# THREE ESSAYS ON WATER

by

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A Dissertation
Submitted to the
Graduate Faculty
of
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in Partial Fulfillment of
The Requirements for the Degree
of
Doctor of Philosophy
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George Mason University
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# Three Essays on Water

A Dissertation submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy at George Mason University

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# DEDICATION

This is dedicated to my parents and Uncle Dick. It has been a long road to walk, but it is done.

# ACKNOWLEDGEMENTS

I would like to thank my friends for their inspiration and help during this process. Thank you Eli, I couldn't have done this without you. To Jason and Lauren and Dave and Emily, your friendship means the world to me. Drs. Boettke, Leeson and Coyne provided invaluable feedback and comments.

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**ABSTRACT**

THREE ESSAYS ON WATER

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This is a dissertation about water in California. This is a dissertation with three chapters. The first chapter is about the knowledge problem in water governance. Without market prices goods cannot be rationally allocated amongst competing ends. The second chapter is about the growth of water infrastructure and the polycentric nature of water governance. The last chapter is about water and institutional change. Normally institutions are thought of as being slow to change, this chapter provides examples of where the institutions governing water responded rapidly to changes in scientific knowledge and new technologies. Institutions change when the benefits of changing exceed the costs of change.

# INTRODUCTION

“Whiskey is for drinking and water is for fighting” is an oft repeated aphorism usually credited to Mark Twain. The wisdom contained within this statement is that water is rivalrous and land becomes much more valuable and agriculturally productive when it has access to a reliable source of water. Water is a valuable input in production. The city of Modesto, California, near my home town, bears the motto: “Water, Wealth, Contentment, Health.” In the dry American West water and wealth are synonymous. Cities need water to thrive. The more than 20 million people living in Southern California rely on imported water to drink and flush their toilets. Without water, Los Angeles could not exist as a thriving metropolis. The economic gains from agglomeration within a city would be lost. Specialization is limited by the extent of the market and without a reliable source of water the extent of the market is limited by the lower population limit.

The conflict comes from the question of who gets the water, the farmer or the cities. The answer to this question is often decided by the government and part of the goal of this dissertation is to ask the question: “Can government actually allocate resources to their highest valued use?” Spoiler alert, we argue that government cannot perform such a task.

One of the aspects that makes water unique and interesting to study is that it has a low value to weight ratio; in other words, while diamonds are light and valuable water is heavy and relatively cheap per unit. This is the origin of the famous diamond water paradox and the discovery of the marginal revolution in economics. The result of water's physical properties is that if one wants to create economic value, it requires a large amount of water. It takes a large capital investment to capture water and distribute it. Dams are large structures that take specialized engineering and maintenance. Safely containing billions of gallons of water is not a trivial task; this is best exemplified by the recent failure of the Oroville Dam spillway that lead to the evacuation of 180,000 people. As another example, In China in 1975, when two dams failed, 171,000 people died and over 11 million homes were destroyed.

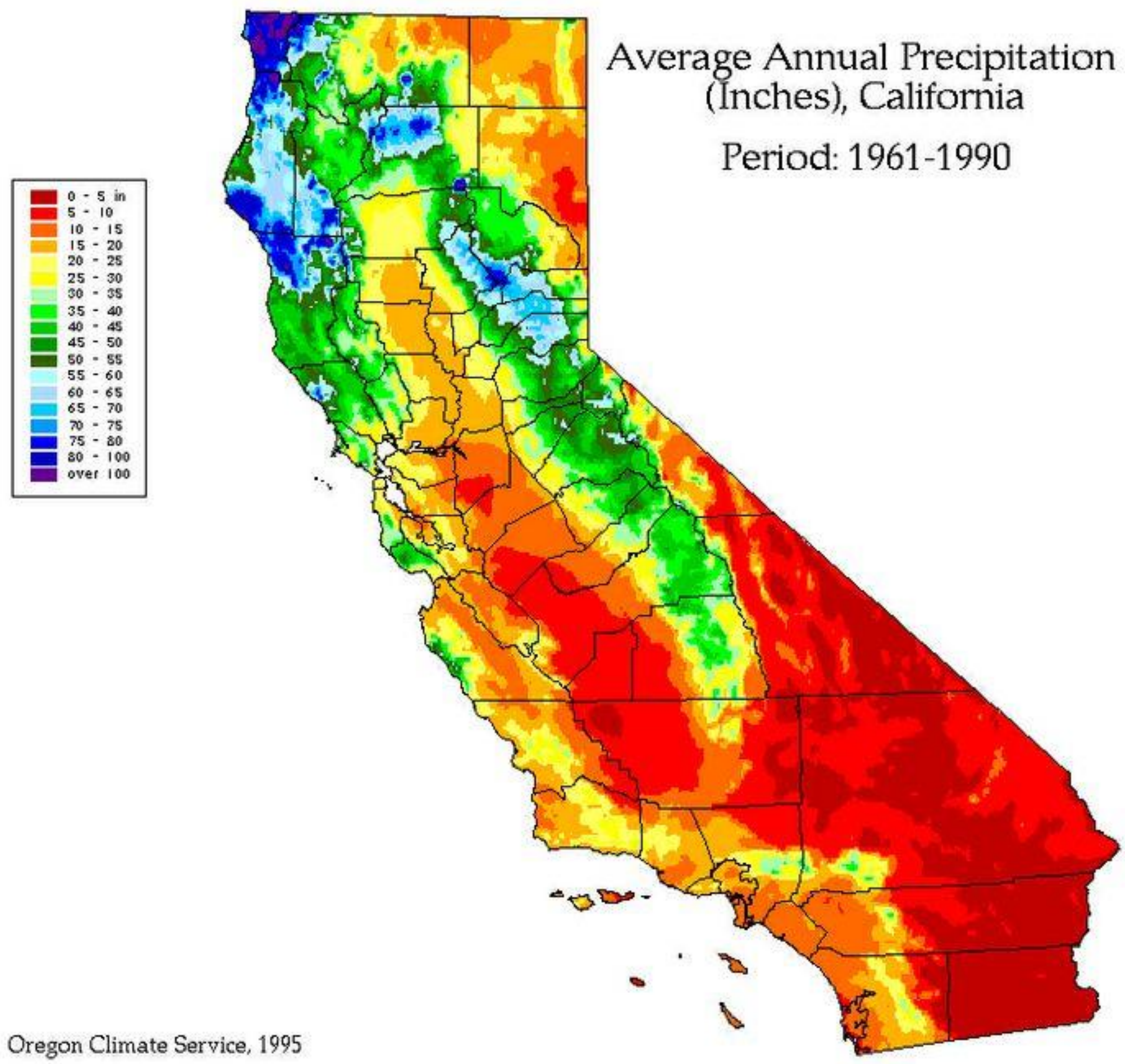


Image from Orgeon Climate Service

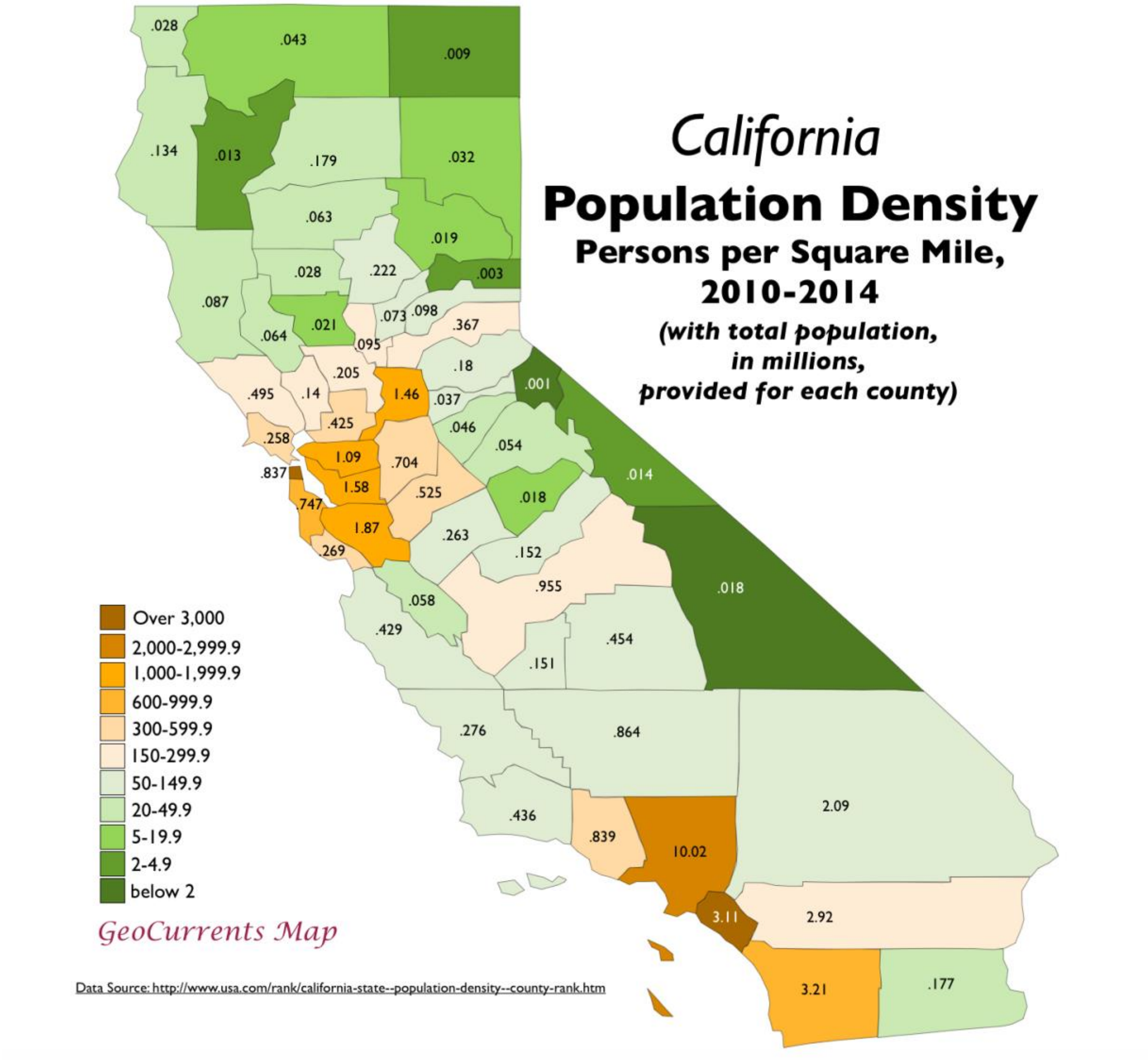


Image from www.geocurrents.info

The above two pictures illustrate two of the most important geographic and demographic characteristics of California. The majority of the rain and snow falls in the North, the dark blue areas, while a tremendous number of people live in the South. Water gains value from changing both its physical and temporal location. Damming water when it is plentiful and releasing it later through a system of aqueducts and canals is how value is added to water. It is also important to note that historically, California faced a problem of severe flooding. Too much water, especially uncontrolled water, is a destructive force.

