Restoring the Colorado River Delta: Finding common ground for our water

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A thesis submitted to the
University of Colorado at Boulder
in partial fulfillment
of the requirements to receive
Honors designation in
Environmental Studies
May 2014

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Abstract

This thesis explores the way people are achieving a collective shift in the overarching perception of natural resources in the United States. The first perception I have observed is a paradigm where humans see themselves as separate from and dominant over the natural world and the resources it provides. Based on this perception, humans modify, commodify, and consume resources for their benefit without questioning long-term sustainability of those resources, which leads to resource degradation that harms our environment and, in the long run, ourselves. The second perception I am observing is a new paradigm where humans understand themselves to be enmeshed in the natural world and its resources. In this paradigm we perceive natural resources as equal and supportive foundations that we depend upon and must maintain and work with to sustain those resources and ourselves for the long term. I am exploring this paradigm shift specifically with regard to the Colorado River Delta.

The development of water projects on the Colorado River funded and undertaken by the Bureau of Reclamation have been the result of a mindset of dominion over resources that stems from a Christian worldview, linear systems thinking, and the ideals of capitalism. This mindset has created damming and diversion of water on the Colorado River so profound as to prevent flows reaching its delta. The delta was once a two million-acre expanse of vital wetland and estuary habitat for animals and humans alike that has shrunk in size by 90% in the past century because of lack of water.

A shifting paradigm based on a mindset of sustainability of resources is leading the change in the way we understand Colorado River water to help restore the watershed and especially the parched delta. Minute 319, a 2012 amendment to the 1944 Treaty between Mexico and the United States, is an example of the new paradigm in action as it is the first legal allocation of water to the delta for environmental purposes. From my research I have found that political action like Minute 319 is necessary to move the paradigm shift and bring the change in perception of water resources to the 36 million citizens that depend on the Colorado River for their way of life. By inviting a mindset of long-term sustainability to guide our behaviors and political decisions, all of us depending on the watershed can work collectively to restore and maintain the Colorado River, including its delta.

I dedicate this thesis to the Colorado River Watershed.
May your waters flow to the sea.

Love,
Amorina

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[1] Introduction

From the Heart

"…ultimately there is no such thing as an environmental impact that is not also a human impact."

Sarah F. Bates et al.: *Searching Out the Headwaters*

This thesis explores the way people are achieving a collective shift in the overarching perception of natural resources in the United States. The first perception I have observed is a paradigm where humans see themselves as separate from and dominant over the natural world and the resources it provides. Based on this perception, humans modify, commodify, and consume resources for their benefit without questioning the long-term sustainability of those resources. This leads to resource degradation that harms our environment and, in the long run, ourselves. The second perception I am observing is a new paradigm where humans understand themselves to be enmeshed in the natural world and its resources. In this paradigm we perceive natural resources as equal and supportive foundations that we depend upon and must maintain and work with to sustain those resources and ourselves for the long term. I am discussing this paradigm shift specifically with regard to the Colorado River Delta.

I aim to inform my fellow Western citizens about the effect human development based on a mindset of dominance has had collectively on the great river of the Southwest, and especially on its neglected delta. I am writing about the delta because it is a vital and highly degraded landscape I had no awareness of until I was in college studying Environmental Studies. The fact that I grew up in the Colorado River watershed but had no idea about the condition of its delta leads me to believe that most people living in the watershed are not aware of the state of their river. My increased awareness about the delta has driven me to write this thesis to raise the awareness of others. I also aim to

inform people about the way human development with a mindset of resource sustainability is mitigating the negative effects of development with dominion over resources.

I believe that we are in the middle of a paradigm shift in the thinking about the way humans progress. Progress is a positive idea. Some proponents of the environmental movement see human progress as a negative concept and want us to collectively "change back" to how we were before the Industrial Revolution or even before we established sedentary civilizations in order to improve the relationship between human and environmental health (Heinberg 1995). Given the impossibility of changing back or making life be *the way it was* (Abbey 1975), we must instead modify the values that we have previously considered progressive in order to address the natural resource predicaments we have effected. We must *change forward*.

Historically, the idea of progress in the United States has stemmed from a cultural desire to change and subdue the environment for the benefit of people. Many people certainly have flourished within this belief system, but at the expense of the health of entire ecosystems – such as the Colorado River Delta in Mexico, which receives almost none of the river water return as a result of the practices applied upstream in Mexico and the United States.

I focus on a change in the definition of progress that specifically works to benefit the environment we live in while also benefiting the people. The Indians who historically sustained their livelihood along what is now called the Colorado River practiced taking care of the environment as the fundamental basis of taking care of themselves. This is an important example of living that can be applied to our way of life today. To shift our way

of life requires a change in an understanding of well-being from one where humans are separate and above nature to one where humans are part of natural processes so we can foster holistic progress in the ecosystem.

In conducting my research I began by collecting peer-reviewed articles on the current state of the Colorado River Delta. Once I had gained a well-rounded body of information related to the delta, I explored the history and philosophy of some of the definitive works of writing about the West, the desert, and human influence on the environment in general. These authors include Edward Abbey, Sarah F. Bates, Murray Bookchin, Dave Foreman, Patty Limerick, Barry Lopez, Jennifer Pitt, and Marc Reisner. I intend to explore more female and multicultural points of view on these topics in the future and formulate my own view with my graduate work.

After researching the science on the delta, I gained ethical views of the colonization of the West, then looked in more detail at aspects of policy and its effect on the development of the West. I also researched the peoples that populated the West before European Americans migrated here. Next I looked at the differing ethical views of progress as an ideal that dominates nature and has produced prosperity for humans in the short run and harm in the long run, or as a concept which can work with natural processes and benefit all parties for generations. I also looked into current efforts underway to improve conditions of the delta, exploring new policies such as Minute 319 of the 1944 treaty between Mexico and the United States that has set a new system of water allocation to each nation and to the delta.

When seeking to solve big problems, awareness of the collective effect of our individual actions is essential. Perceiving people as separate from nature is a reductionist

state of mind, which falsely assumes our behaviors only affect our individual selves. We need to expand our perceptions of ourselves as all part of a greater whole of interacting organisms and systems (Wessels 2013). When we can imagine or see the results of each of our individual decisions multiplied by the 36 million of us who depend on the Colorado River ("Restoring the Colorado River Delta"), it becomes apparent that if each person decided to change his or her behaviors even slightly, the cumulative effect could result in profound positive change.

As a student of Environmental Studies I have become aware of human-induced environmental issues that are shocking and painful to digest. In this document I not only discuss the problem of negative human impact, but I also provide examples of the positive actions humans undertake as solutions to negative impacts. From my experience, the best way to go about reading the hard facts of our times is to keep an optimistic heart. It is difficult for the mind to grasp the doomsday statistics because there are no obvious or immediate solutions. As I've heard it said, *the mind is a terrible thing to mind* (Martinez 2013), meaning that the spiral of doom predicted by the mind hinders the actions taken by the body. Rather, I wish to follow my heart. I am writing this thesis because my heart is engaged in the well-being and the future of the Colorado River watershed.

I grew up in the Mancos River Valley in Southwest Colorado on a tributary of the Colorado River. These days, irrigation withdrawals and other uses cause the Mancos River to go dry in the summer before it reaches the San Juan River, a major waterway that meets the Colorado at Lake Powell (Mancos Valley Watershed Group, 2011). Human uses dewatering the Mancos River harm riparian habitat and species, and less

water reaches the San Juan, which means less gets to the Colorado. This is just one of many examples of the plight of our rivers in the West.

I am an environmentalist, a person who advocates the sustainable use of resources. Being from the Southwestern United States, I believe in the inherent value of a free-flowing Colorado River for the environment and for all of the residents of that environment. I am writing this thesis with the goal to inform the people of the West about the need to improve the conditions of one of the great rivers of our homeland and the Mexican people's homeland and to provide some tools for achieving that goal. Creating a base of accessible information that raises awareness is a preliminary step in creating positive change.

