very different areas, when it comes to law and ways in which you can reduce. In this study only urban water use will be looked at for several reasons. Water for human consumption has to be treated, making it more expensive and even more limited. Communities having long-term plans for their water use can increase their chance of success when it comes to meeting goals. Urban water use is important to control and know about because a change in peoples mindset when educated

about water can cause changes bigger than a reduction in urban use. With population growth continually increasing, it's important for everyone to be well informed about water use. Looking at what works best for water managers can be significant in creating new policies and management plans for water agencies.

REVIEW OF LITERATURE

While a good amount of research has been done on water management strategies in the Western United States, much of has its main focus on pricing changes. Pricing is an important tool used by water districts, but this thesis will be looking more closely at what works around the pricing changes. It's extremely hard to pinpoint just what is causing water customers to reduce their demand when it comes to policies and restrictions, which is noted by many of the authors discussed in this literature review. Few have found that specific restrictions have caused x amount of water reductions.

Kenney, Klein and Clark found that for the 2002 Colorado drought, tighter mandatory restrictions set by the districts led to more success in water reduction by their customers. Another study done by Halich and Stephenson had similar results during their study in 2009. Mandatory restrictions have significantly more success in reducing water demand according to both of these studies. In order for Kenney, et al. to come to their conclusions, they used a regression model that calculated what water use would have looked like without any mandatory reductions. Again, their results showed that with voluntary reductions there is a decrease in water use, but mandatory restrictions are more effective.

A question that I believe many have and was brought up in the Kenney, et al. article is the question of what happens to residential water use after the drought. Will it go back up, and if so, by how much? This is a commonly asked question and an area where further research is needed. To build on this, how a water district reacts to this fluctuation in water usage with its pricing is another area that could use more research. Districts have to tinker with pricing, policies, etc. to decide what their post drought model is going to look like.

Another topic that is commonly discussed in the literature is the shift in focus from supply-side management to demand-side. This is something that I would like to build on with my thesis. While past strategies have focused on gaining water, in recent times this has been far too difficult. With prior appropriation in the western US, there is no water that is unclaimed. Increasing populations and limited water resources makes it hard to focus on the supply-side without risking future water shortages (Halich & Stephenson, 2009). This leads water managers to look toward lowered water use from their constituents, and conservation is something that can immediately make an impact.

With the programs implemented to reduce water use, Halich & Stephenson also discuss how there are varying levels of effort that districts give for certain programs. This is hard to tell from just reports itself. In this way I believe looking at budgets can be beneficial, to see if they put a significant amount of funds into one project. Two different districts may have the same program, but Michelsen, McGuckin, and Stumpf's 1999 paper notes that one city may use considerably more funds in order to make a particular program work, while another lets the program remain stagnant. Their paper looked at the effectiveness of these non price conservation programs and found it difficult to distinguish the effectiveness of a single program as being most effective. They did prove that non-price programs can be effective in reducing demand. They then suggest that utilities maintain detailed and consistent information for their constituents in order for these programs to be most effective.

Pricing is an important tool when working to reduce residential water demand, when used effectively it can reduce residential water demand (Halich & Stephenson, 2009). With non price tools used to manage drought, it's less obvious how effective programs are. It has been seen in

two of the articles mentioned above that mandatory restrictions are more effective in reducing water demand than are voluntary. They also showed that the tighter the mandatory restrictions, the higher the water savings—which is what you would expect but is important to study.

BACKGROUND

Introduction to Water in the West

Water is a vital resource. While it is renewable, it is also finite and its flows are easily influenced. Many pressures are put on it, including the continual growth of the global population. The demand for water is also growing exponentially, while its existence is often taken for granted. Water is necessary not only to sustain human life, but it also supports industry and many businesses such as agriculture and energy production. The importance of water is unparalleled, and with the stress that humans put on it, a delicate balance is needed.

While water is used in many different ways, the main source in which fresh water goes toward is agriculture. Irrigation for agriculture accounts for 81 percent of water use (esa21.kennesaw.edu). Water for domestic use is just a small percentage of this pie chart. That being said, there are more than one billion people who live in water scarce region, a number which may continue to grow (wri.org, 2015).

This scarcity is due to several contributing factors. As many know, more than 95 percent of the water on Earth is contained in the oceans (Perlman, 2015). According to the USGS, of the 2.5 percent of water on earth that is fresh water, only about 30 percent is accessible to humans, while the rest is locked up in ice caps and glaciers. Rivers make up only 0.49% of surface freshwater, while just over 20% is in lakes. The rest is in either ground ice and permafrost, the atmosphere, or swamps (Perlman, 2015). Since we only have a small number of resources in which we can get water from, it's important that we do not deplete those sources. Groundwater is another place where fresh water is stored, and many of our most important aquifers are being over-

pumped (Pacific Institute). The Colorado River, an important source of water for the western United States, will not reach the sea in most years (Pacific Institute).

There are many environmental factors that impact water scarcity. Rainfall in a region is obviously a large factor, but larger forces like El Niño years and global climate change will change the amount of water regions are getting each year. Climate change may cause an increase in droughts, El Niño completely shifts weather patterns and 2015 and 2016 are going to see the effects of it.

Humans have also worked to control water sources by damming it and creating aqueducts to guide water to the more populous regions of the world. Rivers and lakes are naturally occurring, but the impact of humans shows in many of these systems. Past studies have shown that the hydrologic cycle has been significantly altered in the past 70 years due to human alteration (Barnett, et al. 2008). This has led many areas with depleted water resources and forced to either reduce or find new water sources. With this, many water managers have had to be especially innovative in order to ensure their regions are water secure. Desalination of sea water is an idea that has been toyed with often, but as of yet has not seen a completely successful integration into the US water system.

Water Law in the West

Prior appropriation dominates western water law. The doctrine generally governs the control of water in all seventeen states west of the Mississippi, but only actually is applied fully in eight states. These eight states are Arizona, California, Colorado, Idaho, Kansas, Montana, Nevada, New Mexico, Utah and Wyoming (Gopalakrishnan, 1973). Because of the extremely limited supply of water in these states, prior appropriation has been an important part of the sys-

tem of western water law. The doctrine defines water rights as determined by priority of beneficial use. This dictates that the first person to use the water or divert it for beneficial use can acquire individual rights to the water (Legal Information Institute, 2015). So first in time, first in right, along with the fact that the person must put the water to beneficial use. Beneficial use is a "cardinal principle" of the appropriation doctrine, and means that water must be used in a non-wasteful way (fws.gov, 2015). While beneficial uses vary by state, they generally include uses such as for fire protection, industrial and commercial uses (aqwatec.mines.edu, 2015).

Defining Drought

Drought is defined differently depending on local climate. While a few days without rainfall is a drought in some places, such as Bali, in most other places that's completely normal. In a very general way, drought can be defined as a period of time, usually one season or more, in which there is a deficiency of precipitation that results in an imbalance of the water cycle (drought.unl.edu). This leads to issues with having enough water to sustain human and environmental stressors. There are three types of drought: meteorological drought, agricultural drought, and hydrological drought. A meteorological drought is defined by the prolonged lack of precipitation, agricultural is determined by soil moisture deficits, and hydrological droughts are decreases in rivers, reservoirs and groundwater levels (Arnell, 2014).The beginning and end of drought is something that is hard to determine and scientists don't always agree on (Wilhite, 2005). Since droughts come about slowly, it's hard to agree on terms for the start and end of a drought.

As for the areas that were studied, the annual rainfall in Denver, Colorado is 15.54 inches (USClimataData.com, 2015). In Riverside, California, a large part of the Western water district in

southern California, there's an annual rainfall of about 12 inches, and in Oakland, a part of the East Bay district in northern California, their annual rainfall is 23.99 inches (USClimataData.com, 2015). Denver sees 55 inches of snowfall annually, which really sets them apart from the other two districts in terms of precipitation (US Climate Data, 2015).

2014 was California's driest year on record, and the Sierra snowpack was measured April first of 2015 and was five percent of average for that date (USGS, 2015). This is a crucial date for snowpack because it usually when the peak begins to melt and run into streams and reservoirs (USGS, 2015). With that being said, Los Angeles received 5.85 inches of rainfall in 2013 and 6.08 inches in 2014, setting the record for the two driest back to back seasons on record (dailynews.com). The state also saw its two warmest years on record, ending September 30 of 2014 and 2015 (USGS, 2015). In 2013 Oakland saw 57% of its average rainfall with only 13.81 inches in 2013 (Golden gate weather services, 2013).

While California had been enduring drought since 2012 (USGS, 2015), it wasn't until January 17, 2014, Governor Jerry Brown officially declared a drought emergency throughout the state (Boxall and York, 2014). There are technically 5 stages of drought. Level 0 is abnormally dry, level 1 is moderate drought, level 2 is severe, 3 is extreme, and 4 is exceptional. Currently California is in the highest stage. In the governor's statement released at the time of the declaration, he stresses that California's water resources are low, and another low rain year was upcoming. Some areas in Northern California are particularly dependent on local sources which are dwindling, and were forced to reduce much sooner than other communities (Boxall and York, 2014). Several ideas are thrown around at the time (January 2014) by legislators, water managers and water resource directors. They suggest things such as more water storage projects and re

plumbing of the Sacramento-San Joaquin delta. It's also noted in 2014 that because of restrictions in previous years, many Southern California areas didn't feel the need to reduce any more for the time being (Boxall and York, 2014). These differences within the state is what I'm most interested in.