In the case of California, water can often travel hundreds of miles between where it sourced and where it is finally consumed. In addition to the manmade structures, there are also the preexisting rivers and streams that are used to convey water through the California Delta. We are using California as a case study because the majority of water falls in the North of the state but since so many people live in the South, the economic challenge in creating value is to transfer that water over hundreds of miles over land and hundreds of feet over the mountains.

Forbearance is one method of creating value. This is the environmental approach to value creation and it relies upon appropriators refraining from consuming water. The riparian ecosystem, environments located adjacent to rivers and streams, will die without flowing water. A positive flow of water is needed for the fish and animals to survive; more is needed for them to thrive. More is an issue of water quality because more water dilutes pollution that would otherwise threaten native species.

The Delta Smelt is a species of fish that is native to the California Delta and it is used as an indicator species. An indicator species is best thought of as a Canary in a coal mine. The Canary is sensitive to toxic gasses and will die before the miners. The lesson of the Canary is that when it stops chirping, get out. The Smelt plays a similar role. The Smelt are routinely sampled from the environment and if their numbers are declining, this is used as evidence that poor water quality and pollution is placing stress upon the smelt.

The solution is to increase the flow of water through the system, diluting pollution and increasing water quality.

Another method of increasing value is through changing the allocation of water. Water is an input in production and if there are differences in returns, reallocating water will create value. What we will see in this dissertation is that such reallocations are hard to execute in practice. There are legal impediments to transfer and these impediments serve the function of raising transaction costs and high transaction costs can prevent an otherwise mutually beneficial exchange. As a quick example of such a transaction, a farmer might be using water to create hundreds of dollars of value while a real estate developer in a city might use that same water to create tens of thousands of dollars of value.

This dissertation is composed of three chapters. The first chapter is on the knowledge problem in allocating water. This paper argues that part of the problem with the current allocation of water in California is that when water infrastructure was first built, there was no consideration for the environment. The mentality was that any drop of water that was not diverted, dammed, and then consumed was as good as wasted. What is now considered an obvious problem is that there was no consideration for the instream flows that are needed to maintain healthy ecosystems for environmental enjoyment. The challenge now faced is in allocating water between two competing concerns. What was once a simple maximization problem is now an allocation problem and without a system of prices, rational economic planning cannot occur.

An additional problem is that the era of abundance is over. In the past, the solution to the water scarcity was to build a dam and capture more of the water that is flowing through the system and store it for later release. In addition to the ecological challenges posed by new dam construction, dams radically alter local environments, there is a geographic problem: all the best dam locations are already taken. The cheapest sites to construct a dam were the first places dams were built. What this means is that after more than 100 years of building, there are few places where it is worth it to build a new dam. Logically, there is a maximum amount of water that can be captured within a basin and that is the amount of rain and snow that falls annually. Costs increase with the amount of water that one wishes to capture and store. Eventually, even if a source of water isn't literally wrung dry, economically speaking, it is not worth it to try and capture that last bit. If the total quantity of water being captured by a system cannot be increased, then economic gains can only come from the reallocation of existing water rights.

The second chapter is about the regulation and provision of water at the local, state, and federal level. Water is an interconnected polycentric system with differing bureaucracies operating at different levels. This is a chapter about other people's money and the ability to use federal dollars to subsidize local water projects. In the preceding paragraph we discussed how it can be cost prohibitive to capture increasing amounts of water, with Federal dollars water projects that would otherwise fail at a local level become of their expense become possible because someone else is paying for it.

Other people money comes in several forms. One form is a direct cash grant where the government partners with a local agency and shares in the cost. Another source of the subsidizes is through how loans are structured to offer cheap interest rates. In the case of the Bureau of Reclamation, zero interest loans amortized over 40 years can have an implicit subsidization rate of 90%. Lastly, water pricing that only includes the cost of delivery and not the full opportunity cost of water. The simple reason the Federal government engages in these practices is because they are not trying to maximize the economic value created, but are maximizing on other, political margins. Farmers love cheap water and subsidized irrigation networks and construction companies love pouring millions of cubic feet of concrete when they build a damn or aqueduct. Political rent-seeking, rather than optimal resource allocation, explains many of the quirks of current water policy.

It is because of this logic of rent-seeking in the construction of water projects that we are unlikely to see new sources of water, those projects have already been built and in many cases, these projects were an environmental insult where the damage done to the environment was greater than the value of the new water captured. This is why there are environmental movements that seek to tear down dams and restore rivers. If we are unlikely to see new sources of water because of past building, then growth will have to come from the reallocation of water amongst existing users.

The final chapter is about water and discontinuous institutional change. Institutions are often conceptualized as being sticky and slow to change over time, change taking upwards of centuries even. What this paper demonstrates is that institutions, in this case those governing water, have changed relatively rapidly when there is a technological change that acts as a shock to the relative costs and benefits of utilizing this resource. This chapter analyzes several legal cases to show how these institutions evolved in response to technological change.

# CHAPTER ONE – "THERE IT IS. TAKE IT."

Photo from the Los Angeles Department of Water and Power.

## 1. Introduction

On November 5, 1913, a crowd gathered to watch the grand opening of the Los Angeles Aqueduct. The newly constructed aqueduct consisted of 215 miles of conduit and was used to transfer water purchased from the residents of Owens Valley to the booming city of Los Angeles. As the aqueduct was opened and water began to flow to the city the Chief Engineer William Mulholland gestured between the water and assembled crowd and uttered the now famous words: “There it is. Take it.”[1] Water was a resource to be taken, to be dammed and diverted before being consumed for human purposes. Water had value when it ran through pipes and filled a bath tub or irrigated a field. If a drop reached the ocean, that drop was considered wasted.

This mentality was best described in another quote from Mulholland. This time he was visiting Yosemite Valley, the natural splendor moved him and he wished to send photographers to capture the beauty for all eternity but afterwards he “… would build a great dam and stop all the goddamn waste."[2] The Riparian ecosystem, that depends on the flow of water, had no value to him, it merely defined the technical obstacles that had to be overcome for a successful engineering project. The explicit environmental problem is that if water is not flowing through streams and rivers, the plants and animals that depend on that flowing water will die. Without a river, salmon cannot swim upstream to spawn. Damming a river so that the water can be stored and released at a later date fundamentally alters the local ecosystem and given the importance of water for life, it is easy to see how a small change in the flow of water can effect species within hundreds, if not thousands, of square miles.

[1] A more detailed account of the day can be found at: https://boomcalifornia.com/2013/09/23/there-it-is-take-it/

[2] This retelling can be found in Reisner (1993) and at: http://www.metroactive.com/papers/metro/06.19.97/tv-9725.html

This paper assumes that the environment has value. This should not be a contentious claim, Burt & Brewer (1971) provide an estimation of the social value of three lakes in Missouri that comes to a total of $8.5 million dollars. As populations and incomes have grown, so to have demands for outdoor recreation and environmental quality. Crooper & Griffiths (1994) have shown that increases in income have slowed the environmental degradation of deforestation. Damming a river creates value in the form of controlled access to water but it comes at the cost to local species and the environment. Looking at Washington state, Loomis (1996 page 441) estimates that the removal of two dams would generate $138 million annually for 10 years. Loomis (2002 page 7) estimates that in a particular instance of river restoration, the recreational benefits to restoring the river where 6-10 times larger than what they were for the previously existing reservoir. What these estimations show is that value can be created not just through damming rivers, but restoring them as well. The environment has value not just in consumption or as an input into a production function but as a good in and of itself. This means that there are important tradeoffs to be made between consuming and restoring environmental resources as value can be created by doing both.

Growing the total supply of water is unlikely (Zetland 2009, 2011), but that does not preclude the possibility of efficiency improvement from reallocating water resources. This paper argues that in response to the current environmental challenges, market mechanisms are needed to allocate scarce resources between competing ends and without these mechanisms we are left to allocation by politics or bureaucrat. This paper also expands upon two legal doctrines that have served to raise transaction costs and make productive reallocation of resources more challenging if not impossible.

## 2. The Knowledge Problem

The knowledge problem was first developed by Mises (1922, 1966) and then extended by Hayek (1937, 1941, 1945, 1948) during the Socialist Calculation debate. The socialist claim was that Capitalism was inherently wasteful and that through rational economic planning, a socialist economy would be more productive. Accusations of waste are positive claims about resource misallocation where resources are not put towards their highest valued uses. The socialist claim was that rational economic planning would end boom and bust cycle of the market and lead to greater economic output. For a thorough presentation of the Austrian side of the debate see Lavoie (1985a, 1985b). For the unique role of knowledge in Austrian economics see Boettke (2002).

The argument presented by Mises and Hayek was that since we live in a dynamic world, efficient production will have to change on the margin in response to the changes in opportunity costs. For example, if there is an increase in demand for one product containing steel that means less steel is available for all other uses. An efficient uses of resources requires some mechanism for coordinating human action and changing the distribution and utilization of resources within an economy. Mises and Hayek argued that the price system performed this coordinating function and that when Socialists advocating abolishing markets in capital goods this coordinating mechanism would be destroyed. Lachmann (1956) argued that because capital goods are heterogeneous no set formula of production exists, there are a multiplicative number of ways to build goods. The economic challenge then is discovering the least cost method of production that satisfies consumer wants and towards that end we need systems of profit and loss to discipline entrepreneurial discovery. For that system to function, market prices in consumer goods and market prices in capital goods are needed to freely fluctuate.

In a textbook example of supply and demand, a negative supply shock in steel would reduce the quantity available and increase the price. Production plans that were dependent upon the original expected supply of steel would have to be re-evaluated in accordance with this new reality. To avoid resource misallocation, steel must go to its highest valued use and this requires a mechanism to elicit value. In the case of water, availability depends on precipitation, some years are wet while others are dry. In wet years, when water is plentiful, it makes economic sense to employ marginally productive farmland for the production of crops such as alfalfa. The allocative problem is in having a mechanism that cannot only allocate resources during wet years, but take them back during dry years. As an example, almonds are a high value crop, during dry years, allocative efficiency directs taking water away from marginal products and making sure that the orchards stay watered. We can imagine a scenario where a farmer would choose to let their field lay fallow if and only if they could put that water to a more productive use. What we will discuss later in this chapter are the reasons why these reallocations do not occur.