In the second chapter I discuss the history of the Colorado River from its early geology and the first people who inhabited the Colorado River watershed through the developments of the last century that changed the River to the way we know it today. In the third chapter I discuss the origins and dynamics of the linear-thinking, progress-with-dominion mindset that dramatically changed the river, starting with Hoover Dam in the 1930s funded by the United States Bureau of Reclamation. In the fourth chapter I discuss the shift to a complex-systems-thinking, progress-with-sustainability mindset that is necessary to improve the state of the river today. I also discuss ways in which policy and non-governmental organizations are working to achieve a greater balance in the use of Colorado River water and the maintenance of the health of its natural systems.

It is important to value the essential resource of the Colorado River as an interconnected system that needs to be maintained to sustain life for generations, rather than a resource that may be degraded for immediate profit. There has been an innate

understanding in United States policy that resources must be put to human use, otherwise they are "wasted" (Bates et al. 1993). This concept of resources underlies the thinking that has led to over-allocation of the waters of the Colorado River basin.

I hope, with my research, to expand insight into the need for a shift toward the mindset of sustainability – the concept that everything is part of an ecosystem that has natural dynamism. For ecosystems to endure through time, we need to maintain them in a natural state by our everyday collective efforts. The Colorado River system is no longer in a state of natural dynamism; the river systems suffers from human homogenization while people over-consume. It is important to identify this imbalance and look at the system in its entirety to understand how to reach a state of natural variation and rhythm where the environment and the people can thrive together.

[2] Background

Historic Conditions of the Colorado River

The story of the Colorado River began six million years ago when the earliest geologic record of the river's flow is dated below the Grand Canyon (Longinotti). The uplifting of the Colorado Plateau and the Rockies created the source water and elevation change that sent water from northeast to southwest. The water worked its way down toward the Gulf of California, its force eroding a series of basins that carved its channel the way we know it today. The Colorado has been running its current route for about 5.3 million years (Spencer and Pearthree 1-4).

To put human development of the Colorado River in context, bipedalism of our ancestors appeared 4 to 6 million years ago, about the same time as the birth of the Colorado. Modern humans evolved about 200,000 years ago and the development of symbolic language occurred about 50,000 years ago ("Human evolution"). Based on this evidence, the story of humans as we know them today only came into being when the Colorado River was already over 5 million years old. The large-impact, ecosystem-altering effect humans have had on the river in the last century have only taken place in the last 1/60,000 of the river's history.

Before the development in the West that reshaped entire waterways of the Colorado River and its tributaries, the river ran hard and red with sediment in the spring and summer runoff months and would slow to a fraction of those flows in fall and wintertime. The Colorado boasts the highest proportion of endemic fish populations (fish found in no other river system) in North America (Adler 2007). The Humpback Chub and Pikeminnow, to name two, flourished in the relatively warm, murky waters, migrating up

and down the river's length to reproduce and hunt for food. The river's edges were lined with willows and cottonwoods that provided excellent habitat for migrating and sedentary birds. Beavers were innumerable, their wooden dams in mellow stretches of river creating ponds that provided nursery habitat for countless species. The Colorado was a riparian ribbon of life wending through the arid landscape of the Southwest.

As the river approached the Gulf of California, it fanned out across an expanse of 2 million acres, carrying rich sediments and nutrients that supported up to 400 species of plants (Adler 2007). This landscape is called a river delta, which is defined as the geographic region of a river where the moving water flows into ocean water, in this case, the Sea of Cortez. The mixing of the two bodies slows the river water, which deposits the sediment it carries, forming an expanse of relatively level sandy soil where brackish and freshwater habitats mingle.

Aldo Leopold visited the Colorado River Delta in 1922 and saw dozens of bird species and many mammals including deer, bobcat, raccoon and the elusive jaguar. The richness of these waters also brought richness to the Gulf (Adler 2007). Shrimp, and mollusk species were abundant. A large sea bass called the *Totoaba* reached the size of a tall man ("Totoaba"). The smallest porpoise in the world called the *Vaquita* was shorter than the average man ("Vaquita"). A tribe who call themselves the Cucupá – "people of the river" – have lived along the lower part of the Colorado River and the delta for at least a thousand years (Postel 2012). They lived off the variation of the river's flow by planting crops after the spring floods, and made the most of the richness of the delta system by hunting and fishing for protein.

Human habitation in the watershed of the Colorado River is nothing new. There are records of human inhabitants in the Grand Canyon that date back to the most recent Ice Age about 13,000 years ago (Biggs 2010). The Hohokam people lived in the Sonoran Desert of central Arizona between 600 and 1450 A.D. They constructed over 125 miles of canals to direct water from the Salt River, a tributary of the Colorado River, for farming thousands of acres that supported large, complex communities (Bates et al.).

The Western Migration in the United States

Starting with the United States' purchase of the Louisiana Territory from Napoleonic France in 1803, the historic way of the West and the Colorado River would be greatly altered. The Louisiana Territory contained most of the land we know in the U.S. that exists between the Mississippi River and the Rocky Mountains, except for the Spanish and, later, Mexican territory that made up the current southwestern states ("This Day in History: Louisiana Purchase Concluded").

With the acquisition of this enormous frontier, a migration west began as a trickle with government-sponsored expeditions like that of Lewis and Clark. Mountain men came into the Colorado River area to trap and collect beaver pelts for profit. John Wesley Powell and his crew explored the Grand River (the former name of the Colorado River) and the mountains and plateaus to better understand the vast, arid, land that was uncharted by whites. The Western migration accelerated because of wet years on the plains in the late 1800s that attracted people who believed the advertised idea that "rain follows the plow" (Reisner 1993). In 1869 the Union and Central Pacific Railroads met at Promontory Point, Utah, connecting the Pacific and Atlantic Oceans.

With the Homestead Act of 1862 and the advent of trains crossing the entire continent, settlement of the West explored further and further into the frontier until there was no "frontier" remaining (Reisner 1993). This idea is based on historian Frederick Jackson Turner's finding that the 1890 consensus of the Western population had increased to a density of at least two residents per square mile. In his view, this was a high enough concentration of people that the land could no longer qualify as largely uncharted. While this is disputed, 1890 is still considered a landmark date for Westward settlement (Bates et al. 1993).

The problematic issue with the migration west of European Americans was the climatic precedent east of the Hundredth Meridian, the geographic line that cuts north/south through the Midwest states that span from North Dakota to Texas. In that part of the country rain falls year-round and water is relatively abundant, which instilled high expectations of crop production. As you travel west of the Hundredth Meridian, rainfall rates decrease and water is generally more scarce. Farmers on their 160-acre plots specified by the Homestead Act tried to farm relying on rain, but because of scarcity, what water there was in the West was soon in high demand from settlers needing to irrigate farmland.

Not only was the climate dry for crops, but the Colorado River was unpredictable in its variation. Large spring runoffs contrasted with low flows for a majority of the year made it difficult for people to have a consistent agricultural lifestyle. Citizens called upon the Federal government to ensure that the way of life promised by the Homestead Act would be possible by controlling floods and providing water year round. The Reclamation Act was signed in 1902 for the purpose of "reclaiming" the desert by

redirecting water for human uses. In 1907, the Reclamation Service received its own bureau within the Federal Government ("The Bureau of Reclamation: A Brief History"). In 1928 the construction of Hoover Dam was authorized and large federal funds were directed into the Bureau. For the next five decades "reclamation" of scarce water supply was in full force.

The Law of the River

There are a number of policies governing the rights and distribution of the waters of the Colorado River. All of these policies combined form the Law of the River. One of the first established regulations around river water use is the law of prior appropriation, established and followed in Colorado and most of the West ("Water Information Program"). Basically, prior appropriation goes by the saying, "first in time, first in right." In other words, whoever claims water rights first gets to use their water rights first, but the users must put the water to "beneficial use," a productive purpose of human benefit, to maintain a claim to their water right. Latecomers must wait to use water until the senior rights holders have used their allotted water. During drought years junior water rights holders may not get any of their allotted water. This policy follows a "use it or lose it" mentality, meaning that senior rights holders must use their entire allotted water amount every year for fear of losing their right to it. This can lead to overuse of instream flow and loss for junior users.

