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Water Development and Social Change in the Southwestern United States

An Interactive Qualifying Project

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Submitted by

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ABSTRACT

Until the mass construction of dams and water system planning along the Colorado River and its tributaries, the river was uncontrollable and made human survival nearly impossible. Indian cultures first populated this region but established communities high above or completely away from area known to flood and focused technological advances mainly in survival skills rather than military purposes. When the Spanish first began to explore the area, initially looking for untapped resources and chasing myths and legends of hidden treasures, they found that their highly regarded armadas could not navigate the waters of the Colorado and were unable to flourish under these harsh conditions lacking steady lines of supplies and trade. After the land was acquired by the United States, the erection of small dams and diversion canals only complicated matters by causing floods in new places while still unable to prevent them in where they typically occurred. Following the restructuring of the Bureau of Reclamation, big dams such as Hoover, Shasta, Bonneville, and Glen Canyon, and the systematic planning of the Colorado River Basin, the river was soon brought under control and the human population soon flourished in the desert. Once established in this unforgiving environment, social concerns began to shift toward the environment and the overall quality of life rather than survival at all costs.

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INTRODUCTION

The purpose of the research performed for this Interactive Qualifying Project, as part of the graduation requirements of Worcester Polytechnic Institute, is to provide fundamental information for the investigation of environmental trends in the region headed by Professor Theodore Crusberg in the Biology Department of WPI. To meet the requirements of WPI for this IQP, background information on the development of technology and how this has enabled humans to populate the hostile environment of the area surrounding the Colorado River System will be examined as well.

The massive effort that was necessary to convert the Colorado River from destructive and uncontrollable flooding, inconsistent flow patterns and unpredictable changes in course to becoming the lifeline for over 30 million people in this arid climate was admirable to say the least. While impressive, numbers fail to tell the entire story of what made the Colorado River so mysterious and unique among other rivers. The distinguishing feature of the Colorado is not the actual volume of water that is carried as it is actually less than 1/30th of the Mississippi River. What makes this river so unique is the system of canyons and ravines that has been carved by it over millions of years.

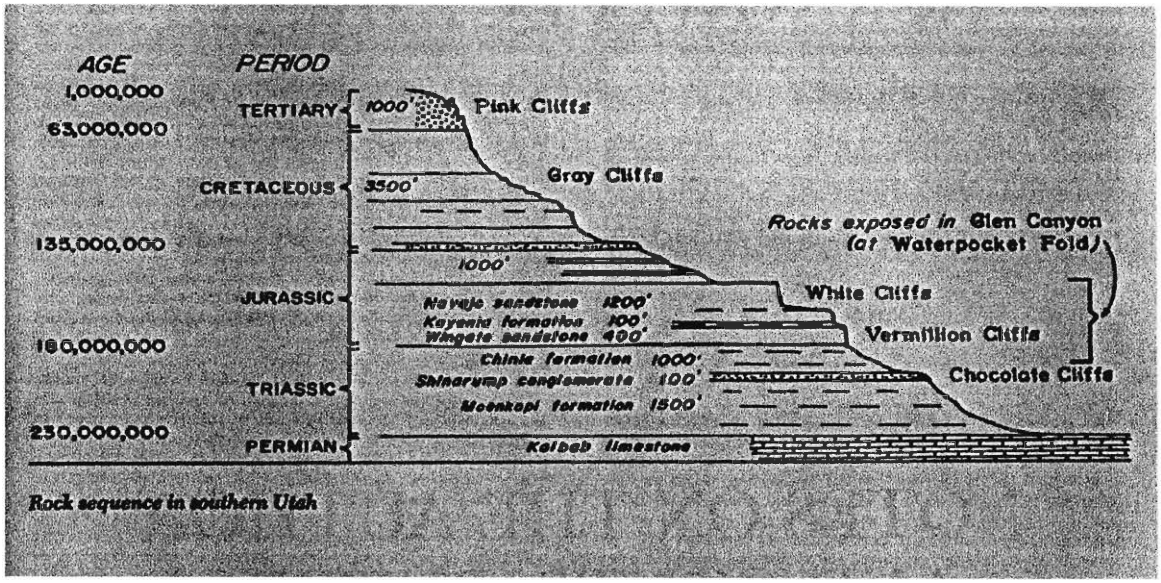

Figure 1: Geologic history exposed by erosion from the Colorado River.
(*The Grand Colorado: The Story of a River and Its Canyons*, p.303)

The River has cut through over 1000 feet of the earth revealing millions of years of geologic history and has created its own funnel through which it must travel (the land has been continuously rising giving the river another 5000 feet to cut through). Regularly,

during the annual spring flood season, the river was known to rise over 70 feet in height as soon as the spring thaw began in the mountains. Conversely, the dry season during the late summer months would reduce the river to a mere trickle through the deep channels. Either way, due to the large amounts of silt carried by the river via tributaries and the erosion of sandstone from the rain, it was commonly said that the water was "too thick to drink-too thin to shovel." [1] Regardless of the accuracy of this statement, until a hundred years ago the Colorado River was deemed useless.

The goal of this paper is to provide a foundation upon which further and more specific research can be based. In Chapter 1, some insight is given to the climate in the Southwest and the questions raised by outsiders as to whether or not humans belong in this desert climate. Chapter 2 will describe the early attempts of exploration and settlement by native Americans and Western Europeans of what is now the Southwestern region of the United States, and how technology and human will has made this feat possible. The conquering of the Colorado River through technological breakthroughs and strong spending from the United States' government is covered in Chapter 3. In Chapter 4 a description of the basic criteria of dams, locating a dam site, and how construction is justified, financially and fundamentally, to offer some insight on the arguments for and opposing dam building and/or demolition. Chapter 4 also goes into detail on some of the logistics on the Hoover Dam, and also touches briefly some of the methods used to measure evaporative losses from the Colorado River System. The history and issue of water rights in the American Southwest is covered in Chapter 5.