Markets as a mechanism resolve this allocation problem through trade by allowing individuals to reveal the intensity of their preferences through bidding via higher prices. Producers who add the most value to their inputs, as judged by the prices that customers are willing to pay, are able to bid away resources from those who add less value. Alert entrepreneurs that spot a misallocation and successfully moves resource to higher valued uses reap a profit (Kirzner 1973). This system of profit and loss not only creates the incentives to avoid misallocation, but to actively seek them out for elimination.

Through market competition resources are moved to their highest valued uses. If an individual is able to use markets to sell what they appropriate, we have strong reasons to believe the resource will go to its highest valued use. This belief is weakened when politics and bureaucracies play a stronger role in determining appropriations. The issue here is that price is not coordinating supply and demand, so there is no reason to believe that only the highest valued users will have access to water. Ultimately, the allocative efficiency of a water district depends upon the relative cost of transferring water between members within a district. If transaction costs are high, potentially productive exchanges will not occur. The challenge becomes even greater when we allow for the possibility of transfers between districts.

### 2.1 Knowledge Problems and Common Pool Resources

Common pool resources provide benefits over time as long as the rate of appropriation does not exceed its natural rate of regeneration. Maintaining the resource requires balancing appropriation against regeneration and successful governance institutions require knowledge about individual activity and the resource itself. The reasoning is simple, without knowledge of individual activity one cannot coordinate activity to limit appropriations because one cannot punish excess appropriation. If poaching is either undetected or unpunished, animals held in commons will likely suffer severe depredations. This resembles the plight of many animals in Africa. Similarly, if one does not know the rate of regeneration, the level of appropriation may be set too high and the resource is destroyed by accident. One such example would be if there was variance in the rate of regeneration. If poor weather is stressing an ecosystem, then appropriations might need to be temporarily lowered to compensate for this additional strain. It is presumably costlier to dynamically set appropriation rates each period than to create a simple enduring rule. The knowledge problem in the governance of common pool resources is determining how much water to allocate to instream flows. To properly ascertain this flow rate depends on the dispersed knowledge about the conditions of numerous plants and animals that are spread across a large geographic area. Currently state water management and environmental protection agencies are tasked with setting this instream flow rate.

While diverting water from a river, no farmer thinks they are depriving their downstream neighbors of a livelihood, yet the combined actions of many individuals produce precisely that result. Without coordinated action, less land is irrigated and agricultural output is decreased. Investing in governance institutions, while costly, allows coordinated action where the benefits of a different water allocations may be captured. In these cases, wealth was created either from either increasing the amount of water appropriated or changing water distribution. Historically, many water management systems were designed to maximize the total quantity of water available for appropriation. From this perspective, water had value when it irrigated farmland or flowed out of the taps of homes and businesses. Water that flowed from the mountains, through the rivers and into the oceans was essentially wasted. The environmental movement, beginning in the 1960's, has harshly criticized this view as shortsighted and incorrect. The mentality of prioritizing the creation of cheap water for growth was fundamentally altered with in 1967 with the creation of the State Water Resources Control Board (State Water Board) by the California Legislature. The mission of the State Water Board is:

> "To preserve, enhance, and restore the quality of California's water resources and drinking water for the protection of the environment, public health, and all beneficial uses, and to ensure proper water resource allocation and efficient use, for the benefit of present and future generations."[3]

This is a neat encapsulation of the public trust doctrine (Getches 2015) and how the environment is conceived of as existing in a trust where current water managers have a public obligation to maintain and improve environmental quality and this expanded their mission statement from being mere low cost providers of cheap water. This cheap water has been primarily put towards agricultural ends and between 1870 and 1978 total irrigated farmland in the West grew from 3.6 million acres to 43.4 million acres (Bretsen & Hill 2006).

The economic insight behind this proposition is that water consumption is rivalrous and when water is removed from the natural networks of lakes and rivers and

[3] https://www.waterboards.ca.gov/about_us/water_boards_structure/mission.shtml Retrieved November 7, 2017.

moved into the network of canals and pipes, the plants and wildlife that depend on this water suffer. Nature has value and political decisions to build dams and pump water did not, in actuality, pass a cost-benefits test. A textbook critique of GDP accounting is that because the value of nature is infrequently captured in market activity the bias is to underestimate the value of nature relative to activities, such as resource extraction, that are environmentally destructive. Salmon that live in the ocean must swim upriver to their spawning grounds. Without the rivers flowing at an adequate rate, the salmon cannot spawn and an entire generation is effectively killed. This is also true if a river is dammed. Water management projects can have a negative environmental impact by destroying or permanently altering the natural habitats of many species. This may or may not be beneficial on net and the reasonable concern was that the policy makers of years past had failed to properly account for environmental concerns.

According to research by the Public Policy Institute of California, approximately 50% of the water in California is used for environmental ends.[4] Of the total water that can be accessed, a subset is left for environmental uses. The water must flow from the mountains, through the rivers and into the oceans. Many people want to divert water from this natural flow because by doing so they are able to capture economic value for themselves. A flourishing environment also creates value, but if it is difficult for an entrepreneur to capture this value, more effort might be put into diverting water for agricultural, industrial, or urban uses than in maintaining a flourishing environment. This has been the historical precedent.

[4] This water usage is as of 2010. Source: http://www.ppic.org/main/publication_show.asp?i=1108

Assuming that environmental quality and protection creates positive value, the institutional challenge is in setting the minimal flow rate of water through the system. Using the previously mentioned salmon as an example, removing water from the system is only desirable when the benefits it creates are in excess of the cost that are manifested in the lower numbers of salmon. The opportunity cost of appropriating water includes lower environmental quality but unless individual appropriators account for this cost, or this cost is not reflected in the price end users pay for water, too much water will be appropriated. The environmental cost of water appropriation will exceed its benefits.

Beard (2015) discusses the phenomenon of "deadbeat" dams. These are dams destroyed more value in environmental than the benefits they provide in the form of flood control, water supply, and hydroelectric power. Beard places the blame squarely on the Bureau of Reclamations and we can understand this from a public choice perspective of a budget maximizing bureau (Niskanen 1968). State and local water control agencies saw the opportunity to use federal dollars to spend on local projects. The purpose of the Bureau of Reclamation is to expand the supply of water that is available for agricultural uses, it is unsurprising that after decades of building that some of their marginal projects would not pass a cost benefit analysis that includes environmental quality.

## 3. The Marginal Value of Water

A bottle of 1787 Lafite, rumored to be owned by Thomas Jefferson, was sold at auction for $156,450 in 1985. At the time, this was the highest price ever paid for a single bottle. It was also, most likely, a fake (Wallace 2009). We are invoking this example because it is easier to appreciate the amount of liquid in a bottle of wine than the number of gallons of in a lake. Adjusting for inflation, those 1985 dollars would be worth approximately $347,000.

Landry (2010) provides water sales data for two regional markets and what we see is a wide disparity between agricultural-to-agricultural sales and agricultural-to urban sales. Simply put, there can be thousands of dollars of difference between the urban prices and the agricultural prices, implying high gains from trade that are not realized. Water is transacted in a unit called an acre foot which is the amount of water it would take to flood an acre of land to a depth of one foot. An acre-foot contains 325,851 gallons of waters. Glennon (2004) reports one case where developers were offering $20,000 per acre-foot that what agricultural users were paying $13.50.

This is because the price is determined, in part, by the unique characteristics of the water district that is delivering the water. For example, a district that is relying on desalination and recycled water will have higher treatment costs, which are passed on to the consumer, than a district that is relying on other, cheaper sources of water. Similarly, if a district has to incur higher pumping costs to move water, these pumping costs will be reflected in the final price. These costs are mentioned to help explain some of the price variation across districts. It is also important to note that many districts are limited to charging their customers only the average cost, which includes pumping conveyance and maintenance. This is less than the marginal cost which would include the full opportunity cost of alternative uses. For these reasons, many final consumers of water are paying what is effectively a subsidized cost because their purchase need not be greater than the full opportunity cost.

The money used to buy the fake Jefferson bottle could have been used to purchase 25,000 acre feet of the cheap agricultural water or 17 acre feet of the expensive water that the developers wanted to use. If those same 25,000 acre feet were transferred from agricultural to urban uses, at the same price of $20,000, the simple calculation would imply half a billion dollars of value being created. We will explore some reasons why this value is not being captured in the next section.

## 4. Politics - Defining Harm

### 4.1 – The no harm principle

Before a senior appropriative rights holder can transfer their water rights, they have the burden of proving that it will not harm junior rights holders. This substantially increases transaction costs as can prevent potentially beneficial transactions. One potential source of damages is changing the time and place of water diversion. The issue here is what is known as "tail water." When a farmer irrigates their field, some of the water flows into the ground helping to irrigate their crops, some evaporates into the air, and some, the tail end, flows across their fields and must be collected before being returned to whence it came. According to Young (1986) as much as 50% of senior appropriation flows back into the stream or down into the aquifer. This water that is used, but not consumed, can now be used by others. What this means is that someone with senior water rights, through the use of their water rights, is actually contributing to the provision of someone else's junior water rights.

Changing the location of the diversion or the time of the diversion can negatively impact junior rights holders. It can also negatively impact those relying on groundwater. If the consumption of water occurs in a differing, unconnected basin, then old wells that were being regenerated through irrigation will find themselves with less water to pump. Additionally, some of the water can flow underground before returning to the original source of the diversion. This means that subsurface flows can be interrupted and if these flows do not return to the river, by definition there is less water available for junior rights holders.

Similarly, if timing is changed, downstream junior rights holders who depend upon the irrigation of upstream senior rights holders will find themselves without water. The simplest way of explaining the problem is to imagine two fields needing to be irrigated. If both fields have the same crops, then both can be irrigated at the same time; the tail water of the senior waters the junior's fields. If the senior holder wants to put the water to a different use at a different time, the tail water will not be available and the junior holder will be harmed.

This is why Liebcap (2005, 2011) argues that appropriative rights that dictate a specific quantity of water, rather than a share of water, build rigidity into the system because it all too often makes the junior rights holders dependent on the actions of the seniors and this reduces the dynamism of the system by increasing the cost of reallocating water. The advantage of having a share of water rather than a quantity is that it would effectively transform the appropriative system into a quasi-riparian system where all rights holders would be on equal footing. With the ladder of junior and senior rights removed, one would be free to transfer water without worry about impacting junior rights holders. This simple change would dramatically lower the cost of transferring water as it would lower one of the primary costs and legal challenges that impede these transactions. The policy challenge is that large numbers of people benefit from the status quo and changing how water rights work would create concentrated costs and dispersed benefits. Current water rights holders benefit from subsidized water and derive economic rents from having a subsidized input of production.