Before the Bureau of Reclamation went into high gear, an overarching policy called the Colorado River Compact was negotiated in 1922 between the seven Colorado River basin states to legally allocate the waters of the river so no one state could take

more than their allotted share. According to the compact, the upper basin states (Colorado, Wyoming, Utah, New Mexico) are required to annually deliver 7.5 million acre feet (maf) to the lower basin states (Nevada, California, Arizona) (See Figure 1). An acre foot is a little more than 325,851 gallons, enough water to supply the household of a family of four for one year (Ketcham 53-63). The Compact did not include the Native Americans who live in the seven-states region. This is a violation of the 1908 Winters Doctrine that outweighs prior appropriation laws in favor of the water needs of Native Americans on federally reserved lands (Longo). Also excluded from the Compact was Mexico, which is home to the delta habitat ("Law of the River").

It wasn't until 1944, when a treaty between the United States and Mexico was signed, that Mexico was legally allotted water under the Law of the River. The treaty promised Mexico1.5 maf annually. A few decades later the U.S. promised to manage the quality of water that was delivered to Mexico by reducing salinity and other pollutants in Minute 242 of the International Boundary and Water Commission in 1973 and in the Colorado River Basin Salinity Control Act of 1974 ("History of the International Boundary and Water Commission").

Water to Mexico was not included in the Law of the River for more than twenty years after its establishment in 1922. The quality of that water was not addressed until thirty years after Mexico's inclusion in water distribution laws in 1944. Based on these facts, it is apparent why the environmental needs of the Colorado River and delta have been neglected. The political boundary with Mexico created an excuse for U.S. policymakers to temporarily exclude communities downriver who depend on the river, namely the Mexican people in Sonora and Baja California.

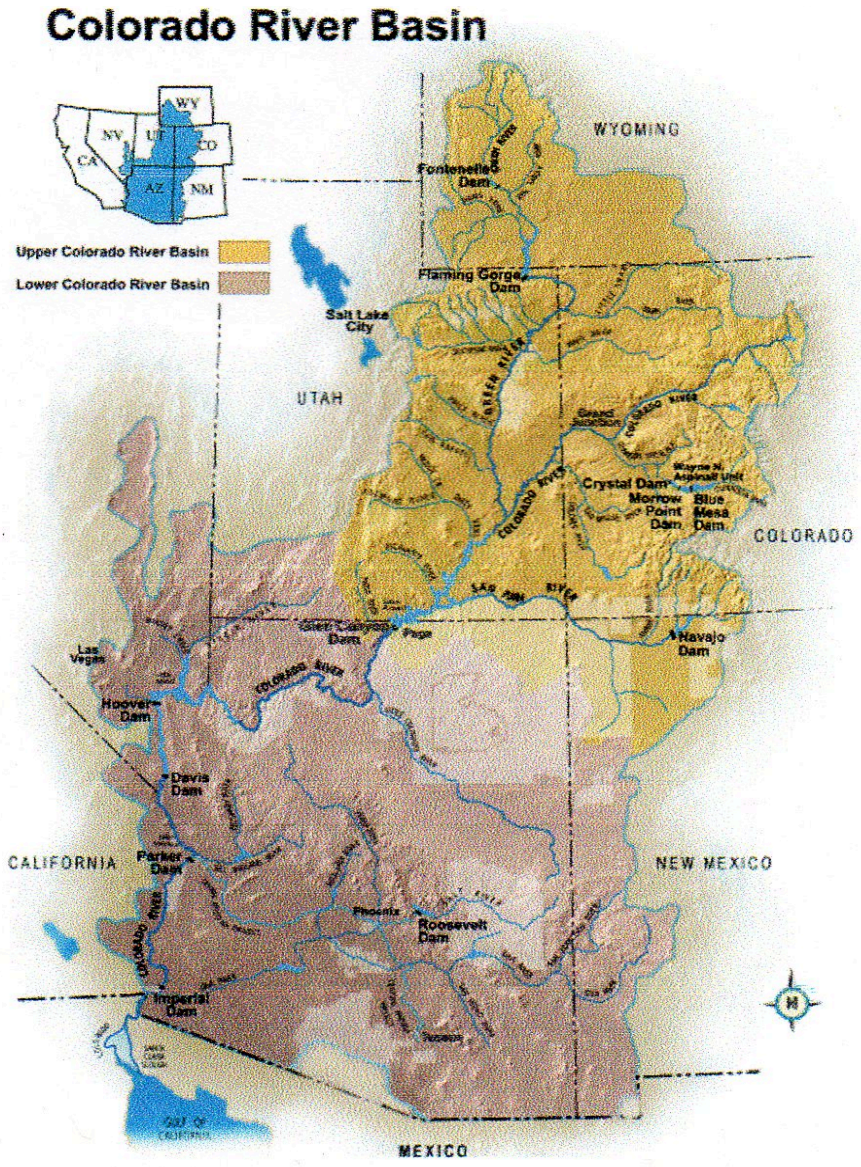

Figure 1. Colorado River Basin. *Source: U.S. Bureau of Reclamation*

The Construction of Large-Scale Dams

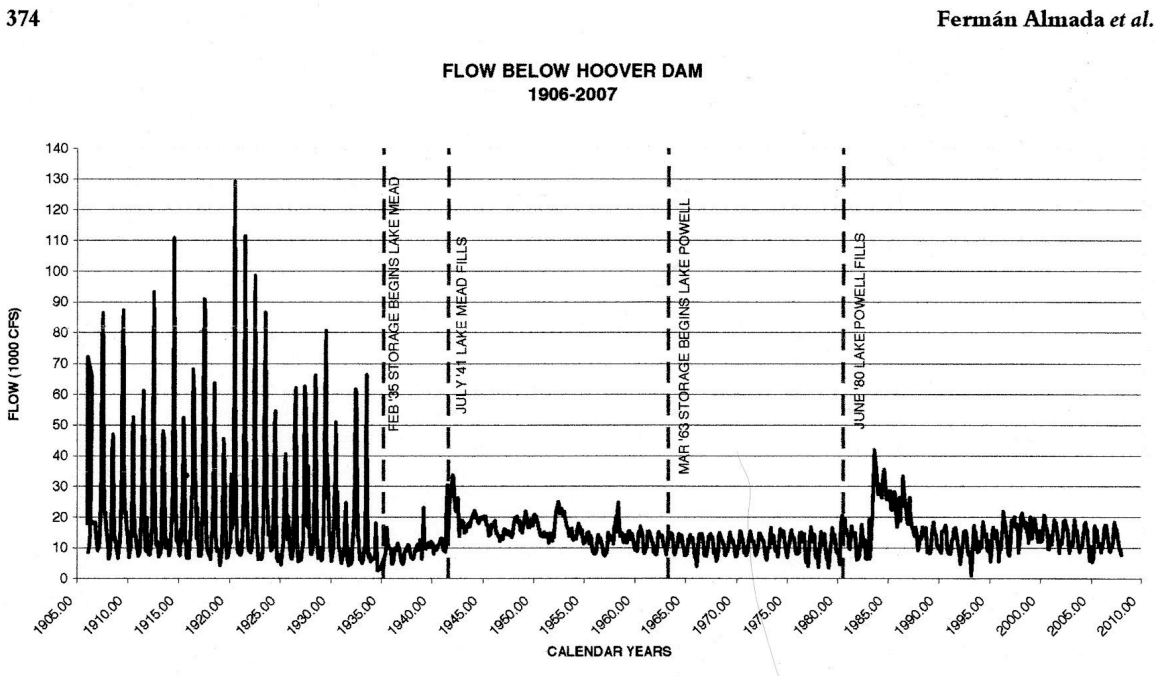

Figure 2. Flow of the Colorado River from the U.S to Mexico *Source: Almada et al. 2008*

The above graph (Figure 2) is one of the images that inspired my interest in researching the Colorado River Delta. On the left side you can see the record of natural flows into Mexico from 1906 to 1935. The river showed a lot of variation in flow with an annual burst of flooding in the spring months and very little flow in the winter months. With the completion of Hoover Dam in 1935 and the filling of Lake Mead in 1941, the first large-scale reservoir project on the Colorado River main-stem by the Bureau of Reclamation, the quantity and variation of water flowing to Mexico were dramatically diminished and homogenized. The completion of Glen Canyon Dam in 1963 and the filling of Lake Powell in 1980 further regulated river flow. Flows below Hoover Dam in

this graph remind me of a heart monitor flat-lining. The spike after Lake Powell filled was the result of heavy snowpack brought on by an El Niño cycle.