While drought obviously affects the amount of water an area receives, lowering its reservoirs, it has other consequences that are not as obvious. Drought conditions also lower the quality of water in the short term. While this is considered less when discussing drought, studies have shown that periods of drought lead to decreased water quality (van Vliet, M., & Zwolsman, J, 2008). One study looked at 24 water quality parameters in a river in Europe, and found there to be a general degradation in water quality during droughts (van Vliet, M., & Zwolsman, J, 2008).

In order to adapt to these stressful conditions, water managers were forced to make decisions on how to either cut back on water use or find new water resources. Pricing is a well-tested and studied way to incentivize people to reduce water use. Most consumers respond to this method-Renwick and Green's study showed moderate reductions of 5-15% with pricing changes (Renwick and Green, 1999).

Droughts are not uncommon or new to California. A drought in 1953 led to the drying up of some natural lakes (Lake Filler, Buena Vista Lake) in the state (The Rotarian, 1963). The next drought occurred from 1976-77, and 1977 was one of the driest years on record (Kotin and Marion, 2014). More recently, there was a drought which occurred from 2007-2009. This drought was mild compared to the current one, but during it they did see several changes including a step up in conservation targets as well as reforms which required local groundwater monitoring (Kotin and Marion, 2014).

Success has been seen in California when it comes to reducing urban use during previous droughts. During the drought which began in 1976 and ended in 1977, the state was successful in reducing water use in the urban sector by encouraging residents to refrain from everyday household activities such as watering the lawn and flushing the toilet (Kotin and Marion, 2014). While that has been seen also during the current drought, circumstances are more dire because of the increased population in many areas of California with the same amount of water that they had during the previously mentioned drought (Pacific Institute, 2013). Californians seem to prefer this method of conservation over big water projects. In 1982 voters in the state defeated a ballot initiative to fund the construction of a canal which would have diverted water from the Sacramento River (McGill, 2012).

Water managers have foreseen drought in the past and know from other regions and what the options are. With that comes new ideas that are thrown around, such as desalinization and finding new water to import. During the drought which started in 1985, a California water company agreed on a contract with a water company of British Columbia, Canada to receive bulk water, but a change in government reversed the decision (Heinmiller, 2003). This example in California's history goes to show that it's not easy to gain access to new water sources, and there's a lot that goes into water management.

Climate Change, El Nino and Drought

As mentioned in the introduction, climate change is one of the factors which must be considered in this day and age when planning for water use in the future. While droughts are caused by natural forces, humans impact on the amount of carbon dioxide in the atmosphere is contributing to the heating up of our planet. Evidence suggests that increased warming of the

planet will lead to longer and more intense droughts (Plumer, 2012). There is no single pattern that droughts have when affected by climate change, though. In some areas droughts are prolonged, while in others, droughts appear to be shorter, less frequent and less severe (Plumer, 2012). So while the effects are not going to be known unless we go through them, it's important to take this into consideration when managing water. Climate change has worsened the current California drought by increasing evaporation from its water supply, further stressing their water resources (Circle of Blue WaterNews, 2015).

El Nino is another natural event that occurs every 3-7 years and is going to affect weather conditions in California in 2016. El Nino is the increasing of sea surface temperatures in central and eastern tropical Pacific Ocean (L'Heureux, 2014). Trade winds that normally blow from east to west weaken during an El Nino event, and may at times switch direction (Erdman, 2015). Generally California sees wetter conditions from this event, and often experiences flooding and landslides (Erdman, 2015). In 2015, what scientists are calling the "strongest el Nino in 18 years" is going to affect central and southern California, bringing wetter conditions (The Weather Channel, 2015). As for northern California and Colorado, there's less of an impact predicted (The Weather Channel, 2015). Summer and fall had already seen effects from this current el Nino, particularly with the flooding seen in Texas and some snow to the Sierras of southern California (The Weather Channel, 2015).

While wetter conditions in the southern portion of the state will be helpful, the Association of California Water Agencies predicts that this is not going to be enough to end the current four year drought. A major portion (over 50%) of California's water supply relies on gradual snowmelt from the Sierra Nevada's. Precipitation would need to be about 120% above average in

key northern California watersheds to make a signifiant impact on the drought (Association of California Water Agencies, 2015). Key reservoirs are at about one third of capacity because of the drought, and without an increase in precipitation in these reservoirs, the drought is likely to continue (Association of California Water Agencies, 2015). Heavy rain and snowfall in 2016 will be beneficial for the current year, but the drought is likely to continue into 2017 regardless (Association of California Water Agencies, 2015).

Governor Brown of California released a drought mandate declaration in April of 2015, calling for a reduction in water usage throughout the state along with an increase in the enforcement of wasted water (gov.ca.gov). The California Water Action Plan notes the challenges of maintaining water resources, such as drought, declining groundwater supplies, and population growth further stretching water resources.

In the midst of this, water managers within California are reacting to these restrictions in different ways. Many are working together in integrated water management plans, and setting further restrictions for the constituents of their district. While in the past supply-side management has been the focus, scarce water resources have caused water managers to shift their focus to demand-side, and push to reduce water use (Arbues, et al 2003). On many websites concerning the California drought, the ‘new normal’ is brought up. This term is referencing a shift in the normal weather patterns that we see, as well as the new water pricing structures that will come along with the amount of water we can use due to decreased supply. This new normal may be California facing droughts and floods more often due to the effects of climate change (Association of California Water Agencies, 2015). It also may be increased prices in order to reduce water use to combat the issues seen with these droughts and floods.

METHODS

To better see the strategies taken on in different areas of the West and how effective they are, three districts were looked at. As mentioned earlier, one is in northern California (East Bay MUD), one in southern California (Western Municipal Water District), and the other in Colorado (Denver Water). The districts or cities selected for this analysis may seem random, but there is a reason that each was chosen. California is going through a historic drought that is garnering a lot of attention. There has been animosity in the past between northern and southern California regarding water, and to build on that I wanted to see if the two regions react differently in the midst of drought. The population of Western Municipal Water District of Riverside is just below 1 million, while East Bay houses 1,390,000 (Pacific Institute, 2015). Denver Water had a very successful drought management plan during their 2002 drought, and I'm interested to see if either of the California districts built off this success when creating restrictions for their residents. Denver Water currently provides services to 1.3 million Colorado residents (denverwater.org, 2016).

One difference between the Colorado drought in the early 2000's and the current California drought that must be taken into account is that the California districts were mandated a certain reduction goal by the state, which was not the case for Denver Water. All of the information looked at in this thesis was found online, most specifically from the district websites themselves. The numbers for gallons per capita per day from the California districts is from the Pacific Institute website, where they are closely monitoring this drought.

In water management, it's notoriously difficult to conclude that any sort of water savings was from a specific restriction or program. While Kenney, et al did show that more stringent restrictions for lawn watering led to lower water use in several cities in Colorado, this type of spe-

cific finding is a rarity. With this being said, it would be great to prove that one program in particular caused x number of gallons saved per month, but this analysis does not strive to do that. Drought response is extremely important and will continue to be in the future for most of the world. In order to learn from past experiences in drought response, it's important to monitor and analyze these past strategies. In order to do this, I reviewed primary materials provided by each district.

First, local policies that the two California districts implemented were reviewed. This includes things such as any ordinances that they may have adopted, water use restrictions (specifically outdoor use), incentive programs, and new technologies or water sources. This information was looked at in order to see if they mandated more stringent water conservation goals or if they just set the goal to be the lowest amount mandated by the state, and to see how willing these districts were to help their consumers save water. While demand-side is the main focus for these districts, having even more reliable sources of water is something that these districts do take into consideration. The governor of California mandated a 25 percent decrease in urban water usage, which some districts met easily because of their local policies in place prior to the official start of the drought. All of this information was found online, most of it from the website of the district itself.

I also wanted to see whether or not budget changes were made within the water districts. While this was not the main point of comparison it helps to answer some key questions. If there was a significant change in staff or where money was allocated, this could certainly help pinpoint what the overall strategy of the district is/was. An increase in the overall budget could also signify that they have a new source of funding that may be directly because of the drought. Conserva-

tion programs are certainly going to be up and running, so also seeing if they set aside a certain amount of money for that can be useful.

Last, water use patterns before 2014 were examined in the California districts, which is the period before the officially declared drought. In order to see how their policies and budget changes affected actual water usage, water use patterns in 2015 were also examined. In Colorado, Denver experienced drought in 2002, and much of the information was found in Kenney, et al.'s 2004 paper. For the California districts, this information was found from the Pacific Institute website. The Pacific Institute is closely monitoring this current California drought and their interactive map allows you to explore trends and patterns in each district's water use since 2013, which I tried to utilize during this project. In order to gain perspective of the district itself, people were contacted from each district. While speculation can be made about what the district's main strategy was, it was important to discuss this with people from the districts in order to gain background on them.

There are many different ways to measure success in water management, but the method chosen for this analysis was gallons per capita per day (gpcd). While this is arguably the best measure of success in residential water use, the numbers are readily available and do an accurate job of measuring demand. For each district there are differences that affect the way that they are allowed to manage their water, which I attempted to take into account. An example of this is that Denver Water is truly its own entity and owns all of its water rights, while Western in comparison is a part of a larger network of water districts and purchases water from another district.