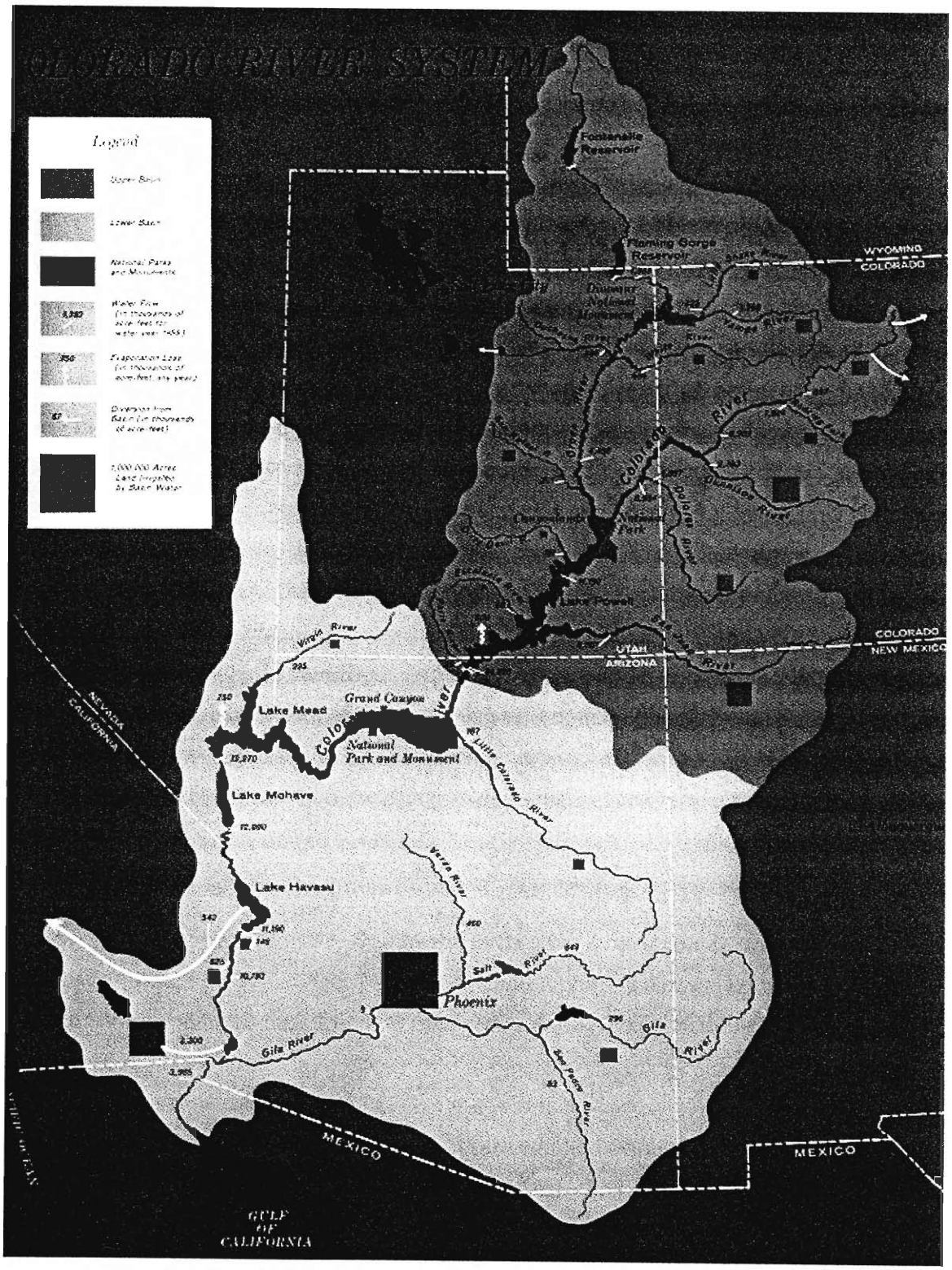

Figure 2: Map of the Colorado River Basin (*The Grand Colorado: The Story of a River and Its Canyons*, p.197)

1. COLORADO RIVER SYSTEM LOGISTICS AND BACKGROUND INFORMATION

1.1 Introduction

A better appreciation of the problems encountered during the Western European and American exploration of the Colorado River can be achieved if the reader begins with a working knowledge of some of the characteristics of the early river. Until the construction of the Hoover Dam in 1936, the Colorado River was untamed and destructive. Many times early explorers found themselves trapped by flash flooding, or just plain lost after realizing that the river had once again changed its course, and even dieing of dehydration and heat exhaustion with the river in sight. The few who did survive the rugged journey to this region lived with the bare essentials with little to look forward to.

Until the turn of the century, technology at was such that transportation was difficult and water delivery to crops inefficient. The draw to the land was to get away from the overcrowding in the East, and that the land was being given to settlers for free by the Federal Government. However, digging irrigation canals in the desert with a wild and untamed river that frequently flooded its banks and changed its course proved to be a much bigger challenge than anything experienced elsewhere in the country.

1.2 Climate of the Southwestern United States

The arid climate of the Southwest makes for a harsh environment where very little should be able to survive. The Rocky Mountains to the west create high-pressure systems and patterns that divert rainstorms from the Pacific away from this region which only receives less than 10" of rain annually (four inches per year is typical in Yuma). Most of the water in the Colorado River is the result of snow melt as the cooler mountaintops get more than 30 inches of precipitation annually. Temperatures in the region average 120 degrees during the day, and frequently drop 30 – 40 degrees at night. During the building of the Hoover Dam, temperatures averaged over 140 degrees in the shade of the diversion tunnels during their construction: there is no escape from the heat.

Humidity levels are also much lower than those known in the East. Even though the Colorado River System drains over 245,000 square miles of land, only $1/8^{th}$ of what

little rain that does reach the ground actually finds its way to one of the many rivers and tributaries. Another example of just how quickly water is 'lost' can be seen in modern agricultural methods practiced on crops today. During irrigation, losses are experienced through evaporation as water is sprayed into the air, and then through evapo-transpiration as the water makes contact with the sun-baked leaves of the plants. Evapotranspiration can be understood as what happens when the water lands on a plant's leaves and immediately evaporates so that calories are taken from the plant in converting the liquid water to gaseous water vapor, and as a result the plant is cooled, i.e. much of it never touches the ground (the same thing happens when humans sweat). Of course water losses in the East also occur due to evaporation and evapotranspiration, but 24 hour watering of crops is required when growing plants in the desert necessitating much more water than that elsewhere in the country.