Today there are 200 dams on the Colorado River (Ketcham 53-63). Seventeen of those dams are large-scale with seven large ones on the main-stem down to the Mexican border. The benefits of these dams include storage and diversion of water for human purposes, including farming. Collectively, the dams in the basin have a storage capacity of 60 maf of water, four times the annual flow of the Colorado River. Hoover and Glen Canyon hold 50 maf of the total capacity. The dams also protect people from regular flooding. They provide water to over 30 million people and 3 million acres of farmland in the seven basin states and Mexico. Hydropower from the dams produces 11.5 billion kilowatt hours, which is enough to supply 13 million households a year. All of these factors have raised the standards of economy and lifestyle for people in the West (Adler 2007).

Impacts of Reclamation On Historic Riparian and Delta Conditions

While the dams and diversions have created some great benefits to people in the West, there have been negative impacts to the environment, which can have long-term negative impacts on the people too. One of the most serious impacts of the many dams along the river is the fragmentation of the riparian habitat, which changes water flows, reduces sediment and nutrient distribution, and harms habitat for native species, allowing take-over by invasive species.

Water that flows from below the dams is clear and cold, which is completely different from the conditions from which native fish evolved in the traditionally

sediment-laden, sun-exposed channel. People have introduced exotic fish species that outcompete and replace native fish. Now, four endemic fish species on the Colorado are endangered because of invasive species and changed conditions (Adler 2007).

Dams stop the continuous flow of sediment that creates sandbars in the river system, which many native species depend on. Dams also create constant and regular river flow that is drastically diminished from historic flows. Many native plant species including cottonwood and willow have lost their place along the riparian corridors because of a lack of annual flooding that brings water and nutrients to germinates seeds and replenish the groundwater for native species. The water moving through the river channel becomes increasingly saline as it goes south, collecting high concentrations of pollutants from agricultural runoff.

The lack of annual flooding and the increase in water salinity has allowed an invasive tree called tamarisk or salt cedar to encroach on native habitat. Tamarisk has a compounded effect because it outcompetes native vegetation such as cottonwood and willow, which shrinks the historic diversity of the ecosystem. This, thereby, reduces the preferred habitat for sedentary and migratory birds and other species, harming their survival.

All of these changes have reverberated down to the delta. The wetlands and riparian habitat of the delta cover about 150,000 acres compared to a former 2 million acres, a more than 90% decrease in extent (Adler 2007). Most of the water it receives is highly saline. The largest portion of intact revitalized wetland in the delta, the Cienega (Wetland) de Santa Clara, a 16,000-acre cattail marsh, is fed by brackish agricultural runoff from the Wellton/Mohawk irrigation district in Arizona.

The Gulf of California has become an inverse estuary, meaning that the sea is more saline closer to the delta (Glenn et al. 2001). The lack of fresh water to the gulf has caused a severe decline in shrimp populations, hardly enough to sustain local subsistence lifestyles of the Mexican people in Baja and Sonora. The *vaquita* porpoise now only numbers in the hundreds and is listed as endangered. The *totoaba* fish is commercially extinct, meaning that fishermen cannot catch enough of the fish to earn a profit. The Cucupá people only number a few hundred today, when records indicate that four hundred years ago their population numbered around five thousand. They had to relocate from their original hometown when the redirection of water in canals during the El Niño floods of the early 1980s washed them out (Postel).

While the El Niño floods were destructive for the Cucupá in the short run, for the long run these large floods will do them well, for the delta itself was renewed. The extra water helped to restore a large portion of the 150,000-acre extent of habitat around the waterways (Jenkins 2007). This rehabilitation of life in what was considered a "dead" habitat brought a lot of new interest from scientists and environmentalists to the restoration of the delta. The habitat is not necessarily dead and impossible to restore. It is just dormant awaiting water. Edward P. Glenn et al. (2001) found in the Science Citation Index that from 1955 to 1989 there were 5 publications about the delta, from 1990 to 1997 there were 10 publications, and during the four years between 1998 to 2001 the number of publications regarding the delta had more than doubled to 23. This demonstrates a mounting awareness and concern for this biome.

Based on the dramatically negative historical changes to the habitats and species of the Colorado River Delta, it is imperative that the United States and Mexican

governments invest in restoration of these areas and regulate river uses for that purpose. There is hope for the delta with increasing awareness and the potential for restoration and maintenance from periodic floods and increasingly holistic management by these governments and by non-governmental organizations. A recent focus on restoration in the delta is Minute 319, a 2012 amendment to the 1944 Colorado River water Treaty between Mexico and the United States. I will discuss Minute 319 among other legislation in more detail in the fourth chapter of this thesis.

In this chapter I discussed the historical conditions of the Colorado River and some of the early peoples who lived and died in this watershed. With the movement west of new settlers and the federal investment in water development, the river was profoundly changed. Some of these changes helped people to prosper and multiply in the West, but many of these changes caused degradation of the river ecosystem from modifications in river flow brought on by dams. In the next chapter I talk about the cultural imperative that drove the water development in the West established in the past century.

[3] The Mindset of Progress With Dominion Over Resources

Contributions to the Dominion Paradigm

There are three concepts I am focusing on that contribute to the paradigm of human dominion over resources. The first is the Christian belief that humans were made separate from nature. The second is the paradigm of linear systems thinking, which sees a system as made up of parts that can be separated and put back together. The third is the capitalist economic drive that values individual accumulation of wealth using natural resources as a means to that end.

Christianity

According to Lynn White Jr. (1974), the Christian perception of the world "not only established a dualism of man and nature but also insisted that it is God's will that man exploit nature for his proper ends." In the Christian ideology "daily habits of action are dominated by an implicit faith in perpetual progress (White 1974)." This religious imperative largely drove the east to west movement and land development by European Americans in the 1800s.

In the 1500s the Spanish came to the Western region of the United States from the South in Mexico. They intended to find gold and convert the Indians to Christianity. To populate the West, the Spanish brought water intensive crops such as wheat, barley, apples, and apricots. Sarah F. Bates et al. (1993) quote Michael Meyer: The Spanish "saw the land as an environment to be changed and dominated rather than to be adapted to." Their religious and cultural ideals disregarded the adaptations of native species and habitats to the arid environment of the West.

Linear Systems Thinking

René Descartes is considered one of the founders of linear systems thinking. In the 1600s his study of machines, notably clocks, concluded that systems are made up of many components that add up to a whole. He stated that components interact linearly, meaning that there is a sequence of interaction among parts that leads to a predictable outcome. He perceived that removing or adding one part will only remove or add as much to that system as that one part contributes. This is known as reductionism, a perception that leads people to believe that components of a whole only interact in a linear fashion and should be understood separately to understand the system as a whole (Wessels, 2013).

If you think this way, it makes sense to build a dam in a sandstone canyon on a river to store water for the needs of the human system. But, over time, the changing of the system proves to have a non-linear response. Silt builds up in the reservoir, reducing its storage capacity. The surface area of the reservoir allows for a lot of evaporation every year. The porous walls of the sandstone canyon absorb significant amounts of water. As time passes, the reservoir as a cog in a machine is no longer behaving linearly. It is losing water in response to the many interactions of a complex system. This is the downfall of linear systems thinking.

Capitalism

Within the capitalist mindset is the linear thinking that economic growth is a constant and that individuals have the right to accumulate their own wealth. Also present is the Christian mindset that people are separate from their resources. This combination of ideas lead people to believe that there is no connection between the well-being of

natural systems and themselves. Therefore, people don't question the extraction and modification of natural resources for the sake of increasing wealth and economic growth. If economic growth and personal gain are the main goal, the health of the system as a whole is not taken into account until people feel the negative impacts to the system following long-term modification.

Within this mindset, the Progressive era of the early 20th century birthed the concept of "conservation." Linear thinking saw floodwater in a Western river as "wasteful" because large amounts of the resource flowed downstream when it could instead be "conserved" for people that need it year-round rather than a few weeks in the spring (Hays 1959).

Proponents of the conservation movement such as Theodore Roosevelt saw resources as a means for economic growth. It was his goal to categorize and establish government ownership of these resources for the many purposes they could potentially serve for human benefit. Land was categorized for mining resources, for timber extraction, and for water storage among other purposes. The progressive movement idealized efficiency in public affairs, which meant speeding up and simplifying legal processes. To be efficient, policy makers advocated the "public management of the nations streams" to prevent decisions from becoming bogged down in bureaucratic procedures. They also promoted utilizing "the latest scientific knowledge" in a "highly organized, centrally planned and directed social organization to meet the complex world with efficiency and purpose (Hays 1959)."