In order to compare these data, charts were made. There are several charts, one showing restrictions only for each district, another showing budgetary changes between the districts, and

showing the rest of the data that were looked at. The purpose of them is so the reader can easily see and distinguish between what data was looked at. It also helped in the analysis of data, to look at what each district was focused on and how effective it was in reducing actual water use.

By examining these data I'm trying to see what methods water managers impose on its citizens, and also what works best. By looking at water use patterns I can see how effective the policies are, and see if the district users are taking the restrictions seriously. By looking at the policies implemented, I can see if each district decided to adopt any ordinances, strictly enforce and/or fine for restrictions already in place, or create new restrictions. By looking at the budgets I hope to see a change in the year going into a drought, with the budget maybe more focused on education of the districts constituents or maybe even the implementation of a new conservation program budget. When looking at these, similarities and differences between the districts were noted. If there were similar programs or policies, especially between Denver and either of the California districts, one could assume that something was learned from earlier drought management plans. Differences in plans may point out why the district has seen success or not.

DATA

This section details all of the information taken into account during this analysis. It is split up by districts. Again, this information is the districts water use patterns during the drought, reduction goals, policies and ordinances implemented relating to the drought, and budget numbers found on the district websites.

EAST BAY (EBMUD)

This district gets its water mainly (90%) from snowmelt from a watershed of the Mokelumne River in northern California (ebmud.com, 2015). They're also licensed to use 325 million gallons daily from the Mokelumne river itself (All About EBMUD, 2013). Last, they store water in two dams along the Mokelumne river: Pardee and Camanche. As a backup, they have a contract with the U.S. Bureau of Reclamation for a supplemental water supply to use during times of drought or emergency (All About EBMUD, 2013). This water comes from the Sacramento River. They

Drought Surcharge

Effective July 1, 2015 a drought surcharge for potable water delivered will be billed per 100 cubic feet as follows:

Maximum Applicable Drought Surcharge

	Stage 1	Stage 2	Stage 3	Stage 4
Single-Family Residential Accounts				
For the first 172 GPD	$0.00	$0.23	$0.59	$0.73
For all water used in excess of 172 GPD up to 393 gpd	0.00	0.31	0.79	0.99
For all water used in excess of 393 GPD	0.00	0.40	1.03	1.30
Multi-Family Residential	0.00	0.32	0.81	1.02
All Other Accounts	0.00	0.32	0.81	1.01

Table 1. For East Bay, showing the pricing changes due to drought, as well as the excessive use penalty.

do note that reduced use is not enough, and that they're always on the hunt for more places to purchase water from.

Through personal communication with employees at EBMUD, I learned that while they are always in the market for more water sources, the difficultly of acquiring it is high. Because of prior appropriation, all of the water in California is already accounted for. The only way they can obtain new water is if someone has a surplus and is willing to sell. The district did find that luckily, because they have the budget to be able to compete for these types of opportunities, they are first in line. For example, they got water from farmers in Placer County, CA during this particular drought, which was mentioned to be a big help in order to keep the district from being extremely water stressed.

Water Use Patterns

East Bay Municipal Utilities District used 111 million gallons per capita per day in 2013, and reduced that number to 86 million in 2015, with a total reduction of 26.4 percent (see fig. 1). Of that water use, residential use went from 69 to 53 million gpcd. Their reduction goal was 16 percent, so they far surpassed this number.

Policies

On the East Bay website (ebmud.com, 2016) they lay out their reduction goals, mandatory restrictions, as well as any changes in policy or rates. They set a community wide goal of 20 percent reduction from their 2013 water use. As of July 1, 2015 new rates were implemented which includes a 25 percent up charge to cover increased charges during the stage 4 drought (edmud.com, 2016). If drought condition reduces to stage 0 or 1, there isn't a surcharge. For each stage

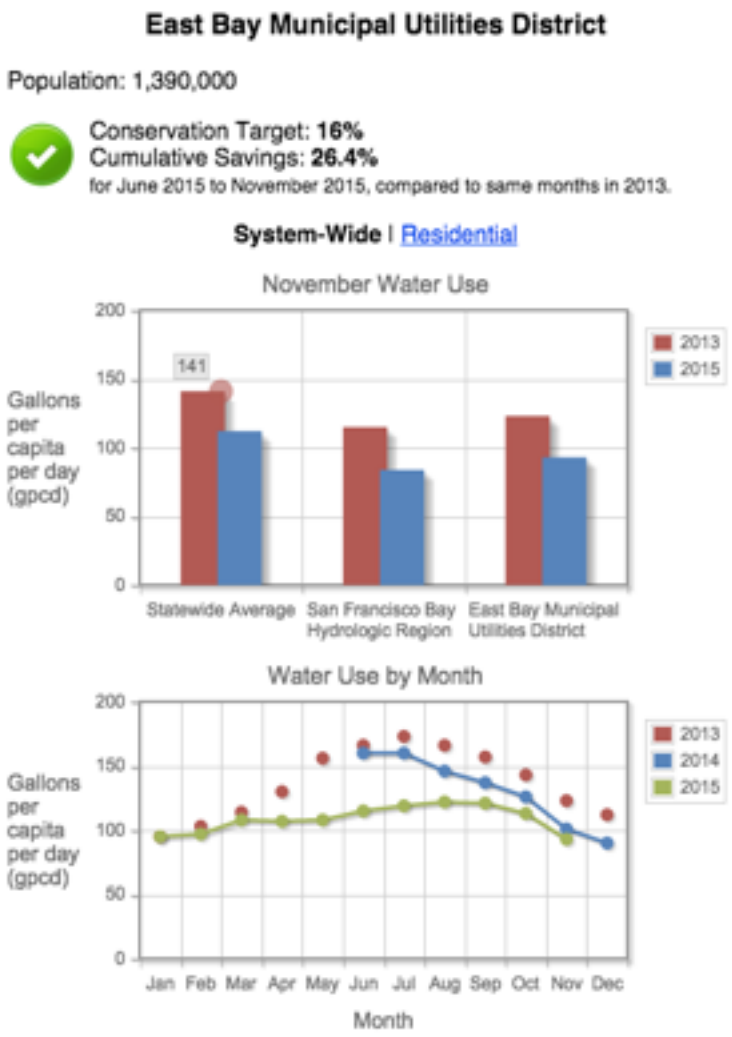

Figure 1. This figure from the Pacific Institute's Interactive Map shows the reductions seen from 2013 to 2015 by the district. It also notes their population and conservation target, and whether or not they met their target goal.

of drought there are different demand reduction goals as well as rates which are listed in table 2, which is from EBMUD website. They tell their customers to strive for 35 gallons per person per day indoors, and to follow the rules for outdoor use.

The restrictions for outdoor use are as follows: watering only allowed on two nonconsecutive days or less per week with no runoff and only between the hours of 6pm and 9am. No watering is allowed within 48 hours of measurable rainfall, on ornamental turf on street medians, or

Stage	0	1	2	3	4
Demand Reduction		Voluntary 0-15%	Voluntary 0-15%	Mandatory 15%	Mandatory 20%
Supplemental Supplies			Up to 35,000 acre feet	35,000-65,000 acre feet	> 65,000 acre feet
Rates and Charges	Normal rates	Normal rates	Normal rates + 8%	Normal rates + 20% Supersaver recognition* Excessive use penalty*	Normal rates + 25% Supersaver recognition* Excessive use penalty*

Table 2. For East Bay, showing the stages of drought and corresponding demand reduction, supplemental supplies, and rates/charges. From EBMUD.com.

on sidewalks or driveways. When washing cars, hoses need shut-off nozzles, and decorative fountains need to be turned off unless they're recycling water.

In order to achieve 35 gallons per person per day, EBMUD has a link that teaches you how to "save like a pro". This really encourages their users to be aware of their water use and how they stack up against other people. The use of competition can be important—people don't want to be the ones who are using the most. They encourage you to create a budget for yourself, indoor and outdoor use. They also give suggestions for what these numbers should look like… they say 35 gallons per day indoors (as mentioned earlier) and give you an equation for calculating your use.

The district also adopted two ordinances in 2015 in order to reduce excessive use and water theft. These two ordinances are the excessive water use ordinance and the water theft ordinances. The excessive water use ordinance penalizes people who use over 4 times the amount of a normal residential customer uses by charging $2 for each unit over the 80 unit threshold (ebmud.com, 2015). Both ordinances went into effect on May 29, 2015. The water theft penalty allows EBMUD to fine those that make unauthorized use of public hydrants or are caught stealing water, and EBMUD encourages its customers to report any cases of this. If a customer is consistently wasting water, the district will go as far as discontinuing service (ebmud.com, 2015). There are four notices that come to the user before they will discontinue their service.

Budget and Pricing

FY 2015	FY 2016	FY 2017
$740,231	$901,083	$932,149

Table 3. Shows total budget numbers in millions for East Bay Municipal Utilities District for fiscal years 2015, 2016 and 2017. Information taken from *Biennial Budget Fiscal Years 2016 & 2017*.

East Bay's budget had several interesting changes. Table 3 above shows the total budget from fiscal years 2015-2017. All of this information was found on their website, on their most recent budget for fiscal years 2016 and 2017. Their total budget for from fiscal year 2015 to 2017 went up, with a significant change I believe because of their budget for drought contingency. What's really interesting is that there was no budget for drought contingency in 2015, but in 2016 there's a budget of 64 million dollars. The adopted budget for 2017 is 62 million in drought contingency.