Shifts in tectonic plates over millions of years have caused abrupt upheavals in the landscape and, contrary to the desert environment previously described, snow covered mountains can often be seen while standing among cacti and sidewinders. The steep faces of the Rocky Mountains were the primary source of flash flooding and the severe changes in the amount of water flow in close by rivers and tributaries before the construction of dams and diversions. The marriage between the rivers of the Colorado River System and the surrounding area is very intimate as one could not exist without the other.

1.3 Characteristics of the Colorado River System

The Colorado River begins in the mountains of Eastern Wyoming and builds in strength and size from its many tributaries until it finally empties into the Gulf of California 1700 miles later (roughly the distance from Boston to Miami). The region it drains accounts for one-twelfth of the land area of United States, 245,000 sq mi, or 157,000,000 acres (one acre is approximately the area of one and a half football fields), plus 50 miles of land in Mexico before reaching the ocean.

The Colorado River is actually young in terms of rivers at a just 12 million years. At its very beginning as an ancient stream, the young river immediately began carving its way through two billion years of sediment. As seen in Figure 1 in the *Introduction*, the earth's geologic history is exposed in layers of limestone, sandstone, shale form the Permian Period more than 200 million years ago, the Mississippian, Devonian, and

Cambrian Periods of more than a billion years ago, and finally down to the Archeozoic Era – the beginning of time. The sudden upheavals of land have given the river an additional 6000 feet of earth to cut through. Canyon wall heights of 1000 feet are common at this stage of the River's existence, although some can reach heights of up to 1400 feet from the riverbed below.

Special attention should be given to that last statement. Before the Industrial Revolution, Manifest Destiny, and even before the first humans set eyes on the marvels of the Grand Canyon over 4000 years ago, the Colorado River would scour the canyon walls with over 380,000 tons of silt/day. 9,000,000 tons of salt were discharged into the Gulf of California carried by over 15 million acre-feet of water every year. For 12 million years the Colorado River has been raging and flooding and carving paths at random through the desert. In all that time, only 1000 out of 6000 feet of rock has been worn away, and today barely a trickle makes it to the sea.

1.4 The Debate over the Development of the Colorado River System

There are, of course, two sides to every story. The bringing of the mighty river to its knees was the result of many people, most of which had never seen the Colorado except maybe in photographs. Indians who were displaced from their native homes still cannot understand why the white man would ever build communities in the river's flood plain in the first place. Common sense should tell anyone to move to higher ground and out of harm's way after the first one, two, or three times their house was washed away by flooding, shouldn't it?

The other side of the story is that the flood plains of the Colorado River make home to tons of silt that was once carried by the River, and are replenished yearly during annual floods at no expense. The 1800s and even into the 1900s occurred the height of the American 'reclamation' of this wild and useless land. There was an honest belief in Manifest Destiny. The government was giving away land to anyone willing to 'improve' it and directed federal funding to water projects with the Reclamation Act of 1902 while dreams of gold and quick riches drew even more people to the region. Mostly, however, there was an overall feeling that taking control of this uncontrollable river was God's wish. There are other rivers in the Colorado River System, however, the Colorado itself proved to be the biggest challenge.

Along with all the romance and heroism that comes with conquering the unconquerable comes the bottom line. This is America and Americans raised large crops to maximize profits. Motorized transportation was more of a luxury than an everyday convenience and it was necessary for farmers to live fairly close to their fields so time and energy wouldn't be wasted everyday by traveling great distances in the desert sun. After a few normal or dry years, small towns would begin to develop near these farms so that goods could be bought and sold, and low and behold, small populations living in the middle of a flood plain.

Being completely separated from the situation makes it very easy to point and wonder what sense it made to rebuild in the same place that a flood had just occurred and washed away all the homes. Maybe it's arrogance, severe ignorance, or a way of thinking that doesn't make a whole lot of sense to those living in the East in this day and age. However, there is another side to this debate.

The Hoover, Bonneville, Shasta, and Grand Coulee Dams were the four largest structures in the world, yet were all built at the same time: during the Great Depression. With millions of people were out of work, California was still growing quickly and needed electricity to keep up with the booming population and farmers all along the Colorado needed flood control and a reliable source of water during the wet and dry seasons. The power supplied to Southern California also powered military aircraft manufacturing facilities during World War II. Arizona is the second driest state in the country (only Nevada gets less rainfall) yet has some of the best golf courses in the world. One development just outside of Phoenix uses a fountain that shoots water straight up into the air 500 feet as a sales pitch: the tallest in the world. This previously useless and barren land is also one of the biggest agriculture centers in the country. For growing plants and vegetables in the middle of the desert, the land is cheap, available, and leaves other land in more geographically desirable areas available for homes or businesses.

Water in the Southwest symbolizes power, security, opportunity, self-determination, life, and status. There is no more flooding of the Colorado River, and no more random changes of its course. By reclaiming the southwestern region of the country, people can now settle in the region and have access to as much water as they can use to keep cool, for recreation, irrigation, municipal purposes, etc. There is no question that some unwanted effects result from the construction and development of a system such as this, but the benefits are very difficult to give up.

2 EARLY SETTLEMENT AND EXPLORATION OF THE SOUTHWEST

2.1 Introduction

Humans have occupied the southwestern region of what is now the United States for over 4000 years. The river as it is known now would be unrecognizable to the native Indians and first Western explorers who intimately discovered the lack of compassion possessed by the Colorado River and the surrounding landscape. This chapter will give the reader an idea of why the first humans decided to settle the region as well as the tenacity of Westerners to make their claim.

2.2 First Inhabitants

Through the use of radiocarbon dating, artifacts found in caves show the first signs of human activity in this region between 7000-2000 B.C. These hunters and gatherers were among the first humans to come to North America across the Siberian Peninsula during the Ice Age while following the migration patterns of their prey. It is not surprising to learn that little is actually known about this small Desert Culture except that the caves within the canyon walls were used as religious shrines to their deceased and to the land itself. Mysteriously, all evidence of human occupation of this land ceased after 2000 B.C. for over 2500 years.