The Bureau of Reclamation was created in this atmosphere of progress based on goals to develop the United States in a manner that was scientific, efficient and forward

thinking while also preserving agrarian values. Roosevelt regarded both these ideals as important to facilitate on a national level. He believed that promoting agriculture as a means for Americans to provide for themselves was the way to distribute wealth and keep the economy vital. Based on the underpinnings of Christianity, linear systems thinking, and capitalism, the Bureau of Reclamation utilized the sciences and engineering to store massive amounts of water for the purpose of agricultural lifestyles in the West.

Effects of Dominion Over Western Water

Based on the conservation mandate of progress it is not difficult to understand why the United States government through the Bureau of Reclamation made so much effort to try to modify the West into a land like the East. Redirect the "wasted" river water to make the desert fruitful for citizens. In the long run, though, this type of thinking is doing our environment in, which does not bode well for all of us in the West. For over a century the West has been dammed and transformed as much as possible. We are seeing and feeling the delayed effects of such intense transformation.

Economically, the dam building has not been largely profitable. The Bureau of Reclamation spent about $7 billion to fund the great water projects in the West. Only about $1 billion of those dollars have been paid back from agricultural profit (MacDonnell 1999). No economist would argue that as good business. Socially, this water system, which was originally established with the intent to serve family farms, has mostly benefitted large centralized corporations who have made great profits while exploiting migrant workers and artificially cheap water (Bates et al. 1993). What's more, money devoted to Western reclamation created competition between Western and Eastern

farmers. Because reclamation was subsidized, water in the West was cheaper than in the East, so over time Eastern farmers were outcompeted leading to abandonment of at least 5 to 18 million acres of farmland (Worster 1985).

Environmentally, the delta is but one example of much deterioration in the quality of once flourishing places. The damming of the Columbia River, for example, has all but eliminated the salmon upon which the Native people historically based their economy and which are still in high demand today. Much time and money are invested in human effort helping the salmon up the rivers when it could be more feasible, economically and environmentally, to implement river flow below dams that mimic natural flow patterns and also invest in fish ladders to help salmon get themselves up the river to restore their populations (MacDonnell 1999).

Colorado River Compact “decisions were made during the 1920s, which was an extremely wet decade. Allocations were based on an estimated 18 million acre feet of water, when, in fact, the river yields only 15 million acre feet of water on average." (Osvel Hinojosa Huerta). Records show that the twentieth century was one of the three wettest centuries in the past thirteen centuries. The 1900s saw an average flow that was 15% higher than the average of last 1,300 years.

Today, the West is increasingly feeling the effects of climate change, which is causing greater extremes in the variation of vital snowpack that feeds most of the rivers in this part of the world. The Colorado River is currently in its fourteenth year of drought. Warming from climate change is predicted to reduce precipitation, causing Colorado River flow to decline by 5 -35% (Wines). Based on this information we cannot assume

how much water the river will produce. It is in our best interest to conserve water as much as possible in preparation for the potential of less water in the future.

Both Lake Mead and Powell are at about 50% capacity as of 2013. The maximum water elevation for Lake Mead is 1,221 feet while its current elevation is 1,106 feet (Lauer 2013). In 2014, the elevation is expected to drop twenty more feet. At 1,075 feet, rationing begins. The first Las Vegas water intake is left high and dry at 1,050 feet and the second intake goes dry at 1,000 feet (Wines). Many believe that Lake Powell will never be full again. Lake Powell reached full pool in 1980. The 2002 drought saw some of the reservoir's lowest levels, which have never fully recovered. This shows that the ambitious idea of Glen Canyon Dam as a large back-up storage basin was not as fruitful as anticipated considering the less-than 30-year lifespan of the reservoir at full volume. Lake Mead is no better off. This is evidence that even a very expensive, elaborate and radical system of river storage and diversion cannot necessarily sustain itself over time. If this is so, why not invest in sustaining the fundamental resource of the river in its natural state if the investment in elaborate and expensive river modification is not proving sustainable?

The supply of water in the West is exceeded by its demand. That supply is shrinking as weather patterns reduce snowpack while demand increases due to consumptive agricultural water use and growing populations in cities like Phoenix, Las Vegas and Los Angeles. U.S. agriculture accounts for 80 to 90 percent of the Nation's consumptive water use. Consumptive use is water lost to the environment by evaporation, crop transpiration, or incorporation into products. Seventeen Western states make up about 75% of U.S. irrigated agriculture. (Schaible, and Aillery). In 2008, The Western

states consumed 74 maf of water, with 52% coming from surface sources and the other 48% coming from groundwater sources.

There are many stakeholders besides agriculture that draw from the agricultural sector for water supplementation, such as urban and industrial demands, environmental and recreational flows, and Native American water rights (Schaible, and Aillery). Los Angeles and Phoenix are in the top ten most populous cities in the United States as of 2011 (Mackun, and Wilson 1-11). If we are to sustain such large and growing population centers, water will need to be redirected from agricultural uses.

There is a silver lining to the increasing demand for this shrinking supply. While population has increased markedly in the West for the past few decades, the use of water has leveled off and even decreased. Improvements in technology and conservation measures can work to curb water use. Population density is expected to increase in the next few decades. If we are to have water available for human use, let alone environmental purposes for the sake of watershed health, these technological and conservation efforts must be our top priority.

Because agriculture makes up 80 to 90% of consumptive water use, investment in water conservation efforts in this sector should be top priority. As of 2008 "at least half of U.S. irrigated acreage is watered with less efficient traditional techniques (Schaible, and Aillery)." With increasing improvement in irrigation technologies, the challenge is to provide incentive to farmers to invest in the technology. In 2008, 0nly about 10% of farmers reported investing in these technologies with the help of public financial assistance programs. But, from 2003 to 2008, investment in improved irrigation technology by farmers increased 92% (Schaible, and Aillery). This shows a growing

commitment to water-saving effort. It is imperative that farmers continue to invest in technologies and behaviors that mitigate the consumption of water to reduce the potential of conflict between the agricultural sector and other stakeholders. Government incentives and financial aid programs could help farmers afford to improve their agricultural practices. In the next chapter I discuss ways that people are working to share water among varied stakeholders such as ecosystem needs and urban and agricultural needs.

[4] The Mindset of Progress With Sustainability of Resources

Complex Systems Thinking

Unlike the concept of a linear system, complex systems are unpredictable and each part of the system interacts with every other part in dynamic ways. You cannot look exclusively at individual components to understand complex systems. Rather, observing the interactions of the different parts of the system one can find patterns of behavior that are consistent. From these consistent patterns, we can adjust our interactions with the system to change its behavior. Interaction between different components creates results that cannot readily be predicted by studying each component alone (Wessels 2013). *The whole is greater than the sum of its parts* (Meadows 2008).

Our actions can create dramatic reactions of behavior in a system. It is through this lens of understanding that we can change our perception of our natural recourses and progress in a way that considers the possible consequences of our actions as they affect our environment and, ultimately, ourselves. All of the systems we depend upon, such as ecosystems, hydrologic systems, and socioeconomic systems, are complex. Complex systems thinking rather than linear thinking is necessary to consider the way a system behaves and sustains itself. This type of thinking is key to the sustainability paradigm.

The Changing Water Paradigm

Peter H. Gleick (2000) defines the changing water paradigm as a shift from finding new water by building more dams or facilitating more transfers across basins to, instead, using water more efficiently by increasing productivity for each unit of water.

This changing paradigm is a product of people's growing understanding of the limits to our hydrologic system.

An example of the changing water paradigm can be seen with industrial water uses having dropped 40% since 1970 while productivity from those industries continues to rise. Irrigation and land preparation technologies that I discuss in more detail on page 30 have been found to increase crop productivity of water inputs almost 100 percent ("Agricultural Water Conservation Practices"). Water usage was on the rise until the 1980s when it leveled off and has remained stable while productivity from that water continues to increase. This demonstrates that improved technology can maintain economic prosperity with a fixed water supply (Gleick, 2000).