The highest amount of revenue for East Bay comes from 3 places: 84 percent from water charges, 5 percent from property taxes, 5 percent from SCC (system capacity charge). As for changes in staff, I learned through discussion with EBMUD employees that the water conservation department was able to hire more staff due to the drought. Finances always take a huge hit during drought times because their main source of money comes from water charges. Beginning July 1, 2015, East Bay introduced a 25 percent surcharge to help offset this deficit. With each stage of the drought, their pricing changes, which is shown in table 1 from the EBMUD website above. Along with this, they have their excessive use penalty, which was mentioned earlier.

WESTERN MUNICIPAL DISTRICT OF RIVERSIDE (WMWD)

Western Municipal District of Riverside is 527 square miles of Riverside County in Southern California. They get water from 13 different agencies and 38 water storage reservoirs (wmwd.com, 2015). They get about one-fifth of it's water from purchases from the Metropolitan Water District of Southern California (Metropolitan), water that comes from the Colorado River Aqueduct. Most of their imported water supply is provided by the State Water Project, which transports water from Northern California via the California Aqueduct. They also get a small amount from the San Bernardino Basin, and have several wells for pumping groundwater (wmwd.com, 2015). They are also a part of the Santa Ana Watershed Project Authority (SAWPA), which is a regional water resources planning and project implementation organization.

Water Use Patterns

Western had a conservation target of 32 percent from their December 2013 water use of 160 million gallons per capita per day (gpcd). In December of 2015 they dropped that number of 135

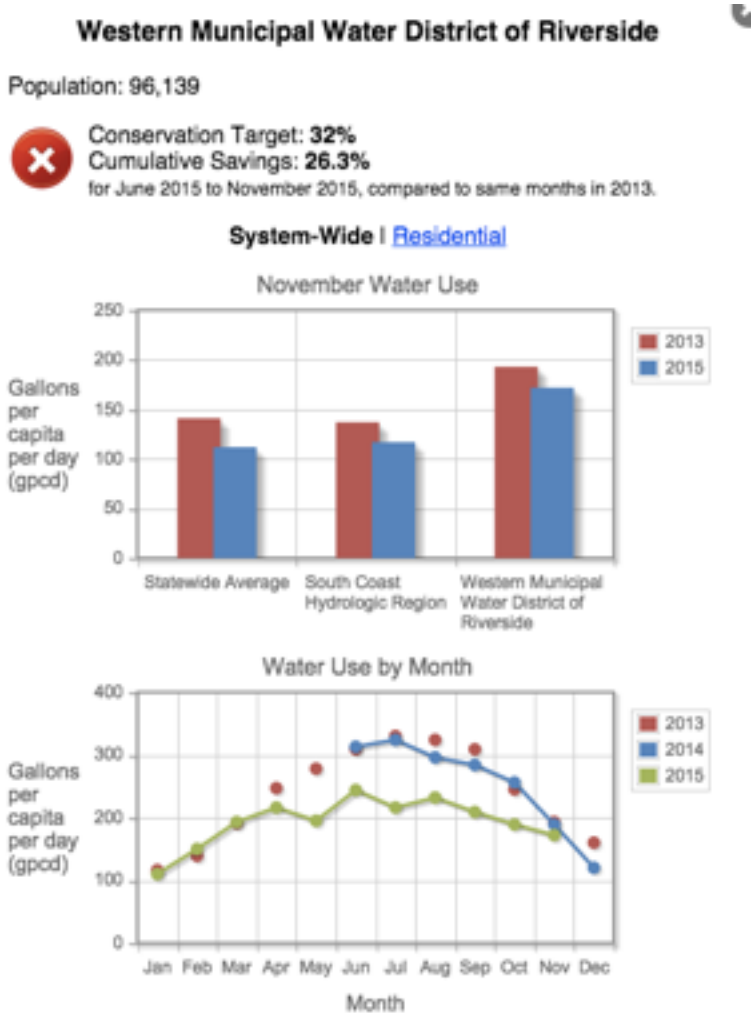

Figure 2. From the Pacific Institute's Interactive Map, showing Western's conservation target, whether they met the target, and their actual savings.

million gpcd, a cumulative savings of 25.4 percent ("Interactive Map…", 2015). Of the 135 million gpcd, 82 million is residential use, which was dropped from 104 in December of 2013.

Because of where this district is located, they don't have access to ocean water. Instead, Western uses brackish groundwater to desalinate. They have two plants currently operating— the

Arlington de salter in Riverside, CA and Chino de salter in Chino, CA. In the Western budget, they note that water from the Arlington de salter helps reduce dependence on imported water. This de salter began operations in 1990, and provides about 6,000 acre-feet of water to the cities of Norco and Corona, CA (wmwd.com, 2015). The Chino de salter is part of one of Western's major district incentives, in that they are expanding it to increase the amount of water obtained from it from 24,600 to 35,200 acre-feet per year (wmwd.com, 2015). They are definitely big on having a local source of water and reducing reliance on water from Northern California or the Colorado River.

Policies

Western says that over 60 percent of water is used outdoors, so their main restrictions are set for outdoor use. The goals in place for this district are set at reducing the outdoor budget by 30 percent, and commercial customer budgets by 10 percent. Some of the most notable restrictions are: no landscape watering between 8am and 8pm, irrigate only three days a week during the summer and two days a week during the winter, and no washing drive ways or sidewalks. Total there are eleven mandatory reductions listed on their website, and the other eight are as follows:

- Water trees once every four weeks, shrubs, young trees and roses no more than one time a week
- Add four inch layer of mulch to all soil areas
- No irrigation runoff
- Hoses need an automatic shut off nozzle

- Fix leaks within 96 hours of WMWD notification
- No pruning or fertilizing plants
- Only install new plants during the cooler season
- Turn off irrigation within 48 hours of rainfall

Western also adopted ordinances in 2015, ordinance 384 and ordinance 385. These two ordinances are less specific than the ones that East Bay adopted. The two ordinances are called the Retail Water Supply Shortage Contingency Program (384) and the Wholesale Drought Allocation Plan (385). Ordinance 385 was adopted on May 20, 2015 and recognizes that this district is going to follow the Drought Allocation Plan (DAP). Western purchases their water from the Metropolitan Water District of California (Metropolitan), and Metropolitan is getting less water during drought times. These two essentially were implemented because Western needed to ensure that they were within their bounds to restrict the use of their customers water during drought times.

Western is focusing on their drought outreach and education plan, thats goal is to educate the citizens of their district on effective water practices. Some of these programs include free efficiency evaluations, turf replacement rebates, and master gardner workshops. These are fairly self explanatory programs, but I think it's important to note that they're focused on outdoor use. Another goal of Western is to reduce water use through efficiency programs. Again—there are several types of programs including rebates and tips to saving water. FreeSprinklerNozzle.com is a program that helps their customers save money and save water. Garden friendly landscaping is encouraged with a financial incentive of up to $2 per foot of replaced grass. They have a garden

that you can come see called Landscapes Southern California Style and workshops are held there.

Other notable programs that Western has is that there is an app where you can report water waste. If you see someone wasting water, you submit a new request and picture if you want, and it's sent to Western to investigate. There are also free evaluations to see how efficient you're being at your home or business. This service is for outdoor use, where a water auditor comes to evaluate your water use and provide suggestions on how to be more efficient. They also have a recycled water plant up and running, which they provide to their non-potable water customers.

Budget

This information was found on the WMWD website, in their fiscal year 2014-2016 budget. Their total operating funds for fiscal year 2014-2015 was $104.9 million dollars, and has gone up to $108.9 million for FY 2015-2016.

This district gets most of their money from water sales as well. They also get a much smaller amount of money from water service and waste disposal revenue. They purchase water from Metropolitan, which has steadily had increasing prices since 2008. Treated water pricing from Metro has been increasing—it went up 3.7% from 2014 to 2015. If Western purchases more than 21,1000 acre-feet of water from them, the rate goes to tier 2, which is $132 higher per acre-foot than the tier 1 rate. Western has a budget based rate structure (and has since 2008). Their residential customers are assigned a water budget based on how many people live in the house as well as the size of their lot.

In the budget, the district lays out its major initiatives in the 2014-2016 budget. These are important to gain more insight as to what their main points of focus are going into 2015. These initiatives are as follows:

-Expansion of the Chino Desalination Plant

-Drought outreach and education

-Water use efficiency initiatives

-La Sierra pipeline project: This is to be completed 2018, connection to bring desalted water into Western's retail service area by connecting the Arlington De salter to the La Sierra tank in order to reduce their dependence on water from Metro District.

-Arlington Recharge Basin: Introducing captured groundwater, to be finished 2017

-Bay Delta Conservation Program: building new water delivery system on Sac-San Joaquin Bay

DENVER WATER

Denver Water gets its water from rivers and streams in Colorado that are fed by snowmelt. Their primary water sources are the South Platte River, Blue River, Williams Fork River and Fraser River watersheds. They also get water from South Boulder Creek, Ralston Creek and Bear Creek watersheds (denverwater.org, 2016).