The Pueblos were very different culturally from the first inhabitants of this region. Known mostly for their basket-making skills, these people were typical hunters and gatherers, but also grew corn in the fertile valleys. Originally from Mexico, the Pueblos wove sandals and blankets to keep warm in the winter months and which enabled them to push as far north as the Four Corners region.

By 500 A.D., beans and new types of corn were discovered and they began to move from the caves within the canyon walls to open-pit houses made of adobe. Fired pottery was also discovered to hold water without leaking, and the bow and arrow was quickly replacing the spear. Advancements in fabrics, stone axes, and masonry are also credited to the Pueblos of this region, but the canyons continued to prove inhospitable and their exploration for new lands was halted.

Settling in to this environment, the development of adobe structures of up to five stories were seen by 1000-1200 A.D. which were capable of housing hundreds of

people. Geologic study shows that this was a wet period for this area, which was good for crops and for the growing Pueblo communities. Small buildings and religious shrines were created within the canyon as it was believed that this hostile environment kept them humble and developed a closer relationship between them and the other world. While many communities built caves along the cliffs of the canyons, separate structures were always close by to provide storage, social gathering places, etc. They adapted well to their environment and developed a balanced economy though the hunting of deer, rabbits, and sheep and growing and gathering of fruits, beans, cotton, and corn. While some stayed during the winter months and through the dry spells, others frequently migrated south and small bridges, low dams, and diversion walls that were used can still be found (a primitive irrigation system consisting of 77 dams was found at one site). Signs of early attempts at erosion control and conservation were also obvious during these discoveries. Difficulties adapting to the land were justified by these people since there existed no enemies except for the environment. These were gentle people who built defenseless communities and were at peace with one another.

The Pueblos were, for the most part, the most productive and unified people to populate the Southwest until the migration of American farmers and businessmen in the 1800s. Soil stratigraphy and pollen and tree ring evaluations show a decrease in rainfall and climate changes around 1150-1200. It was about this time that the Pueblos left the canyons and areas north and south to find more preferable conditions for growing maize, which depends on large amounts of water and constantly wet soil. From 1150-1300 the Pai began taking over the abandoned Pueblo ruins and started to build defenses to protect their reliable water sources. Until the late 1880s and the violent American takeover of the land, many tribes and Indian cultures came to the area to try and fight off others in order to secure these precious water sources. The Pueblos never completely left the area, but a civilization like the one they knew for over 700 years was never again realized. The Pai remained the dominating culture until peace was made with the United States and they were forced onto reservations in the 1880s after valiant attempts were made to defend their land.

2.3 200 Years of Spanish Exploration

During the 16th century, conquistadors came to the New World with brutal force looking for riches to fund the building of a modern Spanish navy. After finally recovering from fierce internal conflicts and the grueling Moorish invasions Spain was on a mission

to join France and England as one of the world's superpowers. They needed money desperately and the Americas were targeted.

Following Cortez's conquering and looting of the Aztecs in Mexico (1521), stories of previously unheard of amounts of gold into the country thousands of miles away made their way bake to Spain. With Francisco de Pizarro's domination over the Inca's in Peru (1533) bringing home even greater wealth, the New World appeared to have a never ending supply of gold and silver that Spain wanted at all costs. Legend told of seven cities beyond Mexico's northern mountains of seven rich tribes living in seven rich caves in a country called Cibola, but the locations of which were not known. After depleting the treasures of the Aztecs and Incas, the conquistadors set out to find these mythical cities with their beaches of gold sand and trees that grew gold bells.

The first encounter with the natives to the north started with a black priest named Esteban who was sent out with the Spanish explorers. He pretended to be a god to the people who had never seen a black man before, and was more or less accepted by the Indians. The battle hardened explorer Fray Marcos followed closely behind hoping that the clever story and persuasive abilities of the priest would reveal the secrets to the legendary cities and blaze a trail for a quick defeat of the unsuspecting inhabitants. Surprisingly, Esteban was unable to fully convince the skeptical locals who had heard of the fates of the Aztecs and the Incas by unknown invaders. Unwilling to accept his own claims of supernatural being, Esteban was assassinated by the Zuni's while residing among them in their pueblo of Hawikah. Marcos had been within sight of the city and noted how it seemed to shimmer in the sunlight; this was obviously one of the seven cities of Cibola. However, with the assassination of Esteban, Marcos called off the attack and quickly returned with the story and seeking additional support from the King.

By 1539, almost 70 years before the battered English settlers began their failed attempt to colonize Jamestown, Marcos reached the Colorado River by sailing up the Gulf of California. He wrote of the fury of its tidal bores that rushed up the river and back to sea with the tides, and how his frightened men were helped by the native Indians who pulled their technically superior sail driven vessels up the delta with ropes thrown to the shores. Coronado led an even larger expedition by land in 1540 followed by a group of priests who sought the conversion of the pagan inhabitants. In July, it was Coronado who reached Hawikah first traveling by land where he quickly learned that this was merely an adobe city-state with little gold or silver. The riches and treasures of the mighty civilizations to the south were not known in the desert of Cibola.