According to Sarah F. Bates et al. (1993), the mindset of dam building and water use for industrial purposes such as mining and agriculture has only been prevalent for a few generations of the countless generations of people in the West. Below are some examples of agricultural behaviors before the industrial revolution that can and still are being applied today.

The Spanish who came to the West established a water system of *acequias* (community ditches) where water belonged to everyone in the community and maintenance of water infrastructure was shared by all water users. During surplus years, people used as much water as they needed. During dry years, people reduced their water use accordingly (Bates et al. 1993).

The Mormons "planned towns around shared water resources" and "placed great emphasis on the community model of water development." The Tohono O'odham people of the central Sonoran desert practiced farming where "their crops required no diversions

from streams, no pumping of groundwater, and almost no structures." Their cultivation of drought-tolerant crops and use of natural crop management of weeds and insects sustained "food production for centuries without destroying the desert soils (Bates et al. 1993)." Because water was relatively scarce, group efforts and agreements united around this resource to ensure its availability to the community. We can learn from these community and local environment-based practices to improve industrial-based agricultural practices in the West.

New Paradigm Behaviors and Technologies

Postel and Richter (2003) discuss a phenomenon called the "tyranny of small decisions." This is defined as the "large cumulative impact caused by numerous small river diversions or hydrologic alterations that individually would not raise much concern." The tyranny of small decisions can be applied to a more positive angle on human interactions with resources. I would call it the "community of small decisions." If every person makes a little effort to practice stewardship of their local resources, these efforts could have a compounded positive effect on the health of ecosystems and people. If everyone is taking care of his or her local resources, then all the resources will be taken care of. Rather than telling people they make little decisions that have a negative cumulative impact, I think we can change minds and behaviors by showing people they are capable of making little decisions that have a *positive* cumulative impact.

To show people how to make positive decisions in their watersheds it is important for individuals to understand where their water comes from. This is a good first step toward understanding how to change water consumption. If you know what watersheds

and infrastructure you depend on for your water, you can have a more personal connection with that water, which can lead to more active stewardship. Knowing that my water comes from the Mancos watershed, I can relate the snowpack I see in the nearby mountains to the water that comes out of my faucet. When I can understand the source of my water, my stewardship behaviors focus on the watershed I depend on.

Depending on the type of use each individual engages in, there are options for water-saving technologies such as low-flow toilets and laundry machines, xeriscaping, efficient energy-using appliances like refrigerators, and using low to no-water energy from solar panels and wind turbines. Using energy more efficiently is helpful for conserving water. "For a nuclear or coal plant to generate the electricity for one load of hot-water laundry (using electric appliances) 3-10 times more water must be withdrawn at the plant than is used to wash clothes ("The Energy Water Collision: Ten Things You Should Know")."

For the agricultural sector there are many technologies that can help increase productivity of water input and reduce inputs of water needed. Laser leveling of fields can make the land perfectly level so that water gets evenly distributed and fully utilized by crops. An irrigation technology called Low Elevation Spray Application (LESA) releases streams of water about a foot off the ground rather than spraying water about seven feet off the ground like traditional sprinkler systems. The LESA system reduces water loss due to evaporation and wind-drift by applying water to a more concentrated area and closer to the ground. This system also uses at least 30% less energy input than traditional sprinkler systems ("Agricultural Water Conservation Practices").

Subsurface drip irrigation (SDI) is another method of irrigation that is at least 90% efficient. The system delivers water directly to plant roots. In Lubbock, Texas, a farmer who switched to SDI irrigation from traditional sprinkler irrigation almost doubled his cotton yields from 650 pounds per acre to 1,200 pounds per acre with the same amount of water input. The above methods and technologies are examples of ways to increase agricultural productivity and conserve water at the same time ("Agricultural Water Conservation Practices").

Below is a statement made by the Metropolitan Water District of Southern California in their Annual Progress Report to the State Legislature in 2012. "Launched in 2008, SoCal Water$mart provides rebates to residential customers to reduce the purchase cost of water- efficient products. Metropolitan projects to save about 1,520 acre-feet of water annually from 41,000 rebates issued through the region-wide residential program in fiscal year 2011/12." This type of incentive-based method for changing behavior to conserve water is a great tool that can be used in the entire Colorado River basin.

An informed collective of water users has the power to make profound shifts in how we consume. Sarah F. Bates et al. (1993) discuss an example of how an informed public may voluntarily pursue conservation measures. Their anecdote tells of Los Angeles officials instigating mostly voluntary water conservation measures a few years into a dry spell. Under these measures, Los Angeles citizens conserved more water than the conservation goals specified once they knew the problem and what to do to improve it. "With the benefit of knowledge and understanding of the consequences, it appears that people are willing to modify their own actions to do what is better for the larger community, even if it causes them some discomfort, expense, or problems (Bates et al.

1993).” If people are inclined to voluntarily change their consumption habits when informed, collective conservation efforts could be even more robust with government incentives like the SoCal Water$mart program.

The above examples of water conservation efforts and technologies are evidence of humans progressing toward sustainable use of our resources. The application of technologies and education to reduce water consumption and increase its productivity demonstrates the benefits of human ingenuity in development. We have so much potential to push our progress to the realm of zero waste and 100% productivity if we continue on this path of working together to sustain our environment and ourselves.

Strategies for Watershed Restoration

While the modern West has been characterized by development that sees water resources as something to be utilized for human priorities, large communities in South Africa and Australia are taking a different view. Because they did not develop their watersheds heavily until later in the game, these communities have had the advantage of learning from the difficulties of completed large-scale water development when it comes to finding a balance between humans and the environment (Postel and Richter 2003).

Sandra Postel and Brian Richter (2003) discuss two means of working toward river restoration based on complex systems thinking by implementing natural flow regimes: “holistic methodologies” and “adaptive management.” Holistic methodologies are river flow restoration and management approaches that consider the entire ecosystem as a whole as well the human needs of that water. Traditional flow prescriptions would cater to specific species such as a key native fish, but that kind of strategy tends to

exclude the needs of the rest of the ecosystem. Scientists and water managers tailor holistic methodologies to each specific river system and the people depending on that system to gain overall health of the river.

Adaptive management stems from the predicament of needing to restore flows to reach a certain level of river health without full knowledge of how much water will be enough to restore that health. Hence, scientists and water managers need to "learn by doing" and try to be flexible by adapting their restoration techniques based on results found in monitoring and managing flow regimes. Holistic methodologies and adaptive management are understood as necessary to restore and improve river conditions that have been severely altered (Postle & Richter 2003).

An image of the Colorado River hydrograph (a visual plot of river flow rates over a period of time; refer to Figure 2 on page 11) shows an annual pattern of high flows in the spring and early summer, periodic flooding during the summer months, low flows in late summer and fall and then a relatively consistent base flow in the winter. In different years there may be larger floods or smaller spring runoffs, but over time the variation creates a relative consistency of pattern that riparian species have adapted to over millennia. There are plants that begin to release seeds with the receding of the spring runoff so they can germinate in freshly wet sediment-rich soil. Many fish lay their eggs before the spring runoff so that the young can develop before floods and hatch during high water, which creates shallow nutrient-rich habitat that helps the young grow strong before heading out into the main currents (Postel & Richter 2003).

A river's variation in flow is essential to its residents' way of life. Dams create a whole new flow regime. As you can see from Figure 2 on page 11, after the construction

of a dam, the river's flow not only is severely decreased, but the flow is also homogenized. Low flows are normal in rivers for certain parts of the year, but homogenized flows create stagnant conditions of low oxygen, high concentrations of pollutants, and build up of debris in gravel beds. Flooding naturally flushes out the riverbed and brings in new sediment. Dams completely stop up sediment flushing and deposition, both necessary parts of river lifecycles for many species. (Postel & Richter 2003)

Postel and Richter tell us that in South Africa, scientists and politicians worked together to establish a new way to manage water resources. First of all they created a priority list of water uses. Human subsistence needs are met first for drinking water, cooking, and sanitation, among other purposes. Instream flows are allocated next to sustain ecosystem health and function for the natural services they provide to people. Agricultural and industrial sectors can only withdraw water if the first two priorities have been met. Postel and Richter also found that to sustain river health or to restore a river there are several conditions:

1) The human induced flow regime should mimic the natural flow regime of the affected river
2) The river's natural perenniality should be maintained
3) Most water should be harvested during wet months
4) Floods should be present in the system
5) The first flood of the wet season should be allowed to flow naturally with no human modification

Postel and Richter discuss an example of adaptive management techniques used in the Colorado River watershed for ecosystem restoration. The Colorado Pikeminnow, a minnow that can reach 1.3 meters in length, evolved with the annual floods of the Colorado River. It would migrate upstream to spawn and lay its eggs in alcoves below boulders. The young would hatch a couple weeks later while waters were still high enough to provide shallow warm pool nurseries for the Pikeminnnow to grow. This fish dominated the food chain of the Colorado River for millennia.