Denver Water ran a very successful conservation plan for the 2002 drought. They had a large focus on reducing outdoor use, specifically reducing lawn watering by mandating specific time frames. They also had rebate programs for switching to water efficient appliances (washing machines and toilets). Their main slogan was “use only what you need”, which they began a large campaign on in 2006. Their drought response plan sought to “strike the appropriate balance

between using water wisely and reserving it in storage" (denverwater.org, 2016). The plan's primary goal was to successfully manage water use so that there will be enough supply available for the most essential uses for the duration of the drought.

Similar to both of the California districts, they set a reduction goal for their residential customers of 30%. For their actual reductions, Kenney et al. found that they reduced their water use 22% from what the expected use would have been. Actual numbers from the Denver Water website show that they reduced water sales from 2002 to 2003 by 13%.

One factor that Denver dealt with during their drought that the two California districts haven't had issues with thus far is fires. They spent significant sums of money on firefighting efforts as well as to rehab environments in order to keep their water safe from further damage from these fires. They also had to restore watersheds that were damaged by fire, so this is another significant issue that Denver had to deal with during their drought.

One project that they put a lot of money into according to their 2003 budget was their recycled water project. This was supposedly going to bring recycled water to homes starting in 2004. They note in their budget that they kept several construction projects ongoing and on time, despite any losses due to the drought. These construction projects included the recycled water project which was discussed above, and the Moffat Collection System Project, which was a new water system reservoir.

They also invested in cloud seeding, which began in 2001. The goal of this program was to increase the snowpack in the South Platte watershed. One of their reservoirs, Antero reservoir, was so low at one point during the drought that they decided to drain it and move the water to storage facilities in order to prevent anymore evaporation loss.

Twelve agencies in Colorado collaborated to bring awareness to the drought through advertising. They did this through a combination of advertisements found in newspapers, on television, on the radio, as well using billboards. This was a huge joint effort that was pretty unique. This mass market advertising was followed by two more campaigns by Denver Water to encourage water savings in homes.

Xeriscaping is one other program that Denver put a good amount of money into promoting. They set an example, too, by xeriscaping Denver Water. The district offered free seminars, planning and design clinics. This encouraged their customers to get away from "water-hungry" turf, and to switch to water tolerant landscaping. They also had a water auditor that could go to homes or businesses and make suggestions for being more water conscious.

Denver Water adopted a surcharge for residential water customers as well as a tap surcharge in 2002. The tap surcharge is an addition fee that is paid by a developer for connecting a new customer to the utility's water-distribution system. With the money made from these surcharges, they provided the rebates for energy efficient appliances. They spent $2,962,000 on the rebate program. This surcharge also helped to partially offset the losses seen because of the 13% decrease in water sales.

RESULTS

From the data it is clear that all of the districts recognized the severity of their drought and made moves in order to reduce the impact. One thing I was initially looking for in the data was: are these districts taking the drought seriously, and if so, is one more so than the others? All three

RESTRICTIONS	Landscape Watering Hours	Specified Watering Length	FINES
East Bay 2015	9am and 6pm (9 hours)	only two watering days per week	none—get a letter, then will put on flow restrictor, discontinue service
Western 2015	8am and 8pm (12 hours)	no more than three days per week in the summer; two days per week or less in the winter	two notices and then a fine of $100 per day
Denver Water 2003	9am to 6pm (9 hours)	3 hours per day, once every three days	Warned by "Water Savers", then fined if continue to waste

Table 4. For each district, this table shows their landscape watering restrictions. How many hours a day they can water, how many days they can, and if fines are applicable when found to be watering outside of these times/days.

had major programs to reduce outdoor use. This included things like outdoor watering restrictions and rebates for higher efficiency options. While Denver water didn't appear to have a rebate for replacing your turf lawn altogether, they did have an irrigation efficiency rebate which encouraged high efficiency nozzles and such. The watering hours, as seen in the Restrictions Chart (see table 4) are all pretty similar. Western has the least restrictive watering times, allowing a 12 hour period three days a week. They also have different watering hours for summer and winter, which is different from the other two districts. Kenney, et al. proved that less watering days and shorter hours led to more successful water reductions. This may be part of the reason that Western has seen less success in residential water reductions.

Through personal communication, I learned that EBMUD customers are required to have high efficiency appliances, and even with landscaping they have strict requirements in order to get water from EBMUD. I also learned about their fining system because I found it interesting that they don't really have a financial penalty other than the drought sur-

	New Water Acquisition	Ordinances Adopted After 2014	Rebates Provided	Price Changes	Reduction Goals	Actual Reduction
East Bay	Water from farmers in Placer County	Excessive Use, Water Theft	High efficiency toilet, washer; mulch, graywater, retrofitting, converting lawns	25% surcharge per stage (see table 1)	16% from 2013 to 2015	26.4%
Western	Chino, Arlington Desal Plants	Retail Water Supply Shortage Contin-gency, Wholesale Drought Al-location Plan	Turf Replacemen t Rebate, Sprinkler Nozzles, Efficient Appliances	3.7% increase in rate for tier 1 customers, Budget Based Rate Structure	32% from 2013 to 2015	26.3%
Denver	Cloud seeding, Recycled Water Program, undeveloped water rights	—	Irrigation efficiency, Rainfall sensors, Water Efficient Appliances	20% surcharge (2003)	30% from 2002 to 2003	22% (from predicted reductions in Kenney, et al. 2004) 13% actual from '02-'03

Table 5. Shows information taken into account when looking at policy and reduction goals and actual reduction numbers.

charge and the excessive use ordinance charge. Their system is that first they will send a letter if people are watering outside of the specified times, and if this doesn't work they put on a flow restrictor. As a last resort, they pull the meter completely. He said this system has worked well for them, and no one has yet to have their meter pulled. With the letter letting people know that they're out of line, this usually stopped people from wasting water or using it when they weren't supposed to be. On the other hand, Western's system is that they send two notices and then there's a pretty hefty financial penalty. These are very different approaches to ensuring that their consumers are staying within their specified amount of water use.

For the two California districts, you can see there is a large difference in their water use reduction goals from 2013 to 2015. East Bay's goal is half what Western's is (32 percent vs. 16). I believe this can be explained by the gallons per capita per day that each district started at. East Bay has had lower gpcd all along, as their 2013 number was 111 million, compared to Western's 160 million gpcd. But both then had the same amount of actual water reduction, which is significant. They both saw a 26% decrease in water use from 2013 to 2015, regardless of their target to hit that was mandated by the state. So East Bay doubled their conservation target, while Western got just under their target reduction goal. As for Denver Water, the numbers indicated in the graph may underestimate just what their water savings were. The number that I found for water reduction from 2002-2003 is a 13% decrease in water sales between these two years. This 13% is only one year worth of reductions, and Denver was already reducing their water use before 2002. Because the California districts did not already have strict reduction plans in place in 2013, their goals are much higher than Denver's for that two year period. This must be considered when comparing the numbers seen for reductions between the three districts.

In Western's Drought FAQ they mention that they think that the amount they were asked to reduce by the state was unfair because of the way it was calculated. It doesn't elaborate on this topic in that document. But during conversation with Western employees, I learned that because of where Western is geographically, they believe it's harder for them to reduce water use that much. The way these reduction goals for each California district are set is unique. There were categories that each district was put into which ranged from reducing 4 percent to 26 percent in 4 percent increments. But, because this is all measured in gallons per capita per day, Western argues that this is not a measure of efficiency as much as a simple measure of demand.

The ordinances put into place by EBMUD (excessive use and water theft) were very productive in encouraging conservation. Western's links to the ordinances they adopted post drought were hard to read and understand as an average citizen. They were implemented more as an overall plan for ensuring they have enough water during this time, rather than focusing on conservation as East Bays do a bit more. I thought the ordinances put into place by EBMUD made a lot of sense and were helpful in charging people extra during the drought. But, Western does have a similar program to EBMUD's excessive use penalty that punishes users for going over their allotted water-both using other customers to help keep people accountable.

During this drought in California, there is more being done in terms of rebates from the districts for outdoor reductions. Having efficient irrigation is a common rebate program, and another is converting your lawn altogether. This shift from water hungry lawns to drought tolerant landscaping is helping EBMUD meet their reductions goal every month.

East Bay and its constituents have proved that voluntary restrictions do work at reducing water use in residential areas during earlier stages of drought. While this can be effective for

smaller reductions, such as the 10 percent that EBMUD saw in February of 2014 (ebmud.com, 2015) , for the 25-30 percent reductions they're looking for now it's unrealistic. I think from all of the districts looked at you can see that voluntary restrictions do work at lowering water use in residential areas, often just not enough when enduring a severe drought. Denver water mentions in their 2003 budget that there was a positive result from the June 2002 voluntary restrictions, but the severity of the drought caused them to be more strict. This meant enforcing penalties and mandatory restrictions. Kenney, et al. then proved the success of these mandatory, strict programs.

For all three of the districts, budgets appeared to increase steadily—no significant change from pre to post drought. East Bay was the only one where the drought contingency did seem to add a chunk of money for this upcoming fiscal year, 2016. As for staff members, East Bay allowed for the conservation department to add more people. Western, rather than hiring new staff, increased the workload of current staff members, particularly for their field staff. For example, the people who work in the field were encouraged to use their water waste app to report anyone who is wasting water. This is a smart idea because it saves them money as a district with a smaller budget.