### 4.2 – The Public Trust

The public trust doctrine is the common law principle that the government holds some lands in trust so that the public may utilize and otherwise enjoy these lands (Getches 2015). The stewardship of these lands is the government's responsibility and in the case of water, this was originally the property of navigable waterways. Epstein (1987) argues that the economic logic of property in general, both private and public ownership, is that it seeks to minimize transaction costs. Private property in goods places ownership within one individual and that individual need only seek the approval of another, a potential buyer, before alienating their property. In the case of navigable waterways, under a system of first possession, the potential owners and interests are many and the transactions costs of navigation are high. Holding the resource in a public trust where navigation is treated as a public good may be welfare enhancing.

The public trust doctrine was greatly expanded in the 1983 case of *National Audubon Society v. Superior Court* (Mono Lake). The outcome of the case was about diversions from non-navigable waterways and this was a key expansion of the public trust doctrine. Under the standard public trust doctrine, if riparian or appropriative rights diversions where being made from a navigable river, and these diversions caused the flow of water to drop to a level that made navigation impossible, the public trust doctrine would be invoked and these appropriations would be limited until the flow of the river increased to a point where navigation was possible. Simply put, one cannot drain a river to the point where navigation by boat becomes impossible. A minimum flow and depth must be maintained and this is within the public trust.

What the Mono Lake case changed was that it determined that some previous appropriations were, in fact, excessive and wasteful and that protecting aquatic environments was now part of the public trust. For a specific examination of the Mono Lake case, see Blumm & Schwarts (1995). This greatly expanded the role of the state in governing water resources. Previously, we discussed how a water transfer might be quashed if one could not prove that junior rights holders remained free from harm. With the expansion of public trust, the state now has the authority to intervene in almost all water issues.

Wasteful and excessive appropriations are not allowed. What are wasteful and excessive appropriations? They are at the discretion of the State Water Resources Control Board. In this chapter we have discussed the importance of markets in allocating resources. Here we have, in effect, a central planner attempting to make allocative decisions without reference to market prices. We should remain skeptical of such entities abilities to successfully allocate resources. The interconnected nature of water systems and diversions and consumption in one area will impact flows and habitats in another. In effect, almost any action can run afoul of the public trust doctrine if someone is willing to litigate it. This increases uncertainty and transaction costs, making potential water transfers even more costly and unlikely.

## 5. Conclusion

Water is a resource that is regenerated through variable precipitation and in times of plenty, but especially in times of drought, markets are needed to allocate water to its highest valued uses. For example, urban water uses are highly valued on the margin, but without a market mechanism that allows farmers and other users with lower valued uses to profitably transfer this water, this reallocation will not occur. The policy problem is that in the name of environmental protection, we have adopted legal doctrines that severely increase transaction costs, making market transactions less likely.

The expansive nature of the public trust doctrine increases the cost of development and introduces uncertainty about the availability of any given water flow. This is because an environmental activist group can sue over any deviations from the status quo. If a new housing development needs water, activists can sue that new diversions from a river will violate the public trust doctrine. Proving a negative is impossible. So it is impossible to prove that any given diversion will cause no harm. The question is one about the magnitude of the harm versus the size of the benefit. Until the public trust doctrine is more narrowly and specifically defined, water markets will be costly to use as any given reallocation of water can potentially be subjected to costly litigation.

The costs of creating water markets are also high because of regulatory uncertainty over concepts like provable harm and reasonable use. Until this uncertainty is eliminated, thus lowering the potential costs of legal challenge to transfer, we should expect only weakened markets with relatively few transfers and a large price spread between urban and agricultural water costs.

## CHAPTER TWO – OTHER PEOPLE'S MONEY

Photo from the Rich McCutchan Archives

### 1. Introduction – A History of Conflict

In 1924 a group of disgruntled farmers and ranchers bombed the aqueducts in Owens Valley. Water that once flowed into Owens Lake was being diverted to the city of Los Angeles. Water was diverted because the Los Angeles Water Board had been aggressively buying land and water rights within the valley and then exercising those rights to divert the flow of water to the city. When Lake Owens dried up in 1924 it provided a powerful visual testament to the magnitude of Los Angeles's thirst.

The Owens Valley Dispute occurred within a polycentric system where multiple organizations of differing scales and jurisdiction interacted with one another in attempt to further their individual ends. At the local level Frederick Eaton, the mayor of Los Angeles, is an obvious example of an individual trying to further their political career through securing the water the city needed for growth. In Eaton's efforts to purchase land and water rights, the residents of the valley eventually realized they could improve their bargaining position through collective action and formed organizations like the Owen's Valley Irrigation District to negotiate higher prices on their behalf (Liebcap 2008). These organizations bargained and fought within the broader legal rules of the State of California that dictated how water rights are acquired and transferred.

Additionally, by agitating in the State Capital of Sacramento, residents of Owens Valley attempted to bring outside political pressure onto Los Angeles. At the Federal level, appeals to the President were not uncommon as Los Angeles argued they could put the water to a more beneficial use. The aqueduct that would feed Los Angeles needed to cross Federal land and a federal veto would damn the project to failure.

There were also rumors that Eaton's cronies inside the Reclamation Service derailed a federal irrigation project that would have benefited the residents of the Valley (Reisner 1993). A successful irrigation project would have increased land values by securing a more reliable flow of water, thus increasing the agricultural value of the land. This would have been to the detriment of Eaton because then Los Angeles would have had to pay more for individual farms, effectively increasing the price they would have had to pay to secure additional water rights. The outcome of Owens Valley was the result of coordination and conflict across and in between multiple levels of governance.

While the bombing was a vivid illustration of local anger and discontent, it was ultimately a futile gesture; Los Angeles targeted the largest landholders and by offering them sweetheart deals, caused them to defect and broke the irrigation districts. Los Angeles kept buying land and water rights and eventually spending $219,727,905 in 2003 dollars (Libecap 2007). Los Angeles was willing to pay this price because the city could not grow without water. At the time, the acquisition of these rights was one of the largest transfers of water rights in the American West. The legacy of Owens Valley is about the bitter and contentious political fights surrounding the sale and transfer of water rights.

The solution to Los Angeles's increased demand for water, was to reallocate water away from the rights current holders in Owen's Valley. As we have detailed above, this was highly politically contentious and effectively raised the transaction costs of potential transfers going forward. Rather than repeat these fights, many individuals, both in the private and government sectors, lobbied to increase the total volume of water available. This lobbying has resulted in billions of dollars being spent on water infrastructure projects.

This paper will look at several of the governmental entities responsible for the growth in water infrastructure over the past century. The growth of infrastructure is important because there are two ways to increase the economic value of water. The first is to reallocate it away from existing users. As we saw in the above example of Owens Valley, this is a hard and politically contentious method changing water rights. The second method is to increase the total amount of water that is captured in the system. This has been the path taken for roughly the last 100 years. The problem with this is that one cannot build forever. At some point there is a limit to the rain that falls from the sky and there are only so many locations that are cost effective to build a dam or reservoir. This paper explores the various entities that are responsible for the growth in water infrastructure.

We will look at look at the following four entities: The Metropolitan Water District of Southern California (MWD), The State Water Resource Control Board, The Army Corps of Engineers (ACE), and the Bureau of Reclamations (USBR). Our selections consist of two entities at the state level and two at the federal level. Water infrastructure has been highly subsidized over the past century and has led to a false sense of abundance and the belief that infrastructure expansions could continue indefinitely. This is not true. The purpose of this paper is to look at how these entities are funded and how they allocate water resources under their control.

## 2. Financing Water Projects - The Metropolitan Water District

Water projects are expensive. The California Department of Water Resources has $2.79 billion dollars of outstanding debt with a final maturity of December 1, 2035.[5] The repayment of this debt was done through an interesting partnership with water wholesalers. The Metropolitan Water District of Southern California (MWD) provides water service to 19 million people and is the largest water district in the world. Its size is

[5] Debt Outstanding and maturity taken from: https://water.ca.gov/About/Financials Retrieved June 13, 2019.

not an accident; the MWD is comprised of 14 cities and 12 water districts/authorities and acts as a wholesaler for its members.[6] The MWD is exceptional because of its size. It functions as a wholesaler by design, through bundling the sales to its members, the MWD, along with others, was able to enter into long term contracts that helped finance the State Water Project and the construction of hundreds of miles of aqueducts.

The economic challenge with issuing bonds for these public projects is being able to match future repayments with future revenues. With its size, the MWD was able guarantee that a minimum quantity of water would be sold at a given price, the bundling meant that each member was obligated to buy a given quantity at a given price. This effectively reduced uncertainty about the schedule and likelihood of repayment and subsequent bonds could be offered at a lower interest rate.

An additional benefit of this arrangement, as discussed by Bennett & DiLorenzo (1983), is that by tying the repayment of the debt to water sales as opposed to a general obligation on the taxpayer, the bonds were able to stay on the balance sheet of the State Water Project as opposed to the balance sheet of the State of California. California passed a balanced budget amendment (Proposition 58) in 2004. While this was not a binding constraint when the State Water Project was first envisioned, this system of creating Public Authorities with their own powers of taxation and systems of repayment is one method by which politicians and bureaucrats are able to raise funds for projects within a more fiscally constrained system. For example, a system of proposed twin tunnels in the San Juaquin Delta is estimated to cost in the neighborhood of $14.9 billion.

[6] MWD Member Agencies http://www.mwdh2o.com/WhoWeAre/Member-Agencies Retrieved November 7, 2017.

The MWD uses a series of aqueducts including the Colorado Aqueduct (242 miles), the California Aqueduct (444 miles), and 830 miles of large scale pipes to convey water from afar. The MWD imports its water because Southern California is one of the driest areas of the state with an average annual precipitation of 18.67 inches and local water production is simply insufficient to meet the quantities that are demanded.[7] Since the MWD is supplying water for human consumption, as opposed to irrigation or other industrial uses, it operates five water treatment plants.

Value is created when a resource is moved from where it is plentiful to where it is scarce. In the case of water, a vast quantity of the resource is moved over hundreds of miles and in certain geographic cases, pumps are used to lift the water 1,926 feet vertically over the mountains. The State Water Project alone consumes 11,500 GWh of power in pumping water, making it the largest single consumer of energy in California. To put this in perspective, the State Water Project consumes more power than the 1.6 million people and firms that exist in Alameda County.[8]

Water has a low value to weight ratio and requires large economies of scale to recoup their expenses. The State Water Project delivered 3.7 million acre-feet of water in 2006, that would be approximately $1.2 \times 10^{12}$ gallons of water. If each gallon represented a star, this would be larger than the number of stars in the Milky Way Galaxy, and this is one water project. These numbers and examples are intended to help illustrate the massive quantities of water that are being transported every year.