In the 1900s, dams along the Colorado River altered the annual floods to which the Pikeminnow had adapted. These dams also fragmented the river channel, isolating Pikeminnow populations and preventing the species from migrating throughout the watershed. In the 1967 the fish was formally listed as endangered (Postel & Richter 2003).

"In 1992, the U.S. Fish and Wildlife Service issued a Biological Opinion under the federal Endangered Species Act, concluding that [homogenized low flow] operations [below] Flaming Gorge Dam jeopardized the continued existence of pikeminnow (Postel & Richter 2003)." The Biological Opinion included water management and flow recommendations of variable floods below Flaming Gorge Dam to restore fish populations in the Green River, the largest tributary of the Colorado River. The flow prescription was a groundbreaking effort for river science as it was developed by interdisciplinary scientists who were taking into account the needs of native species and the river ecosystem as a whole. The flow prescription included a five-year experimental period from 1992-1996 to test the flow recommendations. This was the beginning of an adaptive management program for the Green River.

From the experimental program it was found that a mix of large and small floods with very large floods every ten years are needed to restore pikeminnow populations. This type of flood regime mimics historic natural flows. As of 2003, the pikeminnow were responding favorably to the human induced flow variability (Postel & Richter 2003).

In the Colorado River Delta there are efforts underway to restore riparian and wetland habitat in a large-scale experiment that works along the lines of river restoration as Postel and Richter have discussed it. These efforts give hope to long-term future work sustaining habitat that re-creates historic delta conditions for native and migratory species.

Minutes 316 and 319: The New Paradigm in Action

In this section I discuss two amendments to the 1944 Colorado River Water Treaty between the United States and Mexico. These amendments are significant because both of them are designed to restore and maintain the Colorado River Delta region in a manner that considers this system as a cohesive whole. A shift of water priorities from agricultural and water storage needs to environmental needs is apparent in the negotiations.

Minute 316

Signed in 2010, Minute 316 is an agreement between the U.S. and Mexico to maintain flows to the Cienega de Santa Clara to sustain its habitat which is vital for endemic and migratory species. The story of the Cienega is a valuable example of the restoration potential of the delta region. A predecessor to Minute 316, Minute 242, was

signed in 1972 to manage salinity of river water flowing into Mexico because of downstream concentration of highly saline agricultural returns to the Colorado River. The Yuma Desalting Plant began construction on the border in the 1970s for desalinating water in the U.S. before delivering to Mexico. The plant's bypass drain for the brine from desalting was completed first to direct flows to the then-dry Santa Clara Slough located in the delta region in Sonora, Mexico (Carrillo-Guerrero et al. 84-92).

To reduce river salinity before the plant went online, agricultural runoff from the Wellton-Mohawk Irrigation District in the Gila River valley in Arizona was sent through the bypass drain to the Santa Clara Slough, rather than returned to the river. The influx of water to the Slough since the 1970s has inadvertently restored wetland habitat because the agricultural drainage brought to life a 16,000-acre cattail marsh. This marsh is home to the world's most significant populations of the endangered Yuma Clapper Rail bird and endemic Desert Pupfish, making this habitat integral to sustaining what remains of delta habitat and species. This wetland also supports 277 species of bird for at least a portion of their life (Carrillo-Guerrero et al. 84-92).

The Yuma Desalting Plant (YDP) was completed in 1992. Colorado River flows have been enough that the YDP has not been necessary, but with more drought years in the past decade, the plant may have to go online more often, which will take water away from the Cienega. This is the problem that Minute 316 addressed.

During a pilot run of the YDP in 2010-2011, the U.S., Mexico, and a group of Non-Governmental Organizations (NGOs) called the Colorado River Water Trust shared water delivery duties to the Cienega. The U.S. gave water from annual allocations that were released from Parker Dam. The Bureau of Reclamation is unable to store up flows

after they go through Parker Dam, so unused claims were sent to the Cienega. Mexico delivered water that could not be used because of infrastructure damage from a 7.2 magnitude earthquake in 2010. The Trust bought water rights from Mexicali farmers (Carrillo-Guerrero 84-92). “The Cienega de Santa Clara is an example of a wetland developing and thriving with agricultural drainage flows that are unsuitable for crops or human consumption (Carrillo-Guerrero 84-92). From this accidental wetland formation we can see that even brackish agricultural flows can restore life in the desert. Minute 316 gives legal support to sustaining this accidental wetland.

Minute 319

Minute 319 is the latest amendment to the 1944 United States - Mexican Water Treaty. Signed in 2012, the Treaty amendment is an agreement between the two nations addressing the timing and volume of Colorado River flows to Mexico, as well as water quality, continuing to address salinity of water that flows across the border. Objectives of 319 include allowing Mexico to store its water in Lake Mead while the country repairs waterways and infrastructure following the 2010 earthquake (Lauer 2013). Mexico will be allowed to store their water in that reservoir until their infrastructure is able to receive it. Also, the U.S. and Mexico will be more flexible with Colorado River water by sharing river drought and surplus flows, reducing and increasing the water allotments of each nation proportionately.

Finally, in this Minute, Colorado River water is legally allocated to the delta for environmental purposes. Because all the water in the river system is already allocated, water rights for the delta must be acquired through leasing or buying. The duty of water acquisition is divided among the United States, Mexico and three NGOs: The

Environmental Defense Fund (EDF), The Sonoran Institute of Arizona, and Pronatura of Mexico. This amendment is the biggest innovation in the U.S.-Mexico Treaty since its creation in 1944 because of its focus on creating agreements among the many stakeholders of the Colorado River for redirecting some water back to the main river channel and native habitat. Minute 319 calls for a five-year window from 2012 to 2017 to observe and record how water restoration works in the delta (Pitt).

The aforementioned three NGOs make up the Colorado River Delta Water Trust, "the first water bank in Mexico dedicated to acquiring water for environmental purposes (Postel 2013)." With funding from donations, the Trust is buying and leasing water rights from willing sellers in the Mexicali Valley. The Trust currently owns 5,000 acre-feet, which is enough water for irrigating good-quality habitat in the region. Their goal is to acquire 52,000 acre-feet for a year-round base flow, which is only about 3% of the 1.5 million acre feet allotted to the northern Mexican region (Pitt).

The EDF website summarizes their actions in the delta with this statement: "EDF is working with government agencies and conservation organizations in the United States and Mexico to provide 158,000 acre-feet of water for the delta over the next several years. With this small amount of water, approximately one percent of the river's annual flow, we hope to physically reconnect the Colorado River to the Gulf during a limited-duration 'pulse flow,' while also providing water year-round to support the restoration of 2,300 acres of forest and marsh habitat along a 70-mile stretch of river (Restoring the Colorado River Delta)." The EDF shows optimism, which I share, for the groundbreaking restoration and knowledge that can be achieved with a tiny portion of Colorado River flow.

March 23, 2014 saw a pulse flow release of 105,000 acre-feet to test the effects of recreating a miniature spring flood (Dibble) This replicates the natural flood patterns that historically occurred in the river with snowmelt acceleration in the warming of spring. Currently, scientists are observing the movements of the pulse flow as it moves through its dry riverbed, replenishing groundwater and germinating native seeds on its way to the Gulf.

There are three areas of healthy habitat concentration that NGOs are focusing on for delta restoration and maintenance in Mexico. The first is Las Arenitas, an artificial wetland formed from the effluent of a water treatment plant where cattail is being planted to filter water. The second is the Cila Tree Plantation where 20,000 native trees have been planted to reestablish habitat for native and migratory species. The third is the Ciénega de Santa Clara, the largest area in the Northern Mexican Sonoran Desert for birds and wetland habitat (Redford). Work in these areas involves removing nonnative species like tamarisk and replanting native trees like cottonwood and willow.