There is pretty obviously a large budget difference between the districts. Since EBMUD is larger, they have a larger budget and therefore more flexibility in where they spend their money and how they go about the drought issue. This is an important difference between the districts and how they can proceed when faced with drought. Although employees from EBMUD discussed with me the difficulty of moving and obtaining water, they did have first dibs on the excess water from farmers in Placer County because of their deeper pockets. They still have a huge

conservation program, but they have a little more breathing room with the supply from these farmers.

To build on this, I did a budget calculation to try and see how much money these districts put toward each consumer in its service area. This is a simple calculation that of course doesn't tell the whole story, but can help to determine how much money was put toward each person in the district. It also may help determine a certain level of effort put forth by the district. East Bay serves more than 1 million people (1,390,000) and when you divide that by their total budget of 740 million, the result is $532.54 per capita. In 2003, the population served by Denver Water was just over 1 million as well (1,180,000), and their budget of 219 million calculates to $186.28. Last, Western's service area serves 96,139 and their budget was 127 million, which calculates out to $1,238.29.

From this, it would appear as though Western has the highest budget number per capita. They have the smallest budget by far, but also a smaller population served. Again, this isn't a perfect measure of dollars/capita because each district has money allotted for certain programs. But it is interesting to see that the highest dollar per capita is Western, who again has the smallest budget. They also don't have a budget specifically allotted to drought contingency, which the other districts have specified in their budgets. It's possible that they have it labeled as something else in their budget, but from what I could see, there was no money specifically put toward drought contingency.

It can be hard to tell exactly what each district is doing from their budget numbers alone. They have a lot of information on the programs they're running in their budgets, but no numbers specifically for each program. Denver set aside money to deal with the fires they experienced

during that drought, and it is something that neither California district has had to deal with thus far. I thought this was particularly interesting because they had another issue entirely to deal with, as they had to ensure the health of their water supply.

Revenue lost because of the drought is something that came up in each of the districts budgets. Denver's said they had 2.4 million dollars worth of drought related costs in 2002,

BUDGET *(in millions)*	Total Budget	Drought Contingency Appropriation
East Bay (2015)	$740,231	$64,206 (2016)
Western (2015)	$127,700	?
Denver (2003)	$219,807	$2,743 (2003)

Table 6. Comparison of the three districts budgets for the year noted, as well as if they have money allocated specifically to drought appropriation.

and East Bay said they lost 29 million dollars of revenue in 2015. In order to offset these, they use surcharges. East Bay notes in one of their budget meetings that if 20% reductions will be necessary in 2017, they are considering hiking up the surcharge (EBMUD Water Operations Department, 2016). A surcharge of some sort is necessary at this stage of drought for California, and was necessary in 2002 for Denver. The district is going to take a hit financially with the reduction in water use necessary for the amount of water available. EBMUD's surcharge of about 25% and their excessive use penalty. Pricing has been shown to be an effective tool in encouraging lowered water use, and although the surcharges are not exactly the same, they all use pricing in their drought strategy.

East Bay asks their consumers to aim for a certain amount of water per day—35 gallons per capita per day. In Australia, they had a similar approach but for 37 gallons per day (Turner, et

al. 2016). This is very specific and can be good to help customers set goals for themselves if they're striving to be water conscious. Setting a budget and seeing how you stack up against others in your area can be an effective way to encourage consumers to consume less. A study done by EBMUD actually showed this working—in 2014 they ran a pilot program where a program showed water users how they compare to the most efficient water users in their area. This resulted in water reductions (Towns, 2014).

Western has very specific outdoor watering regulations for their constituents (i.e. add a four-inch layer of mulch to all soil areas and water trees once every four weeks). These are things that I believe are extremely hard to regulate, but do give people an idea of how they can make their outdoor use more efficient. There are also more commonly seen regulations in place for Western such as no watering down driveways and hoses must have shut off nozzles. Along with this they try their best to make it easy for people to follow these regulations, such as their free sprinkler nozzle program, reporting waste with an app on your phone, and free water audits. These help show their customers that they're working with them to help reduce water use, instead of just imposing strict regulations and water use goals on them.

Desalination is not something that is widely used anywhere currently, but it was interesting to see the Western had been using groundwater desal for several decades. In the late 1980's they implemented this to bring water to a few cities in Southern California. They use reverse osmosis to remove the chemicals in the undrinkable groundwater to make it potable (wmwd.com, 2016). On the other hand East Bay is looking into using desal, but is being cautious. They are looking into groundwater recharge and desal from ocean water to see how much water they can get from it and what the system would look like. It is a long, expensive process. This helps keep

their options open in terms of supply, and for Western relives some of the pressure, as two cities in their service area use this desalinated groundwater.

All of the districts also either had recycled water plants up and running, or were looking into or in the process of creating them. For Denver, they already had a plan in the works and were moving forward with their recycled water plant in 2002. In 2004, on schedule, the plant opened. For EBMUD, they are considering recycled water to put in aquifers to have as a back up during drought years, but first needs to be approved by the state first (ebmud.com, 2016). For Western, they already take advantage of recycled water. They mix their recycled water with their untreated groundwater to bring to non potable water customers for irrigation (Recycled Water Program, 2010). This reduces their dependence on outside sources of water, and provides a good chunk of water for their non-potable customers.

As mentioned briefly earlier, local weather is something that Western believes is a significant part of why they've struggled to meet their reduction goals. Being further inland, Western's constituents are going to need more water to keep turf and such alive as opposed to those along the coast. East Bay is on the San Francisco Bay and very close to the coastline. For reference, Oakland has an average yearly rainfall of over 20 inches, while Riverside's average is just 12 (UsClimateData.com). Western argues that this is the main reason why they see fewer reductions in gallons per capita. Through personal communication, I learned that there is little water being wasted in Western's service area, as gpcd is more effective at measuring demand as opposed to efficiency. Western's customers are using water efficiently, but inherently need more water to keep landscapes alive because of their location geographically.

One point of comparison I wanted to look at in terms of strategy of each district was whether they focused their plan more on acquiring more water or doing more with what they already have. Both districts in California had a combination of the two. In my communication with both EBMUD and WMWD employees they discussed the difficultly of acquiring new water because of several reasons. One, prior appropriation obviously makes it so all water is already claimed, and their only hope would be that someone is selling water. Two, pipelines and such would be necessary in order to move water-it's truly a difficult commodity to move. So, they both note that conservation was something that could immediately create a reduced demand and relieve some of the stress. But, finding new ways to secure and improve water sources (reservoir storage, recycling water, etc.) and finding new sources is something that is always on the radar for these districts. The Australian study (Turner, et al. 2016) did show that a combination of supply and demand side management was the most cost effective way to manage drought.

Many water districts focus their conservation efforts on lawn watering restrictions and replacement. One program that was successful for EBMUD was their lawn conversion program, which saw a huge increase during this drought (ebmud.com, 2016). This encouraged sustainable landscaping and using drip irrigation instead of sprinklers. Since this is the largest use of water for residential customers, it can be assumed that this is partially why they were so successful in consistently seeing reduced water use.

Western's supply options are a bit more flexible, as they have groundwater desal already in place as well as a recycled water plant up and running. They also have the La Sierra pipeline which is helping reduce their dependence on water from the Metropolitan Water District. Having

these extra options helps them from becoming any more water stressed, but they still need to meet the state mandated reduction goals, which this obviously doesn't help them do.

DISCUSSION

Looking at the strategies that water mangers take on in the midst of drought can be important to find out what works when trying to reduce residential water use, and why these approaches do. Conservation is so important to water districts dealing with drought. It's something that everyone can immediately participate in and can make a substantial impact. Districts encourage conservation with programs, education and rebates. Other opportunities to relieve the stress that water managers feel during drought take time, such as recycled water projects and new infrastructure to bring in more water, but in the long run can help relieve some of the pressure. This is why it's important to know what is effective when setting restrictions and conservation goals for a district.

There were many similarities seen between the three areas that were looked at. As noted earlier, they all had huge outdoor reduction programs, as that's where most of the water use is seen. For all three, lawn watering restrictions were set and were essentially the same—Western's were slightly longer. Although not a drastic difference between the districts, this may contribute to why Western has seen less residential water reductions than East Bay. Having these programs in place that limit watering to certain days and times have been proven to work by several studies that were mentioned in the literature review (Kenney, et al; Halich & Stephenson). Having seen the success of these programs in other places may have led to the implementation for California's current drought.

This is a key similarity of the three districts: their focus on reducing outdoor use, and particularly encouraging the shift from grass lawns to drought tolerant landscaping. This is the most obvious shift in behavior to encourage, as outdoor use is much higher than indoor, and lawn wa-

tering is a huge chunk of this. I also believe this is important because it causes a shift in mindset as well. Many Californians love their plush green grasses, but seeing a neighbor change to drought tolerant landscaping makes people think twice, and realize that these other types of landscape can look good, too. This may start with only the most water conscious people, but eventually can help change the minds of other people who may have been resistant at first. Again, EBMUD saw that competition between consumers can cause a shift in behavior.