[7] U.S. Climate data https://www.usclimatedata.com/climate/los-angeles/california/united-states/usca1339. Retrieved October 16, 2017.
[8] http://ecdms.energy.ca.gov/elecbycounty.aspx Retrieved November 7, 2017.

When Ostrom (1990) discusses the successful governance of common pool resources, most of the cases involve small groups operating in small areas. The reasons for this are relatively simple, the transaction costs of deliberation and obtaining agreement are lower when there are fewer people as opposed to many (Buchanan 1962). Smaller geographic scales, relatively speaking, lower the costs of monitoring. What makes water in California worthy of study is that it travels hundreds of miles across multiple jurisdictions before it ever reaches the final consumer. Additionally, the movement of the water requires large and expensive engineering projects that are often beyond the financial capability of many municipalities. The very nature of the task requires large scale collective action.

**2.1 Pricing Water in the MWD**

The MWD does not charge a market price for water, instead, they uses a complex set of variables in determining their final pricing for their water deliveries. The first variable is called the tier 1 supply rate, this variable includes the cost of maintaining and expanding the system and it is charged by the acre-foot of water delivered.  There is also a tier 2 supply rate and is charged for water that is obtained North of the California Delta and is charged by the acre-foot of water delivered. The stated reasoning behind this charge is a desire to develop local water distribution and supply.

Secondly, there is the capacity charge. The capacity charge is used to recover the cost of peaking capacity within the system. Peaking capacity is when there is high demand on the system and additional resources and equipment have to be used to meet this increased demand. The goal of the charge is to provide a price signal that encourages member agencies to lower quantity demanded from high period both within a single day and across high use months. By charging a high rate at these times of higher use, the MWD is also attempting to delay the expansion of existing capacity.

Lastly, there is a readiness-to-serve (RTS) charge. This is a charge that recovers the cost of emergency storage and available capacity. This is done to meet outages and hydrological variability, i.e. variations in the weather that lead to either a surplus of deficit of rainfall. This charge covers the cost of maintaining reservoirs. Full reservoirs provide capacity for years of poor rainfall and empty reservoirs are able to capture water that would otherwise be unused in years of plenty.

**3. State Water Resources Control Board**

The State Water Resources Control Board (State Water Board) was created in 1967 by the California Legislature. The mission of the State Water Board is:

> "To preserve, enhance, and restore the quality of California's water resources and drinking water for the protection of the environment, public health, and all beneficial uses, and to ensure proper water resource allocation and efficient use, for the benefit of present and future generations."[9]

These functions of the State Water board were previously contained within the State Water Quality Control Board and the State Water Rights Board. The State Water Board has five full-time members that are appointed by the Governor and once confirmed by the Senate they serve a term of four years. In addition to the State Water Board, there are nine Regional Water Quality Control Boards

[9] https://www.waterboards.ca.gov/about_us/water_boards_structure/mission.shtml Retrieved November 7, 2017.

(Regional Boards). A Regional Board consist of seven part-time members that are appointed by the Governor and confirmed by the Senate. The State Water Board is responsible for implementing the Federal Clean Water Act in California and responsible for allocating surface water (appropriative) rights.

In allocating surface water rights, one of the major tradeoffs that has to be negotiated by the State Water Board is that they are also responsible for protecting the environment and environmental resources that are held in the public trust. The tradeoff comes from the fact that one the most productive methods for protecting the environment is to preserve water for what are known as “instream flows.” We have previously mentioned the issue of streams running dry and harming the plants and animals that depend on these flows. How this relates to the State Water Board is that they effectively set the minimum rate of water flowing throughout the system. If a species of fish, perhaps the aforementioned Delta Smelt, is struggling under current conditions, one response would be to increase the volume of water flowing through their habitat.

Instream flows are only effective when the water remains instream. This is water that cannot be appropriated and put to other beneficial uses. In California, water use is broken down in the following manner: 50% environmental, 40% agricultural, and 10% urban. In practical terms, more water for the fish means less water for agriculture. The result of this tradeoff is a political battle where farmers and environmentalists both are lobbying to change how water rights are allocated.

The State Water Board is an inherently political task as both farmers and environmentalists are organized special interest groups that have specific policy preferences. It is safe to say that in the rural areas of the state, where the farmers live, they want more water for agricultural uses. In the cities and urban areas of the state, environmental causes are more popular. In the past, politicians negotiated this tension by attempting to increase the total supply of available water through infrastructure spending. As discussed previously, this is not a viable long term solution.

**4. The Army Corps of Engineers**

Among its many duties, the Army Corp of Engineers (ACE) is charged with flood prevention and water control in the United States. This duty was not always a mandate of the ACE, founded in 1824, but resulted from the passage of The Flood Control Act of 1936. The act gave the ACE the mission to provide flood protection through the construction of dams, dikes, levees, reservoirs, and other water control mechanisms. What is also important to understand is that reservoirs that control floods are also a source of water for irrigation networks. Previously, a major focus of the ACE was on the navigability of waterways for the purposes of commerce and transportation (Arnold 1988). By expanding the mission of the ACE, this act greatly expanded the number of eligible projects for federal funding and was done so, in part, as one of Franklin D. Roosevelt's New Deal plan to combat the Great Depression.

For those unfamiliar with its activities, the operational scope of the ACE can be easily underestimated. In order to give a sense of the scale at which the corps operates, we will provide some figures taken from the missions page of the Corps' website.[10] The ACE owns and operates more than 600 damns, maintains 926 harbors, and maintains 12,000 miles of commercial inland water channels. In maintaining the harbors and waterways, they dredge more than 200 million yards of dredge material annually. Since the ACE operates so many dams, it also plays a significant role in power generation with 24% of U.S. hydropower capacity which translates into 3% of the total U.S. power capacity. These figures illustrate the numerous activities of the ACE and the significant assets the operate and maintain. According to the Fiscal Year 2016 United States Army Corps of Engineers - Civil Works Annual Financial Report, the organization has a balance sheet with a net book value of more than $30 billion in general property, plant, and equipment (Army Corps of Engineers, 2016 page 60).

When the ACE begins a new water control project, it enters into a Project Partnership Agreement (PPA) with the non-Federal sponsoring agency. This sponsor can be an individual city or state; other possibilities include flood control districts and port authorities. The purpose of the PPA is to describe the relationship between the ACE and the sponsor while detailing the expectations and responsibilities for cost sharing and executing the plan. The partnership allows for an implicit subsidization as the local partner can engage in marginal projects that they would not otherwise find it worthwhile to fund themselves. The economic logic is that because of these partnerships we see more infrastructure construction than we otherwise would expect.

[10] http://www.usace.army.mil/Missions/ Retrieved October 30, 2017.

Municipal bonds finance large amounts of state infrastructure spending. Issuing new bonds can be a contentious political process and new spending will not always be approved, especially for large and expensive construction projects which describes most water control projects. Additionally, depending upon the credit rating of the local issuing agency, financing the interest on the debt may prove burdensome to smaller agencies and they will be unwilling to incur these costs. Cost sharing in effect subsidizes the construction these projects thru the influx of federal dollars. Agencies at all levels of government are more willing to engage in infrastructure spending when they are using other people's money to finance their construction projects.

Flooding occurs when the quantity of water flowing through the system of rivers and canals is greater than that system's ability to carry that flow, to use a familiar example, a bath tub will fill up and overflow if the rate of water flowing into the bath tub is greater than the rate of water going down the drain. Since we currently lack the weather control technology to diminish the water falling from the sky and into the system, flood managers have historically focused on building a bigger tub. The "drain" in the California example would be the rate at which water would be flowing into the ocean and is also largely fixed.

The "tubs" that the ACE constructs and operates are reservoirs, dams, and lakes. Taking the information from their Missions page, the ACE has a total water storage capacity of 329.2 million acre feet of water (approximately 98 trillion gallons). Geography plays an important role in constructing a dam. It is much cheaper to build a giant wall, a dam, at one end of a valley than to build numerous giant walls or dig a very large hole. Since geography is largely fixed, the cheapest dam locations have already been utilized and at last count there were over 1400 dams in California.

Dams that control flooding can also store water for later release. Cheap water for irrigation and municipal use are dependent upon reservoirs storing large quantities of water. As the quantity of water demanded increases the available supply will remain relatively fixed. This is because even though there is variability in annual precipitation, it is expensive to significantly expand water storage. As Zetland (2011) argues in *The End of Abundance,* water projects that once contained abundant, and cheap, water, have been unable to keep up with the growth in demand. Some mechanism must be chosen to allocate water and this has increasingly become a contentious political issue. Water is not priced at the opportunity cost of the marginal user but at the cost of delivery. This results in water being systemically underpriced and increasing the quantity of water demanded. When reservoirs are full, this gap between supply and demand can be “financed” by spending down the reservoir. A long term solution would entail raising the price of water to equalize quantity demanded with quantity supplied and will likely encounter fierce political resistance.

The ACE gets its funding through the Congressional budget and is in the billions of dollars. For an example of how their funding is allocated, in 2020 there was $4.8 billion in discretionary spending in Civil Works program. Additionally, $1.9 billion was allocated for Operations and Maintenance while $1.1 billion was set aside for new construction.

## 5. The Bureau of Reclamations

The United States Bureau of Reclamations (USBR) was established in 1902 with the passage of the Reclamation Act. The USBR is the: "largest wholesale water supplier, operating 338 reservoirs with a total storage capacity of 140 million acre-feet.[11]" The goal of the USBR is to "manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public."[12] In actuality this has meant subsidizing the construction of irrigation systems in the American West. The construction is subsidized and so is the price of water that the Bureau sells. Kanazawa (1993) argues that the USBR subsidized pricing for water is flawed for the following reasons:

> "First, it may distort the farmer's decision regarding the mix of factor inputs used in crop production, leading to overly water-intensive production techniques. Second, it may encourage too much entry into (or too little exit from) agriculture. Finally, it may enhance the attractiveness of receiving irrigation water from the bureau, thereby encouraging farmers to apply political pressure for additional projects."