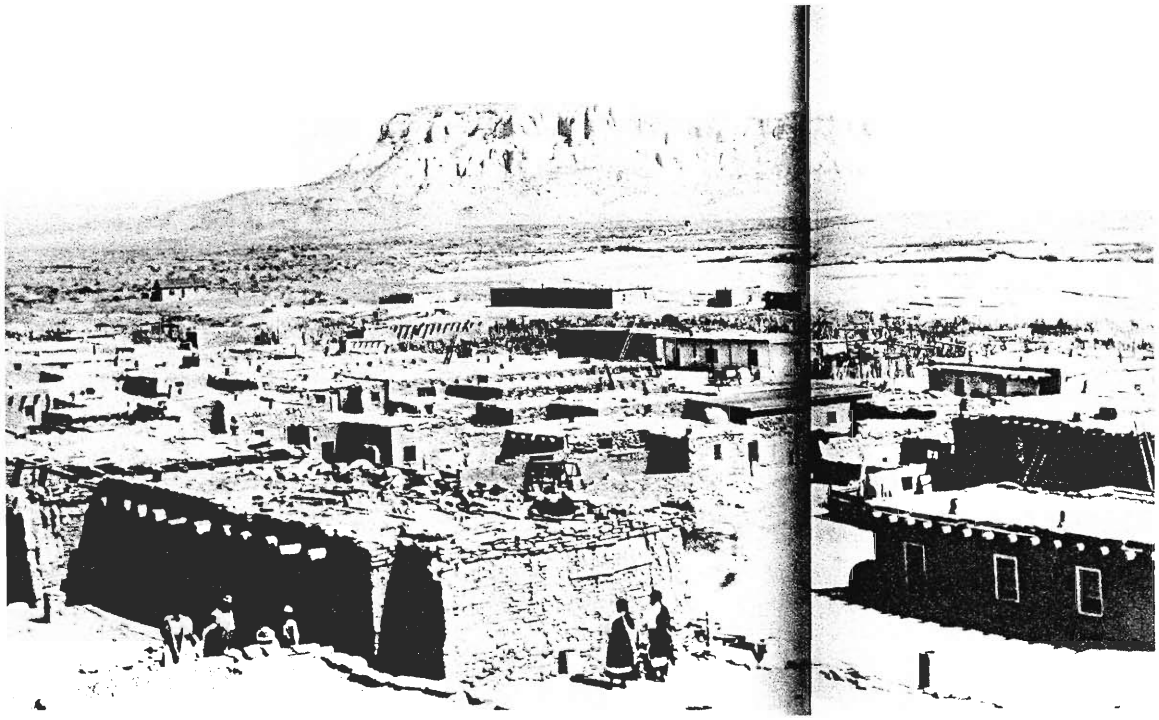

Figure 3: Photograph of the early Pueblo community of Hawikah, thought to be one of the seven cities of Cibola. (*The Grand Colorado: The Story of a River and Its Canyons*, p.36-37)

By winter of 1540, it became obvious that there was no Cibola and the expedition was considered a complete failure and an embarrassment. A huge amount of territory had been covered and the discoveries of the Colorado River and the Grand Canyon had occurred a full year before Desoto reached the Mississippi River to the east, but the King's only concern was gold and the mighty conquistadors returned home. The Colorado River and the Grand Canyon would be ignored for the next 60 years.

Toward the end of the 16th century, in Spain's empire in North America was one that it did not know. The boundaries still were not mapped, its treasures had been depleted, and relations with the natives were permanently ruined by the ferocity of the conquistadors. Neither the King nor Christianity were accepted and local tales of the bloodshed and disease brought upon them by the white man left little desire for peaceful acceptance of their ways. This proved an embarrassment and a nuisance to the King and he was determined to collect taxes from its inhabitants.

In 1590 the Spanish colonized the Pueblo region of New Mexico in an attempt to establish a route to the South Sea and to convert the 30,000 Indians who lived there. Stories of the South Sea claimed that pearls littered the beaches, and the prospect of

30,000 new tax payers to the crown were too much to let pass by. After 20 years of fighting, the Indians were finally able to successfully revolt and reclaim their native land. This was one of several failed attempts to colonize the region and to convert the Indians, but one by one each failed and the Spanish returned home. The Colorado River would not see another white face for the next 75 years.

Attempts to map and determine what to do with this land continued until the 1800s. A quick description of some of the ships of the Spanish Armadas is given in Appendix A, while maps produced by Spanish cartographers during this time and descriptions of each can be found in Appendix B.

2.4 American Exploration (1803-1902)

The era of traditional nomads and explorers ended within the first 100 years of takeover of the Southwest by the United States. Unorganized attempts to settle the region by prospectors searching for copper, asbestos, lead, salt beds, and other miners brought big mining equipment and saw the building of fixed cable crossings over the Colorado River. Even though the Colorado River had been 'discovered' and explored by the Spanish for over 200 years, neither the course of the river nor the canyons had been mapped. Still surrounded by myths, even the Indians did not attempt to challenge this uncontrollable force. However, with the arrival of the Anglo-Saxons with their need to satisfy their natural curiosity and to exploit their surroundings, this was soon to change.

Ideas of Manifest Destiny began with the Louisiana Purchase of 1803 as the 'West' became part of the Union, although much remained property of Mexico until 1848. In 1825 William H. Ashley became the first American to lead a fully documented journey through the canyon walls of the Green River. In his diary of events he reported the hostilities of the Indians toward them (obviously the result of the Spanish invasions 300 years earlier) and the constant searches for the same crossing points used by the Spanish (Morgan, Dale L., *The West of William L. Ashley*, Old West Publishing Co., 1964). Despite the difficulties encountered with the local inhabitants and the fact that he returned at all, Ashley returned with over 9000 pounds of beaver hides and new interest in the region was sparked.

British Lieutenant Robert W. H. Hardy set to explore the mouth of the Colorado River in 1829 chasing the same myths of rich oyster beds and an abundance of pearls

that Coronado had over 200 years prior. Funded by the General Pearl and Coral Fishery Association of England, Hardy spent three weeks exploring the mouth of the river and fighting the raging tidal currents with limited success in a steam powered ship. Unable to find the mythical treasures he set out for, Hardy did come back with maps that charted the river all the way back to the Gila junction and took time to replace the Spanish names of the channels, islands and shoals with those of British origin (Figure 12, Appendix B). Although there weren't any rich oyster beds, Hardy left his mark in history by becoming the first man in 300 years to navigate some part of the Colorado River.

Over next 30 years the river would continue to be explored and mapped. In 1847 Brigham Young lead the Mormons to Utah and began their settlement near Great Salt Lake and sent his followers to colonize the land. Most of the sights used by the Spaniard Escalante and his worn out men in 1776 were found and developed during this time, and the crossings that were discovered allowed both Mormons and non-Mormons to populate the area. The Gold Rush in California in 1848 lead to its ratification as a state in 1850, barely two years after it had been surrendered by Mexico. From 1849-1850, many Americans used the trails created by Coronado and his men 300 years before to get to California, but traces of the bad blood also created by him between the Indians and the white man was also obvious.