They all had set goals for residential use, and particularly the California districts were held accountable for meeting those goals, because of the state mandate. The state mandate in California forced districts to have (for the most part) high reduction goals. Although the system wasn't perfect, I think it was important for districts to be put into categories to help them realize where they stack up in comparison to the rest of the state. They're also being tracked by the Pacific Institute where I got much of the California information from, which I believe is beneficial for several reasons. For the districts, they don't have to worry about paying anyone to keep track of their water use, as the state is doing it for them. Also, districts are held accountable. The information is collected and calculated the same way, which makes it easier and more reliable when comparing districts. This was the first time that state mandates were in place for water, as the governor was adamant about changing the mindset of Californians.

East Bay's overall reductions were pretty impressive, which might be attributed to several things. As mentioned earlier, the location of the district and amount of rainfall seen might be why they can afford to use less water. EBMUD saw a huge increase in their lawn conversion program during this drought, and because lawn watering is a large chunk of outdoor use, this might be the reason that constituents have continuously lowered their water use. EBMUD also may have a

better advertising and/or education campaign being run, but I didn't find any significant difference in the amount of stress put on it in their budget and other website documents. It also could be just the constituents themselves. EBMUD has seen voluntary reductions be extremely successful, so the mindset and culture of the Oakland area might be inherently different than the people of Riverside in southern California. Again, they also encourage their customers to look at how they stack up against their neighbors, which they proved to be successful in helping to reduce water use.

Advertising and education is another important link in this study. Getting the word out about reducing residential demand is very important. While I would assume that they all had programs to do this, it was hard to determine the scale and effectiveness of their programs from online publications. As a resident of southern California, I've seen signs above the freeway set to say phrases that encourage reduced water use. This is effective as it is a daily reminder to be conscious of the amount of water you're using.

One thing I was looking for was how the California districts responded to the state mandate reduction goals. While they didn't necessarily have the same reaction in how fair the mandates were, they both did take steps to meet their goal. There are a lot of factors that go into lowering water use in residential areas, and it's hard to find one measure that can tell the whole story and include all of the factors necessary when asking consumers to reduce their water use. Indoor use is similar nationwide, but outdoor use can fluctuate based on the type of landscaping a customer has as well as the climate in which they live in. In this regard it's been shown from EBMUD that encouraging changes in landscape can greatly benefit in the way of water conservation.

An important point of discussion for the California districts is how significantly different 2016 has already been for them in terms of reservoir capacity. I mentioned in the introduction that climate change and El Nino are going to have effects on water in upcoming years. In several board meeting power points there are numbers for what reservoir capacity is currently compared to last year, but one example from East Bay is on January 25 of 2016 their reservoirs were at 117% of normal, compared to just 27% in 2015 (EBMUD, 2016). This takes a bit of pressure off of the districts when thinking about future water reserves. El Nino will certainly not solve the drought problem completely for California.

Another interesting question to consider is how tight these restrictions will stay post drought. We would expect that they are going to be more lenient, but especially in California where drought is so common, they don't want to let consumers get too comfortable. For East Bay, they have it set up so that for each stage of drought (including no drought at all), they have restrictions and pricing in place. For Western, their approach is their budget based rate structure, which was based on each individual household. Their budgets for this were cut 30% because of the drought, so we would expect that they would go back to the normal rate structure, which doesn't include the 30% reduction or any surcharge. For Denver, their pricing did go up after the drought to try and alleviate some of the damage done to their finances during the drought. According to later works, this got them into trouble with their customers. But, as I learned through personal communication with water managers, there is a justification that districts must have for their changed pricing post drought.

There wasn't huge differences in the way that these districts approached the drought. One of the things I was looking for during the beginning of this process was some notion that one wa-

ter provider was taking the drought more seriously. Going into it, Denver water's success was already known, but the two California districts programs and success were completely unknown to me. Again, Denver Water's number might not accurately represent how successful their program was. Both California districts reduced water use and East Bay was technically more successful because of the gpcd change from 2013 to 2015. They were placed in a lower category for necessary water savings than Western was, but saw the same amount of savings anyway.

Both districts had the same amount of water savings, and again, their programs are pretty similar. In this regard I think it's important to think about where these districts are, and how they operate differently because of this. Because Western is so far inland, desal from the ocean is not necessarily an option for them, and they see significantly less rainfall than places near the coast. Northern California is also generally wetter than Southern. While these are just observations, they do play a role in the gpcd we see from these two California districts.

As for their strategies, all looked for and were open to new water opportunities, but focused on their conservation programs. The main common threads between all three I found to be: lawn watering restrictions and programs to encourage drought tolerant landscaping, rebates for efficient appliances, recycled water in some capacity, and programs to limit water waste and encourage water use efficiency. That being said, each appears to have its own strengths, which are mentioned in the results section.

In a report done by several teams studying drought (Turner, et al. 2016) it was shown that having more flexible supply options (i.e. dams, major pipelines, desalination plants, recycling) can save a lot of money. The report looked at what worked in Australia and is being used to help water mangers in California cope with their drought. In this sense I believe the California dis-

tricts are taking these findings into consideration. The report also discussed how both supply and demand approaches are necessary when facing a severe drought, which both California districts did. By looking into water districts and their drought contingency plans, you can learn a lot about what is effective in water management conservation strategies and why they work. Finding common threads in these plans I believe points out what has worked in the past, and this leads districts adopt these methods in current droughts.

There are limitations when it comes to studies like this. Short of studies like Kenney, et al. there are few that show specific water reductions leading to a huge success in water conservation. It's hard to pinpoint exactly what program or policy led to the water reductions seen by each district unless there are regression models involved. There are also arguments against the use of gpcd as the main way of describing successful conservation plans, which is how success is measured in this study. Gpcd really is a measure of demand and doesn't tell the whole story when it comes to efficiency, as some consumers inherently need more water for outdoor use. In this case, the consumer is forced to make changes to lower this need, which is probably for the best. While it may not be a perfect way of measuring success, it is what is currently used and districts have to find ways to lower that number.

An important next step is to figure out what the new normal is. After drought, EBMUD believes that they know how water users react when conservation rules are applied. From their experience, the first year of drought people are water hogs and use doesn't go down very much, the second year they start to conserve, and continue a downward trend from there. After years of drought restrictions, there isn't much known about what happens in the long term. From personal communication I learned that EBMUD expects 3 to 4 years post drought, people become more

sloppy with their use and use goes back up. WMWD is expecting use to go up, but how much is unknown. EBMUD also believes that as a district they have to figure out what their rate system is going to look like, and how they're going to justify their pricing structure. Through personal communication I learned that Denver got into a bit of trouble with their constituents after the drought, because the district raised prices in order to relieve economic pressure, and their customers didn't find to be justifiable.

California is not done with this drought yet. It's important to keep monitoring what the over 400 districts in California are doing, which groups like the Pacific Institute are doing quite well. When the drought is over, I think it will be interesting to look at the most successful districts at reducing water use and try to tease out what made them successful. Also post drought, monitoring what the reactions of constituents in terms of water use patterns will be something to watch out for. What the districts themselves do will also be something to look into—will they continue to have tight restrictions or go back to the restrictions that they had pre-drought?

One thing that became very clear from looking at this data is that there are a lot of factors that go into drought management, and monitoring it is very difficult. Not only are there different ways to track the success of districts, but there are also factors within districts that can make it more or less easy for them to see residential reductions. Despite this, it's important to try and monitor it so that water providers can put effective policy in place.

BIBLIOGRAPHY

Aqwatec.mines.edu,. 'What Are Beneficial Uses?'. N. p., 2015. Web. 4 Dec. 2015.

Anderson, Mark Theodore, and Lloyd H. Woosley Jr. “Water Availability for the Western United States - Key Scientific Challenges.” Report. Circular, 2005. USGS Publications Warehouse. http://pubs.er.usgs.gov/publication/cir1261.

Arbués, Fernando, María Ángeles García-Valiñas, and Roberto Martínez-Espiñeira. "Estimation Of Residential Water Demand: A State-Of-The-Art Review". The Journal of Socio-Eco nomics 32.1 (2003): 81-102. Web.

Arnell, N. (2014). Climate change: California drought linked to humans. Nature, 509(7498), 10-10. http://dx.doi.org/10.1038/509010b

Association of California Water Agencies,. (2015). WILL EL NIÑO END CALIFORNIA’S DROUGHT?. Retrieved 4 December 2015, from http://www.acwa.com/sites/default/files/news/water-supply-challenges/2015/11/acwa-el-nino-and-ca-drought-infographic.pdf

Boxall, B., & York, A. (2014). California declares drought emergency. LA Times. Retrieved from http://articles.latimes.com/2014/jan/17/local/la-me-brown-drought-20140118

Biennial Budget Fiscal Years 2016 & 2017. 1st ed. Oakland, CA: East Bay Municipal Water Dis trict, 2015. Web. 27 Nov. 2015.

“CAdrought.com - Living with California’s Drought.” CAdrought.com. Accessed October 15, 2015. http://www.cadrought.com.

“California Urban Water Suppliers Water Use Map.” Accessed October 15, 2015. http://www2.pacinst.org/gpcd/map.html#.

Circle of Blue WaterNews,. 'California Drought - Town Hall - What Is The New Normal? - Circle Of Blue Waternews'. N. p., 2015. Web. 23 Nov. 2015.

(Data, US. 'Climate Oakland - California And Weather Averages Oakland'. Usclimatedata.com. N. p., 2015. Web. 10 Nov. 2015.)

(Data, US. 'Climate Los Angeles - California And Weather Averages Los Angeles'. Usclimatedata.com. N. p., 2015. Web. 10 Nov. 2015.)