The USBR enters into long term arrangements with farmers, as is its role as a water wholesaler, and determines what quantity of water and at what price water from a project will be distributed. This becomes known as the farmer's entitlement and this is, more or less, the quantity of water a farmer can expect every year, taking into account fluctuations due to seasonal variety. One interesting quirk of the way this water is priced is that the USBR is restricted in that it must internalize the interest costs of this water. What this

[11] Information taken from: https://www.usbr.gov/main/about/fact.html Retrieved June 19, 2019.
[12] Mission statement taken from: https://www.usbr.gov/main/about/mission.html Retrieved September 25. 2019.

means in practice is that the water price is often below development costs and the farmers are able amortize forty-year interest free loans to pay for this water project. The rent-seeking opportunities are strong as the payoffs are so high. As shown in Rucker & Fishback (1983), at a forty year rate of repayment, because of the lack of interest payments and the time value of money, the implied rate of subsidization on such a project can be upwards of 90%! Cheap water that can be purchased with long term loans without interest. Another constrain on the efficient allocation of water is that water transfers are constrained by type of use. This means that while a farmer could transfer some of their water entitlement to another farmer for the purposes of agriculture, they could not enact that same transfer if the recipient was a municipality. The practical outcome of such restrictions is that farmers growing lettuce or alfalfa in Imperial Valley California, where it is very hot and has limited precipitation, are unable to sell water to thirsty Southern California cities like Los Angeles and San Diego.

## 6. Conclusion

Zetland (2009, 2011) argues that the era of abundance is over. Water that was once abundant has been steadily consumed by agricultural and urban users. Environmental flows needed to protect the public trust have bit heavily into the amount of water available for these users. Billions of dollars have been spent on water infrastructure in the American West, the thousands of dams and hundreds of miles of canals are testament to this effort. The majority of these projects have been funded at the State and Federal level subsidized loans that were amortized over long periods of time, sometimes upwards of 40 years. Water projects are effectively subsidized through the cheap loans and the water sold is often sold at below market prices. The price of water does not reflect the true opportunity cost of water as pricing is often limited to a cost plus basis.

This investment has caused tremendous environmental damage while channeling hundreds of millions of dollars to Beard's so-called "water nobility." With the easiest and most cost effective construction accomplished decades ago, billion-dollar water projects are now the new normal. The success of past lobbying efforts for more construction has undercut efforts to price water and incentivize conservation. The subsidies need to end and prices need to increase. This will be unpopular.

The era of abundance is at an end and new research will be needed to design mechanisms and markets for reallocating existing water resources. The practical challenge will be in enacting reforms across multiple levels of government as these systems are intertwined and dependent upon one another.

## CHAPTER THREE – DISCONTINUOUS INSTITUTIONAL CHANGE

### 1. Introduction

Douglas North argues in *Institutions, Institutional Change and Economic Performance* that institutional change occurs at the margin and occurs "incrementally rather than in discontinuous fashion (North 1990, page 6)." This paper will look at several examples of what we consider discontinuous institutional change. North offers the cases of war and conquest as examples of discontinuous change and these are obvious and strong examples. If an invading army creates their own system of courts, judges, and rules this will fundamentally alter the parameters of exchange within a society. For example, if a new ruler forbids the charging of interest on loans, a common historical prohibition, new financial arrangements will need to be created in order to deal with this new institutional environment. North is concerned with explaining the diversity of economic outcomes and focusing on such macro level questions makes sense given his research question.

North defines the functions of institutions as providing "the basic structure by which human beings throughout history have created order and attempted to reduce uncertainty in exchange (North 1990, page 118)." This functional explanation of institutions is not restricted to macro level phenomena like revolutions and conquest and can be applied to narrower markets, indeed: "Institutions reduce uncertainty by providing a structure to everyday life (North 1990 page 3)." By focusing on smaller markets and smaller institutions, we are provided with additional opportunities to look for discontinuous institutional change.

This paper focuses upon the historical evolution of water rights within the state of California as a case study of discontinuous institutional change. Water as subject deserves study because it is a common pool resource that exists quite far from ideal conditions. Observing groundwater is difficult and costly, one can look at a lake or reservoir and see the water levels deplete with use. Groundwater basins can cover a large geographic area and before the advent of reliable survey technologies and techniques, their borders were poorly mapped. Groundwater is appropriated through drilling wells and while an individual may have knowledge of their own pumping activities, the same is not true about the activities of their neighbors. The lack of common knowledge about appropriation activities raises the cost, and the difficulty, of achieving successful governance. What we will argue in this paper is that as technology changed the marginal cost of obtaining information about the specifics subsurface water flows, institutions, as exemplified through the legal system, rapidly adopted these new findings and changed dramatically.

The paper is structured as follows. In section 2 we will provide a literature review of the institutional change and property rights. In section 3 we will discuss property rights in ground water and the end of the ad coleum doctrine. Section 4 will be about restrictions on pumping for sale and the ability to mine groundwater. Section 5 will address water quality and the use of surface water as a means of conveying pollutants.

This section will focus on the historical regulation of water quality. Section 6 will conclude.

## 2. Why California?

California provides a unique legal and institutional framework for studying groundwater. The state has changed greatly since it was first founded in 1850. The state is not only the most populous in the nation, it is larger than the smallest 22 states combined. California has experienced a massive population increase over its history with more people competing for resources that were once abundant. With increased competition for these resources, new rules for governing appropriation were needed to coordinate individual activity and reduce uncertainty about final distribution. In addition to its large populace, the state itself is geographically large. Large population and geographic size introduces heterogeneity as individuals have differing plans and beliefs about the appropriate, and best, use of the limited water resources. Size is important because California covers multiple climates and individuals in different climates will want to use different resources more intensely. For example, farmers in the drier southern parts of the state will be less willing to rely upon natural precipitation to water their crops and will be more than willing to pump groundwater if the weather and surface water supplies are not accommodating. The thesis of this paper is that as new technologies and developments in the hydrological sciences have expanded the potential uses, and value of water, new institutional rules were quickly adopted in response to conflicts that emerged from these new technologies.

Our analysis starts in the past, we do this to show how simple rules evolved to changing circumstances as new knowledge and technologies changed the costs and benefits of appropriating water resources. Currently, water regulations are complex and a lawyer could have a successful (and profitable) career solely litigating water law and guiding their clients through application and permitting processes. While we cannot rule out the possibility of rent-seeking within this system, we will instead focus our attention on the institutions governing water. We will start with an economic explanation for the formation of property rights. We will then modify this theory and show how changes in both information and transaction redefine these existing rights. With this as our theoretical framework, we will show how changes in information and transaction costs have been reflected in an evolving body of law.

## 2.1 Theories of Rapid Institutional Change

Leeson (2012, 2014) provide some instructive examples of what I am calling rapid institutional change. In both cases, we see a religious institution that was created to reduce violence amongst people by altering the perceived costs and benefits of violence. In the case of Leeson (2012) monastic maledictions increased the costs of engaging in violence, in Leeson (2014) this religious practice lowered the benefits of violence by lowering the amount of wealth that could be physically expropriated. What is important about both cases is that as property rights became more secure, these religious practices went away. The religious aspect is key because one would normally hold religious beliefs as mostly immutable over time and some of the hardest aspects of human behavior to change, we have stories of martyrs for a reason. It is for these reasons that institutions based in religious practice are important examples of discontinuous institutional change.

Leeson (2014) provides a historical analysis of the institution of human sacrifice where the Kond people of India preemptively sacrificed human victims as a way of lowering the risk and uncertainty that came from internecine conflict. The simple version of the explanation is that wealthy communities were more likely to be targeted by their neighbors for raiding so they preemptively destroyed their wealth in the form of human sacrifice. Victims were purchased from outside the community, causing wealth to leave the community, and murdered in a highly visible, verifiable, and spectacular fashion. What is interesting about the case of the Kond is that while the British hated this practice, they were unable to put an end to it through violence or education.[13]

What did end human sacrifice was the British promise of justice and arbitration between neighboring tribes. Human sacrifice, as an institution, despite its religious justification served a role in reducing uncertainty by reducing the payoffs to tribal violence. Previously, those injured by tribal violence had no recourse for justice. British arbitration and justice was a substitute for the institution of human sacrifice and because it was successful in limiting tribal violence, a religious rite that had been practiced "from time immemorial" (Leeson 2014 page 162) ended within years. Human sacrifice was costly, relying on British arbitration to serve the same end at a lower price was a powerful substitute. The end of human sacrifice within years qualifies as discontinuous

[13] Even in cases where the British were able to rescue some of the intended victims, the Kond resumed the practice once the British left (Leeson 2014 page 161).

institutional change, especially when we consider that the explicit purpose of the practice was to pacify a malevolent earth deity.

### 3. Evolution of Property Rights in Groundwater

The theoretical starting point for this paper is that property right in resources are endogenously created in response to changes in either the benefits of controlling a resource or the cost of enforcing that control. Demsetz (1967) provides a model where a resource that was previously held in common, animals, experienced a rapid increase in value due to developing markets in animal furs. The result of the increase in value was a change in the norms regarding who and under what circumstances may appropriate from the commons.

Creating and enforcing property rights costs real resources and in environments where the benefits of creating property rights are low relative to the costs one would not be surprised if rights were either weak or nonexistent (Anderson and Hill 1975). This paper conceives of property rights as a bundle of rights.[14] As the environment within which these rights exist changes, so too should we expect the bundle of rights to change. For example, changes in the cost of enforcement may change the composition of this bundle of rights. Using the earlier case provided by Demsetz, if more trappers are seeking to harvest fur in an area, rights regarding who may hunt what and when may change in response to increased externalities from appropriation. The history of ground water rights in the American West is one where rights have evolved in response to disputes arising

[14] For a discussion of the advantages and disadvantages of the "bundle of rights" approach see: Epstein 2011, Klein and Robinson 2011, and Merrill 2011.

from increased demand for water and changes in the scientific understanding of hydrology.

### 3.1 Absolute Rights – *ad coleum*

Water rights in the American West have Hispanic origins (Meyer 1989). The Treaty of Guadalupe-Hidalgo, which established peace between the United States and the Mexican Republic, bound the United States to respect the existing property rights of individuals in their newly conquered territory and this included groundwater rights. At the time, California was not yet a state. This treaty is the mechanism through which Spanish and therefore Roman legal traditions became a significant legal source governing initial groundwater rights. Groundwater rights were an appurtenance of land ownership. The individual owning the land could use the water for whatever purpose was desired and no limits were placed on quantity. This is best exemplified in contrast to surface water wherein some uses, particularly irrigation and industrial uses, were prohibited without an explicit right that was obtained through purchase, grant, or judicial award (Meyer 1989, page 292).