EDF is using pre-established irrigation canals to direct water toward these habitats where they dig ditches to further direct water toward areas of choice to enhance vegetation habitat (Pitt). To remove tamarisk, the Mexican government is paying local people to clear out the invasive trees. The Colorado River Delta Water Trust buys water from local farmers, which brings them immediate income. The water is put toward habitat restoration, bringing the land back to life in the local area, which brings the land back to life. The Trust also employs farmers for restoration work such as planting native willow and cottonwood seedlings and digging ditches for directing water. These governmental and non-governmental activities are beneficial for the people, the economy,

and the environment in the delta region (Postel 2013).

In an interview with Jennifer Pitt, Director of the Colorado River Project under the Environmental Defense Fund (2014), I learned that in the Mexicali Valley south of the border in Sonora only about 25% of water used in flood irrigation is absorbed by the cultivated plants. The rest of the water goes into the water table around the Colorado River waterway and the delta. This 75% return flow to groundwater supports native vegetation like cottonwood. A lot of native habitat can be sustained with groundwater while only having large pulse floods every few years to germinate native seeds and maintain the vegetation. In the 1990s when flows to the delta only occurred every few years, scientists gathered that even though floods were periodic, much vegetation could live on groundwater. Based on this information, the recommendations for floods every four or five years seem feasible to maintain delta habitat and to be tested once during this five-year period of flow experimentation and monitoring (Pitt).

Funded by the Mexican and U.S. governments, federal scientists from the United States and Mexico, as well as academics, graduate students, and non-profit conservation agencies are monitoring flows released for delta habitat restoration. Scientific observation will help us understand the benefits of base flows and pulse floods to the delta as well as give us a record of what is not successful that we can learn from in this large-scale experiment.

Another effort that is working alongside the governments and three NGOs discussed above is the Raise the River Foundation, a collaboration between the Nature Conservancy, the National Fish and Wildlife Foundation, and the Redford Center. Their goal is to raise $10 million by 2017 for purchasing water to fulfill the Trust agreement of

Minute 319. As you can see from this system, the main limitation to getting water to the delta is the ability to afford water rights, permanently or temporarily. This is because all the water in the Colorado River watershed is allocated out and spoken for. But agriculture uses by far the most water of any stakeholder, consuming up to 90% of allocated water (Ketcham 53-63). The only way to acquire water is to redirect allocations to environmental purposes through purchasing that water from farmers. Donations and government investments from the United States and Mexico are supporting this endeavor.

The efforts of Minutes 316 and 319 in the Colorado River Delta region are evidence of the sustainability mindset paradigm shift in action. These Minutes give priority to the delta habitat with the understanding that the health of the delta affects the health of the entire Colorado River system. As we work to shift the way we perceive our water resources, we can progress in a steadily more sustainable manner and continue to learn from our mistakes by working together to mitigate damage to our degraded resources.

[5] Conclusion

The Colorado River is one of the most heavily developed waterways in the world. Western development, with its underpinnings of dominion over resources, has been the main driver for building radical, large-scale water infrastructure that shapes the river today. People have increasingly reshaped, tapped into, dammed, diverted and over-allocated the river. "More water is exported from the Colorado River's 250,000 square-mile basin than from any other river basin in the world, and every drop of its average five trillion gallons of water is used each year (Lauer 2013)." The river advocacy group, *American Rivers,* designated the Colorado River as the most endangered American river of 2013 in order to raise awareness about the "outdated management" of the Colorado that has dramatically altered the entire watershed, affecting "recreation, water supply and wildlife habitat ("America's Most Endangered Rivers 2013")."

The Colorado River Delta is one of the major casualties of Western development. In the past two decades increasing observation and scientific recording of delta conditions are raising awareness about the plight of this habitat. New information gathered about delta restoration potential and educational outreach is fortifying efforts to evolve the mindset of development in the West from human dominion over our resources to human responsibility to maintain healthy resource systems. We are seeing the delta as part of and fundamental to the greater river system.

With the advent of Minute 319, the necessity of environmental flows in the delta region is given legal standing. This is a sign of the implementation of new paradigm priorities, which include the needs of the environment along with other stakeholders, and allows for implementation of water redistribution and conservation based on the needs of

all those stakeholders. Restoration of the Colorado River and its delta cannot be carried out by *only* a shift in perception of the watershed. The legal actions undertaken to dedicate water to the delta are absolutely necessary to put the paradigm shift into action. When action is taken it brings more people into the movement by raising awareness. Greater awareness can help create more widespread change of behavior in accordance with the natural patterns of our watershed and encompassing environment.

In his book *The Myth of Progress* (2013), Tom Wessels discusses the phenomenon of bifurcation in complex systems. Bifurcation is a sudden shift in paradigm following the building of a reinforcing feedback loop pattern in a system. Wessels uses the example of straws being added to a camel's back – a positive feedback of business as usual – until the final straw that breaks the camel's back – the bifurcation event. With growing awareness among citizens in the West, I believe we are at a tipping point in the shift of behavior around a mindset that considers the connectedness of the entire river system. I believe a new status quo will spread and inform the way we treat our Colorado River and its delta.

When I was about ten years old I had a dream about a village that celebrated its river. The river would flow during the day, but at night it would go bone dry, leaving a bed of sand. The people of the village brought baskets of gifts to the river every night. Looking into the river bed in my dream, I saw it was full of jewels, apples, and precious man-made objects. These gifts were a symbol of love for the river. In the morning, the river began to flow as a tiny trickle on top of the sand. Soon the water was raging and it carried away all the gifts in gratitude. When I think about the actions of Minute 319 returning the river flow to a dry channel, I always think of the love of my dream villagers

that invited the river back every day. Those dream villagers gave precious things to ensure the river's flow. Because people in the West are doing their part to ensure the flow of the Colorado River in the delta, my dream is a reality.

In the eleven-year period from 1990 to 2001 the number of scientific publications about the delta quadrupled. This was the beginning of the paradigm shift for the delta. Based on the graph below (Figure 3) you could call the authors of the first articles before 1990 the "innovators" of the awareness. People with growing awareness during the nineties could be called the "early adopters." Currently, with the event of the first intentional pulse flood release connecting the Colorado River to the Sea of Cortez, enough people are on-board and reporting these actions to place us in the "early majority phase." My intention with this thesis is to further expand the awareness of the innovation of Colorado River Delta restoration.

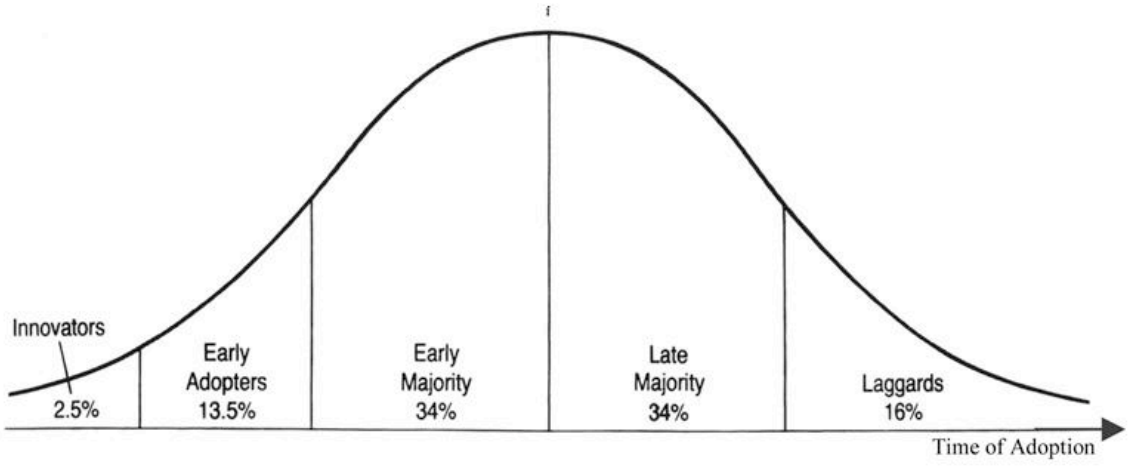

Figure 3. The Diffusion of Innovations Bell Curve *Source: "Diffusion of Innovations"*

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