The U.S. Army built Fort Yuma overlooking the Colorado River to protect prospectors and settlers from Indian attack. Many saw the river as the Mississippi of the West with fairies and steamers navigating its waters and large ports for trade. The first to try to run a steamer this far into the mainland was George Johnson in 1851. In his first attempt Johnson was able to successfully deliver badly needed supplies from the mouth of the river to Fort Yuma. Unfortunately the next two boats sank. The fourth riverboat remained in limited operation for several more years, and business increased as a result. Johnson was running up to eight boats by the end of the Civil War and officially named the operation the Colorado Steam Navigation Company. Slowly but surely, Johnson let his company run itself into the ground until it slowly disappeared.

The War Department noticed Johnson and his work and didn't take long to realize that it needed a reliable line for western forts for communication and supplies. In 1857 the U.S. Government built a 58' steel-hulled vessel named the *Explorer* to continue the exploration of the canyons and mapping of the upper Colorado River. As it set off the boat almost immediately ran aground. Having the push the boat back into deeper

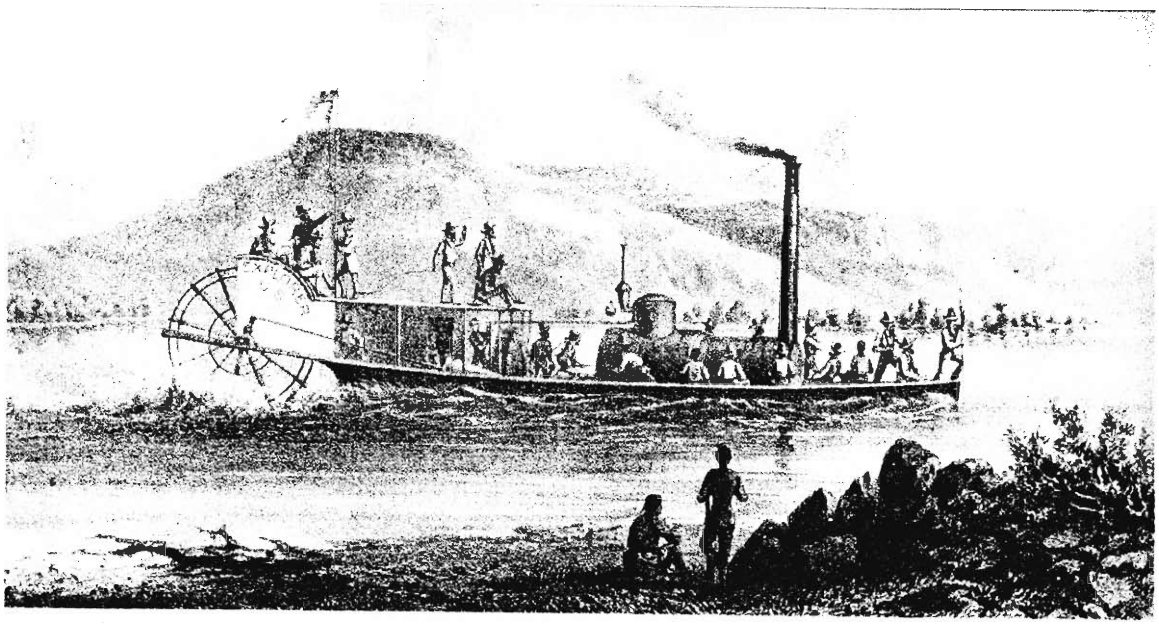

Figure 4: Drawing of the *Explorer* just after launch and freeing itself from an unseen sandbar: January 11, 1858. (*The Grand Colorado: The Story of a* River and Its Canyons, p.72)

water by the crew became normal practice as they soon discovered the river's many sandbars and disappearing rocks and channels. The intense currents forced the crew to stop many times proving a frustrating journey. The crew averaged only 4-5 miles per day as they finally reached Mohave Canyon one full month and only 150 miles later. The boat nearly sank as it struck an underwater rock between Mount Davis and the Black Mountains. Several had been thrown overboard and the boiler was actually displaced from the impact. Most concerning though was that the canyon walls rose straight from the water to heights of 500-1000 feet and the crew wondered how they would have escaped were the ship to have sunk. Notes from the Captain regarding the situation were as follows:

> *"The canyon continued increasing in size and magnificence. No description can convey an idea of the varied and majestic grandeur of this peerless waterway. Wherever the river makes a turn the entire panorama changes, and one startling novelty after another appears and disappears with bewildering rapidity. Stately facades, august amphitheatres, rotundas, castellated walls, and rows of time-stained ruins, surmounted by every form of tower, minaret, dome, and spire…(We) were searching for a spot large enough to serve as a resting*

place, when we came into a narrow passage, between two mammoth peaks, that seemed to be nodding to each other across the stream…over a thousand feet high...not a trace of vegetation…" [2]

The crew decided that it had had enough by the time they reached Great Bend. Weary from pulling the boat over rapids and dislodging it from sandbars and sunken timber and rocks, they were becoming well aware of the fact that the rapids were becoming more intense and more frequent the further inland they traveled. Another concern that was creating tension were the logs and driftwood that were stuck in the rocks 50' above the river. Being at the end of the winter season, the crew determined that the floods that would come with the spring melt were too much to take on and that the river was not navigable above this point. Fears of a rumored Indian uprising also helped in making the decision to return to Fort Defiance by foot.