When California became a state in 1850, the English Common Law was adopted formally as the governing legal doctrine (see Young 1960). This, coupled with the earlier Spanish influences, determined the treatment of groundwater as a function of land ownership. In English common law, land ownership consisted of rights both above and below the land. This is known as the *ad coleum* doctrine and its origins are traced to

Acton v. Blundell.[15] A quick summary of the details of this case is that in excavating a coal mine the defendant interrupted subsurface water flows to the plaintiff's well. The court ruled that the defendant's ownership of the land came with the right to dig into the land and "apply all that is there found to his own purposes at his free will and pleasure." The application of the ad coleum doctrine to groundwater meant that a landowner could not be held liable for interrupting subsurface water flows to their neighbors. This is important because of how it contrasts with the treatment of surface water where impacting one's neighbors was grounds for liability. Kanazawa (2003) quoting Acton explains as follows:

> "The difference in legal treatment, argued Acton, was based on the fact that surface-water flows were obvious and observable to claimants, while groundwater movements were not. Consequently, surface-water rights could be based on the "implied assent and agreement" of various claimants to the same surface source, whereas "[i]n the case . . . of [groundwater], there can be no ground for implying any mutual consent or agreement... between the owners of the several lands beneath which the underground springs may exist, which is one of the foundations on which the law as to running streams is supposed to be built; nor, for the same reason, can any trace of a positive law be inferred from long-continued acquiesence [sic] and submission, whilst the very existence of the underground springs or of the well may be unknown to the proprietors of the soil" (Acton, p. 350)."

An individual knowing the results of their actions is important in establishing liability. If one dams a stream, they know it will impact all downstream users. The same is not true for one digging a mine because subsurface water flows are unknown. This is an important

[15] The doctrine's name derives from the Latin phrase: "*Cuius est solum, eius est usque ad coelum et ad inferos*." Translated: "whoever's is the soil, it is theirs all the way to Heaven and all the way to Hell."

standard because as technology and the science of hydrology advanced, it became possible to have knowledge about subsurface flows and how others would be impacted.

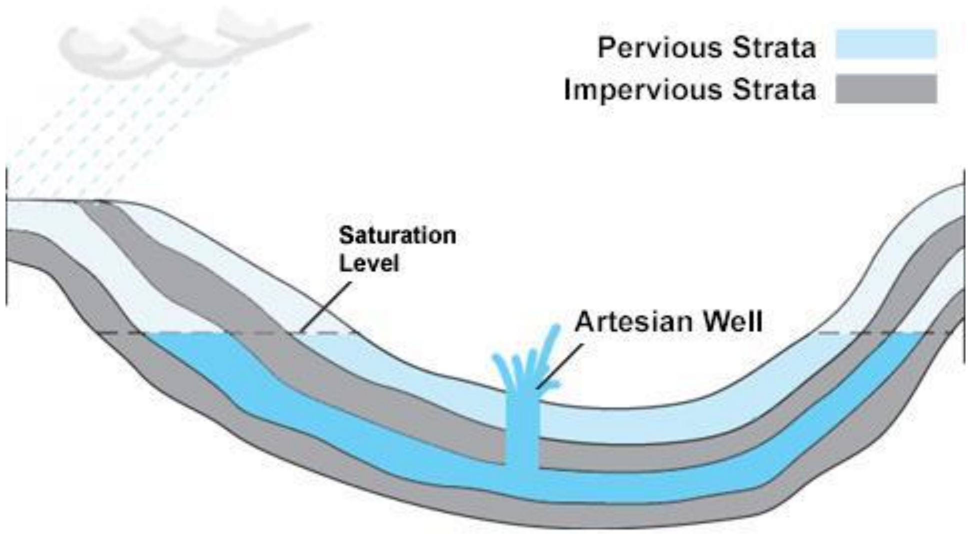


Image courtesy of Wikipedia

Artesian wells do not require pumping to access water, instead rely upon pressure differentials, oftentimes originating at great distances, to push percolating water to the surface. While the owner of one plot of land may have an artesian well, the functioning of that well is dependent upon water flows that occur across multiple land owners. Activities of other land owners could potentially lower the pressure within the system and reduce the efficacy of these wells. Artesian wells provide access to groundwater without the need for expensive pumps and this makes them desirable. This desirability lead to an interest in learning how to maximize water yields. In 1885, the US Geological Survey published a report on strata conditions that were ideal for underground water movement and how multiple wells could be arranged spatially to limit interference.[16] The importance of this growing hydrological knowledge was that it came to be increasingly referenced as pertinent facts in court cases. Plaintiffs now had the ability to provide a mechanism through which the actions of the Defendant lead to specific harms. In addition to describing the mechanism of harm, it was also possible to argue that such harms were a foreseeable consequence of specific actions.

**4. The End of Absolute Rights – Reasonable Use**

In the preceding discussion of the *ad coleum* principle, the right to pump ground water was absolute. This changed in 1903 with the case of Katz v. Walkinshaw (141 Cal. 116 [1903]) which established relative rights through the implementation of a reasonable use principle. A quick summary of the case is as follows: Walkinshaw owned a handful of artesian wells and uncapped the wells so that the water would flow into a stream for sale. The sudden outflow of water caused the subsurface water pressure to drop and Katz's well ran dry and they sued for damages. The result was that in certain cases, subsurface flows were treated as riparian (surface) flows. For a discussion of the details of this case, see Dunbar (1977 p. 665-667). A common way this principle was applied was in prohibiting the pumping of groundwater for export outside the basin. For example, if one farmer was pumping water for overland irrigation use, this would be a reasonable use. If a differing individual was pumping groundwater to sell to another outside the

[16] Kanazawa (2003) provides an explanation of this and other government reports: U.S. Census Office (1902), U.S. Department of Agriculture (1893a, 1893b), U.S. Department of the Interior (1896, 1902), and U.S. Department of the Interior: Geological Survey (1885, 1893, 1921)

basin, the aforementioned farmer could sue this individual on the grounds that their use of water was being hurt and that pumping water for sale was an unreasonable use.

Prohibiting pumping for sale transforms what was the market demand for water into a collection of the individual landowners' demand for water, which was a subset of total demand and limited to the basin within which the water was being pumped. For the individual, the cost of pumping is the energy needed operate the pumps. Individuals will allocate the first unit of water pumped to its, subjectively, highest valued use and all succeeding units will be put to less valued uses (Menger 1871). When the cost of electricity exceeds the benefit of the marginal unit of water, an individual will stop pumping. There is a limit to how much water a farmer can use on their fields, too much water will, in fact, kill their crops. Maintaining proper drainage and soil gradation on fields is important to keep water from pooling and drowning the crops. This is important because one can intuitively see that if water use was restricted to an individual's land, the marginal benefit of pumping would rapidly decline while the cost of pumping, electricity, stayed the same.

Pumping for sale allows marginal water that would not originally be worth the cost of pumping to be sold to someone with a differing and greater volume of water. It takes little to imagine a scenario where the option for sale leads to a massive increase in the quantity of water pumped from underground aquifers. The problem is twofold. First, while our example assumed only electric pumps, artesian wells that depend upon pressure differentials to function could run dry from industrial pumping. Secondly, a well is inherently limited by its depth. If an individual drills 100 feet into the earth and the water table is 150 feet underground, the well will be dry. The economic concern in this was that since drilling a well and installing a pump is a capital intensive process, individuals need a way to protect their investment.

Groundwater is a common pool resource and water that is not appropriated today may not be available tomorrow. Pumping for sale puts individuals within a single basin in a literal race to the bottom as the only way to ensure that one recovers their investment is to drill deep and pump as heavily and as quickly as possible. In addition to the costs that one's neighbors may be incurring, aggressive pumping can also destroy the water storage capacity of the basin through a process known as subsidence where the ground becomes compacted and stores less water in the future. In such a hydrological environment, it takes little imagination to understand why one would wish to sue their neighbors over their pumping activity.

Kanazawa (2003) puts forward the argument that part of the reason we see the law change in Katz v. Walkinshaw is that courts were seeing more of these cases being brought using the specific hydrological characteristics of the land as a fundamental argument. Through this process of repeatedly litigating similar cases, we see an evolution in the common law similar to what we would expect from Posner's (2014) model of efficient common law. As Kanazawa noted (pages 170 - 174) in the preceding decades we see a rapid shift in the types of wells being used: simple pumps that were powered either by animals or the wind were replaced with steam and electric engines. Those who upgraded to new technology were at a pumping advantage relative to their neighbors as they could exert more pressure at deeper depths. For the first time, these new pumps made it cost effective to use groundwater for irrigation. This technology introduced a source of conflict as neighbors now had differing costs structures and ideas about the appropriate use of groundwater. These cost differences coupled with new information about underground flows allowed those with dry wells the credibility to state that they knew, for a fact, that their neighbors were responsible for their current predicament.

What we see in the changes to groundwater institutions is that what was once a previously absolute right to groundwater and the benefits of landownership became abrogated and replaced with a system of relative rights and doctrines of reasonable use. The reasoning behind the change is as technology lowered the costs of accessing subsurface water, economic activities that were previously contained to the land of a single owner started to generate externalities. Institutional rules were changed to deal with this externalities problem and this was ultimately driven by technological change and the lowered marginal costs of pumping water.

### 4.1 Novel Exceptions to Pumping for Sale – Water Banks

The Water Banks was a legislative innovation during the California drought of 1991 that attempted to ameliorate the drought by allowing the sale of water (Israel and Lund 1995). During a drought, the quantity of water demanded is greater than the supply. The problem was twofold. First, individual water rights are only for the use of a quantity of water and not the water itself. For example, one could use their water right to irrigate their fields but could not directly sell the water to their neighbors. Secondly, water rights are established and maintained through use. If they are not used, this can become the legal basis for reducing the quantity of one's water right. Combined, this creates a situation where there is no incentive for forbearance. No one wants to voluntarily use less water.

The goal of the Water Bank was to improve allocative efficiency by enabling transfers between individuals with differing values of water. In practice, what this meant was paying farmers in the northern part of the state to voluntarily fallow their fields and allow the associated water to be transferred to higher valued users in the urban part of Southern California. The Metropolitan Water District, the provider for the city Los Angeles and the largest water district in the world, purchased 55% of the total water available through the bank (Israel and Lund 1995, page 11). The Water Bank was successful because the California legislature explicitly passed legislation that not only exempted farmers from reasonable use restrictions, but also guaranteed that participation in the program could not be used as a future justification for reducing water allocations.

The rules of the Water Bank were updated in 1992, of importance for my analysis was that it prohibited farmers from letting their fields lay fallow. This was a political consideration as supporting industries complained about decreased business. If a famer lets their field of tomatoes lay fallow, then they are not sending their product to the canary and fewer seasonal workers will be employed. What this requirement did was ensure that farmers who transferred their surface water rights compensated by pumping groundwater. Even though groundwater was not literally being pumped for sale, the effect was the same as if it were allowed. The Water Bank was a successful short term solution for dealing with the drought by allowing individuals to voluntarily transfer resources within the framework provided by the Water Bank.