(Data, US. 'Climate Denver - Colorado And Weather Averages Denver'. Usclimatedata.com. N. p., 2015. Web. 10 Nov. 2015.)

Dailynews.com,. 'Los Angeles Sets Mark For Driest Back-To-Back Seasons Ever'. N. p., 2015. Web. 1 Nov. 2015.

Denverwater.org,. 2016. "Key Facts | Denver Water". http://www.denverwater.org/AboutUs/KeyFacts/.

Denverwater.org,. 'Welcome To Denver Water'. N. p., 2015. Web. 10 Nov. 2015.

EBMUD Water Operations Department. 26 January 2016. "Water Supply Board Briefing".

Ebmud.com,. "East Bay Municipal Utility District : About Your Water". N.p., 2015. Web. 15 Nov. 2015.

Erdman, J. (2015). El Nino Still Strengthening, Likely Into Spring 2016, NOAA Says. The Weather Channel. Retrieved 9 November 2015, from http://www.weather.com/news/climate/news/el-nino-outlook-strong-possible-may2015

Esa21.kennesaw.edu,. N. p., 2015. Web. 2 Oct. 2015.

EXECUTIVE ORDER No. B-29-15, 3 C.F.R. (2014). Web.

Famiglietti, J. S. “The Global Groundwater Crisis.” Nature Clim. Change 4, no. 11 (November 2014): 945–48.

Fws.gov,. (2015). Water Rights: Division of Water Resources - U.S. Fish and Wildlife Service. Retrieved 3 December 2015, from http://www.fws.gov/mountain-prairie/wtr/

Golden Gate Weather Services,. (2013). California 2012-2013 Rainfall Season. Retrieved 7 November 2015, from http://ggweather.com/ca2012rain.htm

Gopalakrishnan, Chennat. “The Doctrine of Prior Appropriation and Its Impact on Water Development: A Critical Survey”. American Journal of Economics and Sociology 32.1 (1973): 61–72. Web.

Halich, G., and K. Stephenson. "Effectiveness Of Residential Water-Use Restrictions Under Varying Levels Of Municipal Effort". Land Economics 85.4 (2009): 614-626. Web.

Heinmiller, B. (2003). Harmonization through emulation: Canadian federalism and water export policy. Canadian Public Administration/Administration Publique Du Canada, 46(4), 495-513. http://dx.doi.org/10.1111/j.1754-7121.2003.tb01589.x

“How Some Homeowners Are Prevented from Conserving Water.” CAdrought.com. Accessed October 15, 2015. http://www.cadrought.com/how-some-homeowners-are-prevented-from-conserving-water/.

“Interactive Map of California’s Residential and System-Wide Water Use - Pacific Institute.” Accessed October 16, 2015. http://pacinst.org/publication/interactive-map-of-californias-urban-water-use/.

Kenney, Douglas. 24 Feb 2016. In-person interview.

Kenney, Douglas S., Roberta A. Klein, and Martyn P. Clark. "USE AND EFFECTIVENESS OF MUNICIPAL WATER RESTRICTIONS DURING DROUGHT IN COLORADO". Jour nal of the American Water Resources Association 40.1 (2004): 77-87. Web.

Kenny, J.F., Barber, N.L., Hutson, S.S., Linsey, K.S., Lovelace, J.K., and Maupin, M.A., 2009, Estimated use of water in the United States in 2005: U.S. Geological Survey Circular 1344, 52 p.

Kotin, Adam, and Dru Marion. 'A History Of Drought In California: Learning From The Past, Looking To The Future | Civil Eats'. Civil Eats. N. p., 2014. Web. 13 Nov. 2015.

L'Heureux, M. (2014). What is the El Niño–Southern Oscillation (ENSO) in a nutshell? | NOAA Climate.gov. Climate.gov. Retrieved 15 November 2015, from https://www.climate.gov/ news-features/blogs/enso/what-el-niño–southern-oscillation-enso-nutshell

Legal Information Institute,. (2015). Prior appropriation doctrine. Retrieved 4 December 2015, from https://www.law.cornell.edu/wex/prior_appropriation_doctrine

McGill, Michael. "California's Water Wars: Three Decades, Same Issues". SPUR. N.p., 2012. Web. 5 Nov. 2015.

Michelsen, An M., J. Thomas. McGuckin, and Donna Stumpf. "NONPRICE WATER CONSER VATION PROGRAMS AS A DEMAND MANAGEMENT TOOL". *Journal of the Amer ican Water Resources Association 35.3* (1999): 593-602. Web.

Oc.nps.edu,. 'El Niño's Effects On North America'. N. p., 2015. Web. 12 Nov. 2015.

Owen, Dave. “Overallocation, Conflict, and Water Transfers.” *Environmental Research Letters 9, no. 9 (2014):* 091005.water_rights_def.htm

Pacinst.org,. ' Sustainable Water Management – Local To Global - Pacific Institute'. N. p., 2015. Web. 26 Oct. 2015.

Pacinst.org,. (2013). Energizing Water Efficiency: California Energy Sector Experiences Can Advance State's Water Conservation and Efficiency - Pacific Institute. Retrieved 17 November 2015, from http://pacinst.org/news/energizing-water-efficiency-california-energy-sector- experiences-can-advance-states-water-conservation-and-efficiency/

Perlman, H. 'Source And Use Of Water In The U.S.,, The USGS Water Science School'. Water.usgs.gov. N. p., 2015. Web. 6 Oct. 2015.

Perlman, H. (2015). Where is Earth's water? USGS Water-Science School. Water.usgs.gov. Retrieved 6 October 2015, from http://water.usgs.gov/edu/earthwherewater.html.

Plumer, B. (2012). What we know about climate change and drought. Washington Post. Retrieved 12 November 2015, from https://www.washingtonpost.com/news/wonk/wp/2012/07/24/what-we-know-about-climate-change-and-drought/

Postel, Sandra. The Last Oasis. New York: W.W. Norton, 1992.

Rainfall.weatherdb.com,. 'Denver, Colorado'. N. p., 2015. Web. 10 Nov. 2015.

Rossi, John. *Recycled Water Program*. 1st ed. Riverside, CA: Western Municipal Water District, 2010. Web.

SAWPA,. (2015). 1.2 OWOW Plan 1.0-Moving Towards Sustainability (pp. 1-6). Santa Ana. Retrieved from http://www.sawpa.org/wp-content/uploads/2014/01/1.2-OWOW-1.0-Plan-Moving-Toward-Sustainability_FINAL.pdf

Tanaka, Stacy K. et al. 'Climate Warming And Water Management Adaptation For California'. Climatic Change 76.3-4 (2006): 361-387. Web. 10 Nov. 2015.

Tarlock, D. (2011). HOW WELL CAN WATER LAW ADAPT TO THE POTENTIAL STRESSES OF GLOBAL CLIMATE CHANGE?. Chicago: Chicago-Kent College of Law.

Thompson, Andrea. "100 Percent Of California Now In Highest Stages Of Drought". Scientific American. N.p., 2016. Web. 1 Mar. 2016.

These Rotarians...Their Honors, Records, Unusual Activities. (1962). The Rotarian, (101), 50-52.

Towns, Steve. "A Little Neighborly Competition Can Help Reduce Water Usage". *Governing.com*. N.p., 2014. Web. 9 Mar. 2016.

Turner, A., White, S., Chong, J., Dickinson, M.A., Cooley, H. and Donnelly, K., 2016. Managing drought: Learning from Australia, prepared by the Alliance for Water Efficiency, the In stitute for Sustainable Futures, University of Technology Sydney and the Pacific Institute for the Metropolitan Water District of Southern California, the San Francisco Public Uti ities Commission and the Water Research Foundation.

USGS,. (2015). California Drought Information | USGS California Water Science Center. Retrieved 1 November 2015, from http://ca.water.usgs.gov/data/drought/

Van Vliet, M., & Zwolsman, J. (2008). Impact of summer droughts on the water quality of the Meuse river. Journal Of Hydrology, 353(1-2), 1-17. http://dx.doi.org/10.1016/j.jhydrol.2008.01.001

Western Municipal Water District,. *Drought FAQ Update*. Riverside, CA: N.p., 2015. Web.

“Western Municipal Water District, CA - Drought & Restrictions.” Accessed October 15, 2015. http://www.wmwd.com/index.aspx?nid=391.

Wilhite, D. (2005). Drought and water crises. Boca Raton: Taylor & Francis.

Wmwd.com,. "Western Municipal Water District, CA". N.p., 2016. Web. 15 Nov. 2015.

Wri.org,. (2015). Water | World Resources Institute. Retrieved 26 October 2015, from http://www.wri.org/our-work/topics/water

World Resources Institute. Water Risk Atlas: Current Conditions [map]. 2015. < http://www.wri.org/applications/maps/aqueduct-atlas/#x=-89.78&y=38.72&s=ws!20!28!c&t=waterrisk&w=def&g=0&i=BWS-16!WSV-4!SV-2!HFO-4!DRO-4!STOR-8!GW-8!WRI-4!ECOS-2!MC-4!WCG-8!ECOV-2!&tr=ind-1!prj-1&l=4&b=terrain&m=group>

2003 Budget For Denver Water. 1st ed. Denver, CO: N.p., 2003. Print.