So after 300 years of technological advances and knowledge gained about the land, the Americans were having the same problems as the Spanish had when they attempted to develop the region. There were still few reliable water sources, if any at all, little vegetation for grazing, and hail storms of intensity had never been seen before. More and more valleys were found by explorers seeking them, but each was 1200-1500 feet higher in elevation than the previous making travel very difficult, and each with the same problems of water, vegetation, and weather as the next. Snow storms were encountered with thunder and lightening, their mules and horses went days without grazing and water, and big changes in weather as they climbed higher left the explorers huddled together and shivering around meager campfires. The tops of the cliffs gave them snow and freezing cold while in the canyons below the sun reflected off the shear cliffs and made unbearable heat. The crew of the *Explorer* finally reached Fort Defiance (Arizona Territory) in 1858 and this final observation in the trip log:

"Ours has been the first, and will doubtless be the last, party of whites to visit this profitless locality. It seems intended by nature that the Colorado river, along the greater portion of its lonely and majestic way, shall be forever unvisited and undisturbed." Lieutenant J.C. Ives [3]

In 1865 Samuel Adams made a trip from the mouth at the Gulf of Mexico to Boulder Canyon and reported that the Colorado River was suitable for travel, despite the

report Lt. Ives had given less than 10 years earlier and the stories of other travelers. Congress was quick (and desperate) to believe Adams and proclaimed the Colorado the main route between the Arizona and Utah Territories. Unwilling to make it possible for John Wesley Powell get the fame and glory with his planned expedition, Adams hastily organized another trip. Within 10 days of leaving from Breckenridge, Colorado on July 12, 1869 for the Gulf of California, five of his 10 volunteer crew members deserted him, and within another two weeks all four boats had disappeared in the rapids. Adams and the remaining five members built a raft so they could continue only to have two more abandon them the next day. Finally on August 10, the raft struck a rock and dumped the most of their rations overboard. With this, these last four of Adams' poorly planned but nonetheless courageous expedition returned to Breckenridge on foot. Defiantly, Adams recorded in his diary that he was sure that he and the crew were almost past the worst of it, when in reality they hadn't even reached the Colorado yet.

John Wesley Powell was a self-taught field scientist, soldier, explorer, and public servant. Recorded as the first realist, Powell was so devoted to *knowing* that most of his recordings are on the verge of being romantic. His love was natural science despite religion and blind faith were more popular during his time. One of the first to join the volunteer army of the North in 1861, Powell rose from private to lieutenant colonel during the Civil War. The War not only took one of his arms, but also gave him contacts with General Ulysses S. Grant and many others in government who would later help him with his famous expeditions. Following the War Powell became a professor of natural history at Illinois Wesleyan College (then Illinois Normal College) so he could develop his long-term plan for an expedition down the Colorado River.

Funding for his first expedition came from almost everywhere: several colleges, Illinois Industrial University, Chicago Academy of Sciences, Union Pacific Railroad, the Chicago, Alton and St. Louis Railroad, the Pittsburgh, Fort Wayne, and Chicago Railroad, the Chicago and Rock Island Railroad, and out of his own posket. From Washington, with the support and blessing of Gen. Grant, Powell was given and/or promised rations from western army posts along the river, as well as an escort from Fort Laramie. Boats were built to his own specifications determined from trips he had made down other rivers in the Midwest. But surprisingly, with all the support and funding made available to him, he selected a crew with very little experience, no scientists, and only a few 'professional' explorers.

Figure 5: John Wesley Powell's First Expedition as the push off from Green River City, WY (*The Grand Colorado: The Story of a River and Its Canyons*, p.94)

Finally, on May 11, 1869, Powell and his crew of 10 men pushed off into the Green River from Green River City, WY and began his trip. Three boats and six men made the entire distance to Grand Washington Cliffs (three men died, one deserted). In 100 days he and his crew covered 1500 miles of uncharted waters (details of his trip are documented in his own *Exploration of the Colorado River of the West and its Tributaries (1875)* and in Wallace Stegner's biography of Powell in his *Beyond the Hundredth Meridian (1954)*). He noted in his log that the river was not impossible for navigation, but constantly unsafe. In fact, the only differences between his and other trips were that, first of all, he obviously completed the trip, but also that most other explorers did not bother to make notes or keep logs, and little was generally known about the Colorado until Powell's had actually been published in the early 1900s.

Powell's second expedition in 1871 came with $10,000 from Congress. He and his more scientifically experienced crew took the next eight years mapping the river, studying the geology of the surrounding area, taking pictures, and collecting scientific information that is still regarded very highly even by today's standards. Funding kept pouring in and crew members were added and changed until Powell put his theories together in his *1878 Report on the Lands of the Arid Region of the United States*.

In this report, Powell stated that the West would be inhabitable under the conditions of the Homestead Act of 1862 (guaranteed 160 acres of land to any farmer

willing to go west to 'improve' the land), he claimed that the Colorado River would never be suitable for normal navigation, and Powell called for an environmental approach to settling the land. He pushed for mapping and classification of the land before mines were created, farms cultivated, pastures, established, logging, etc. He professed that great revisions were needed to federal control and for the formation of irrigation districts and regional politics rather than typical state boundaries. Powell argued that the lack of planning that was standard practice back east would devastate this fragile environment and that the development of this land should be carefully planned. Another controversial suggestion was for the Indians, saying that the 'reservation' concept was not a very good one, and that schools and modern homes should be established for Indians so they could learn to adapt to Western culture.

Powell went down in history as a symbol of the American spirit and ideal. He was tough, but well educated and sensitive while being completely logical in his passions. Through his enchanting and detailed observations made during his journeys, he ended the dark mysteries of the Colorado River and its surrounding canyons. Even he, however, couldn't stop the wheels of capitalism and bureaucracy.

Despite Powell's observations and theories on the Southwest, the fact was that the Army still needed a supply route. Several more trips were attempted up and down the Colorado, but none proved as successful as his. A full map of the Grand Canyon was finally completed in 1923 after 21 years of full time study and continuous funding. By time map was completed, ideas of using the river were dominating those of just knowing it.

3 CONQUERING THE COLORADO RIVER

3.1 Introduction

> *"No competent earth designer would have left over a million square miles of the American land without sufficient rainfall to raise a crop…A rational nature, a healthy nature, would be a nature of uniform productivity, where there was no waste, no excess, no deficiency, nothing but a steady yield of the useful forever and ever. In that world, rivers would be transformed into models of reason…Science demanded nature without flaws. The word used by engineers to refer to that work of rationalizing the ricers of the West, and nature in general, was 'conservation."* [5]

In just more than two generations, the river has been transformed from raging to trickle, the effects of which will last the lives of our children and their children. As typical with American society, the funding and the technology were both available, but those making the calls struggled with hidden agendas and idealologies of how things should be done.