*Carleton Watkins, "Malakoff Diggings." (Photo: Bancroft Library, University of California–Berkeley)*

**5. Water Quality**

The California Gold Rush plays an important role in the development of water institutions because it spurred the creation of appropriative water rights and as a result of these appropriative rights being used for hydraulic mining, created some of the very first water quality laws in the nation. Appropriative rights pertain to utilizing diversions from surface flows where the water has to be moved some distance before it can be utilized for economic purposes. Riparian rights are the rights of land ownership neighboring water. Appropriative rights are for taking this water and moving it some distance before it can be used.

In the case of the California Gold Rush, these appropriative rights were used for mining gold. The appropriative rights established a first in time, first in line doctrine of use which limited uncertainty over future use. For example, if one diverted 100 units of water, then that person was entitled to the use of those 100 units. Others could divert additional water provided that their diversion did not disturb the ability of the prior appropriators to utilize their water rights. Practically speaking, if there was a dry season and there was less water available than usual, the oldest appropriators would get their full allotment while the newer claims would go without.

The technological advance that we will focus on is the development of hydraulic mining, see above picture. Hydraulic mining was a process where pressurized streams of water were used to blast apart mountainsides and the run off was then put through a series of sluices where gold particles would be separated from other, lighter, bits of particulate matter. The resulting slurry had to be disposed of and it was deposited back into the river from which the original diversion was made. The problem came from the large scale at which the hydraulic miners operated as they deposited millions of tons of silt and sediment into mountain streams. This consequence of all this sediment was that when the rivers reached relatively flat and shallow areas, the sediment would accumulate and the rivers would flood over their banks and devastate resulting farmland. These sediments were also contaminated with mercury, a byproduct of the mercury amalgamation used during the gold extraction process. Mercury is toxic to humans and wildlife and some California lakes carry advisories against eating the fish because of this mining practice.

In response to the destruction of their farmland and the poisoning of the waters, farmers sued to stop the mining. The pivotal legal decisions was Edwards Woodruff v. North Bloomfield Mining and Gravel Company when in January 7, 1884 Judge Sawyer banned hydraulic mining in the state. Hydraulic mining was only reinstated with the Camminetti Act, passed by the United States Congress in 1893, which permitted the mining as long as sediment abatement and detention structures were used. In other words, mining was permitted as long as miners were internalizing the costs of mining and not shifting it onto farmers and other downstream landowners.

The economic logic of this piece of history is that hydraulic mining shifted the supply curve to the right. This new technology lowered the cost of mining and as a result we see an increase in the quantity and intensity of gold mining. The rivers had a carrying capacity for some amount of silt and detritus. The problem was that hydraulic mining was literally moving millions of tons of material by blasting away mountainsides and the carrying capacity of the rivers was overwhelmed. What was a low cost waste disposal mechanism for the miners instead shifted part of the cost of their economic activities onto farmers and other landowners. In some cases, towns and cities were wiped away by floodwaters.

What started as a part of the reasonable use doctrine, it being unreasonable to dump that much silt into the river, eventually became part of the public trust doctrine.

Apart from the flooding, the silt and heavy metals from mining poisoned the water and devastated the riparian ecosystem. What started as flood prevention eventually morphed into a more generalized environmental protection. Using rivers and waterways as means of garbage disposal are becoming less and less tolerated as it becomes to describe the effects with greater accuracy.

These institutions regarding water quality are a removal of some of the rights in the property rights bundle. Previously, if one had access to a flowing stream, one was permitted to dump whatever garbage or debris they wanted. In small amounts, this was not a problem, all poisons are defined by their dosage. The issue is that as more and more people inhabited the state and engaged in differing degrees of economic activity, the anything goes environment of the past was no longer tenable. The water quality institutions seek to reduce uncertainty not only through flood protection, but through helping to guarantee access to clean water and healthy environments.

## 6. Conclusion

Rapid and discontinuous institutional change is to be expected when the benefits of changing institutional rules exceed the costs of change. In the multiple examples provided in this paper we have shown how changes in technology have altered perceived costs and benefits, thereby altering behavior. Changes in behavior led to natural resources being used with different intensities and purposes and to protect the long term value of the resource, institutional rules were altered to maximize the value of these resources. Successful institutional change may itself suffer from a tragedy of the commons, but as

Ostrom has repeatedly shown, such commons problems are routinely solved and such successful resolutions should not be a surprise.

## CONCLUSION

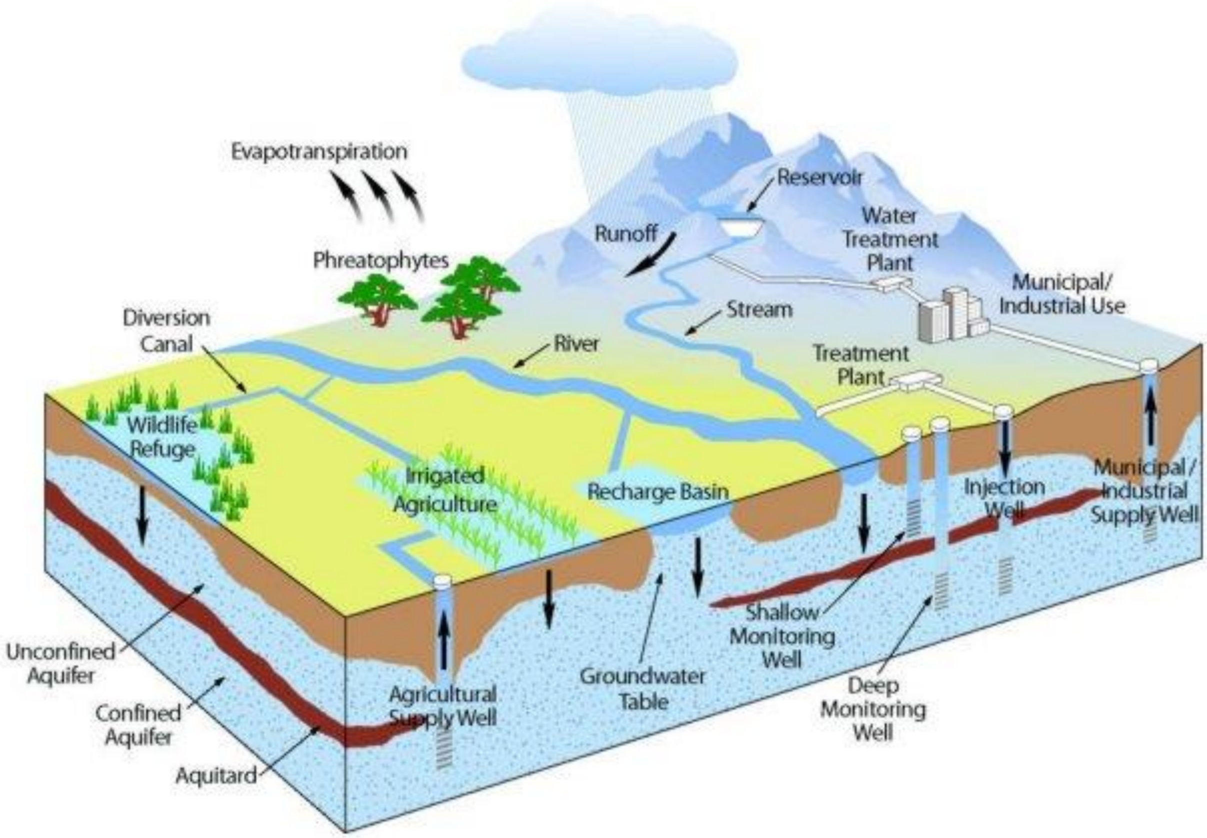


Image courtesy of Wikipedia

The taps have run dry in Porterville, California. The town relies on well water and a punishing drought in 2014 lead to a depleted water table. For an example of the interconnected nature of groundwater, see the above image. It was a race to the bottom with everyone pumping as much as they could, a classic collective action problem. No individual had an incentive for forbearance and as a result, no individual wanted to slow their pumping. The result was a classic tragedy of the commons. What makes this story curious is that while the town ran dry, the farmland bloomed. This is because farmers were spending millions of dollars to drill new wells. These wells were upwards of 2,000 feet deep, a normal household would have a well around 200 feet.

The farmers were willing to spend millions because they had planted pistachio trees and without access to groundwater, the trees would die. They had to protect their investment which meant entering into a literal drilling race with their neighbors. The depths they went to were so extreme that local drilling companies had to utilize technology and equipment usually reserved for oil drilling. The waiting line for a new well was upwards of a year.

Earlier in chapter 3 we discussed prohibitions against pumping for sale. The key difference here is that the farmers were not pumping for sale but for individual use. With the ownership of land came the undisputed right to pump groundwater. The *ad coleum* principle allows land owners to exploit the resources found underneath their land. This is the legal framework that underpins the tragedy of the commons.

Collective action is hard in this scenario because monitoring is costly. Individuals have no way to verify how much their neighbors are pumping and without verification there cannot be punishment for excessive pumping. There have been some examples where individuals have gotten together and voluntarily restricted their pumping, but this was with an explicit quid pro quo from the government that if they restricted their pumping, they would not be regulated. With the passage of the Sustainable Groundwater Management Act in 2014, groundwater basins will be forced to either come to their own agreements for sustainability or face being regulated by the State government. It will be an interesting project for a future date to see which basins were able to successfully manage themselves and which will fail. Explaining the variation will go a long way towards improving our understanding of common pool resources.

Water is hard. Most successful examples of common pool resources being managed occur at small scales. This is because the small scale lowers the transactions costs of negotiation and monitoring. Water in California is not operated on a small scale. Water is transferred hundreds of miles across multiple jurisdictions before it reaches the end user. The large scale increases the costs of negotiation and undermines the formation of common knowledge needed for successful monitoring. Neighbors may know what each other is doing, but not when separated by such large distances.

In our first chapter, we argued that market mechanisms are needed to allocate water amongst competing ends to ensure efficiency. These mechanisms only exist in a weak and hampered state. Changing rights is a costly legal process as public trust laws effectively increase the number of parties that can dispute the benefits of a transfer. The transaction costs are too high and that is a direct result of current legislation and case law. As new sources of water become scarce

In our second chapter, we discussed the polycentric nature of water governance in California. The history of water in the American West is one of subsidy. Subsidized loans backed by Federal dollars backed many water projects. The lesson of this chapter is that water pricing does not reflect the full opportunity cost of water. The beneficiaries of this largess are a powerful special interest and are heavily invested in maintaining the status quo.

In the last chapter, we see that institutions can change rapidly and do so in response to new knowledge and technologies that radically alter the costs and benefits of how resources are managed and consumed. Institutional change is possible and required because as new sources of water are unlikely, reallocating existing supplies is needed for growth.

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