3.2 Logical and Ideological Justification of Federal Water Projects

Now that Colorado River had been mapped from source to mouth and all tributaries and canyons charted, named, and measured, geology and history recorded, and romance and myths sucked out of it, science, technology, and economic greed began to quickly take over. By the 20th century, the Industrial Age had set its grip and man knew that he was capable of great things. A willingness to push everything around him to its limits for the sake of going there, without guilt or hesitation, made for an exciting time. The new myth surrounding the Colorado River was that it was a big garden that Americans could flourish in. This was the same mindset that had created and made something of democracy and capitalism, and thus made Americans special in the eyes of God.

It was quickly noticed, however, that there just wasn't enough water to make the Homestead Act work. Powell had seen problems with water rights and distribution of irrigated land among individual farmers, but not too many were interested. The intent of the Homestead Act was to prevent water monopolies, but this law had more of an annoyance to owners of large farms and manipulators of the system up to this point.

Since this law was simply not enforced, factory-type farms were developed with big corporate funding from back East, and with them large groups of migrating laborers which closely resembled the despairing working class from back East quickly followed work and the harvest schedules. Despite this, the propagation and success of large corporate farms in the West were a simple result of growing crops in the middle of the desert.

The three main problems with development of desert are technological, social, and financial. Technological and financial problems are pretty much straightforward, but the social issue was something that had been difficult for small western farmers and politicians in Washington to learn how to deal with. Socially it was very difficult to get the entire country to all believe that this is good idea. In the East, funding for irrigation and such not a big problem since the relatively wet and cool climate is favored by crops like corn, cotton, etc. What kind of connection could be made between man and the land when the land is completely inhospitable to him and his livelihood? The Homestead Act was made following Civil War to make clear that U.S. wanted small, individual farmers like the ones in the North, not like the plantations in the South. However, this contradicted itself as no individual or group could possibly finance such irrigation; such an undertaking would require involvement from big businesses or from the Federal government.

The Desert Land Act of 1877, the first revision and clarification of the Homestead Act, was the result of even bigger corporate payoffs to politicians, or the optimism of a bunch of dreamers. Congress had assumed that if it gave 320 acres to anyone who would agree to the conditions set, people would cooperate as both the Mormons had for their settlement and the barn raisings and corn huskings in New England. Up to this point, local farmers and big corporate farms were taking water from the Colorado, but the amount of which was not being monitored. The common attitude in the West was first come-first serve. Common sense should tell anyone to go out and claim all water they could in accordance to the half-hazard laws in place and among the understaffed and overburdened local authorities, and then sell it to whoever needs it. Not a very nice thing to do to the others within the community or one's fellow man, but smart business nonetheless. Instead of settlers coming in and digging small irrigation ditches as hoped with the Homestead and Desert Land Acts, one big company could come out, dig a canal, and take over an entire valley. Next they advertise back East to attract unsuspecting customers, and then let sit back and wait for the profits.

The complexity of this situation increased as businessmen and politicians from the East stalled Government action. Many small dams and miles of canals were already in place by this time. There were no permits to acquire for the construction of a dam or canal, and no inspectors to oversee the quality, amount of water being taken, or even safety of these private undertakings. Of course the long-term effects of this situation demanded that it needed to be stopped immediately, and that the Federal Government had the money for very big water projects and the resources to strictly monitor construction. People in the East did not see matters this way and couldn't understand why so much of their money and effort should be put into a *water project* in the middle of the desert. Federal funding of large irrigation projects would only increase the supplies of current owners' of the water available which would allow them to rent out that much more of it, as well as increase the value of the land they owned so they could sell it for much more money (land in the middle of the desert isn't worth much and can be acquired very cheap, with the installation of a canal close-by it increases in value almost exponentially).

3.3 Gaining Support for Spending Federal Resources in the West

Not only was it going to be a problem to convince representatives from the East of the importance and urgency the situation in the West, but representatives from the Western didn't even have a plan put together that was collectively agreed upon.

The International Irrigation Congress convened in Salt Lake City for 1st time in 1891 to find a solution to the problem of water supply and distribution. Delegate Morris Estee from California wanted state control over policy reminding everyone that monopolies had been a very large concern for the state since its inception in 1850. Between 1878-1879 at California Convention, not only did the Desert Land Act deem it Federal Law, but it was also written into the state's constitution that there was to be a 320-acre limit on land grants from the state to settlers. Regardless, in 1886 the state Supreme Court awarded all water in Kern River to cattlemen Miller and Lux. This ended with Henry Miller eventually giving back 2/3 of water that had just won in court, but made losers finance and construct a basin reservoir for his 1/3. Delegate Mordecai of California made everyone aware of California's continued distress over the issue:

> *"If you allow more than 320 acres of land to be taken up you open the door to a continuation of those great domains...Allow syndicates and corporations and*

private enterprises to absorb the territories which belong to the individuals thereof, and I, for one, gentlemen, am opposed to it..." [4]

It is important to note that capitalism was not a proven concept as the United States, while showing considerable economic potential and growth, had not yet truly proved itself as a true world power. Americans were very worried about the amount of money that big industries were generating, and the speed at which it was being generated, and how they might divide the country. This was time of frequent riots and strikes from the working class not only in the eastern United States, but in France, Russia, and England as well. Marx had recently finished writing Communist Manifesto, child labor laws were had not been implemented or suggested, and labor laws, unions, safety commissions, or minimum wages were nothing more than ideas in some philosophical utopia. Citizens and politicians alike were scared but didn't know how to fight the big corporations who had larger gross annual incomes worth more than that of the United States. The government could be economically crippled with little private effort, and the politicians back East felt this pressure more even more than those at the 1st Irrigation Congress representing the poorer western states; this anxiety was blatantly obvious.

With little accomplished or agreed upon as far as Western development was concerned, State Representatives decided to meet again in 1893 for the 2nd Irrigation Congress in Las Angeles. Comparisons were even made between the current economic crisis and that of the Roman Empire to try to assure everyone of the importance and urgency of these meetings (the Roman economy was greatest in history because they realized the value of irrigation). They saw irrigation in the West as the key to their own economic development and the success of the country as a whole. They were still faced with the still same problems however: no available financing and no agreement of how to handle the situation collectively. Large amounts of the land awarded to entrepreneuring small farmers were being taken back because they didn't have the resources to irrigate or could not afford to rent the water from its owner. Corporations routinely bought land for $1.25/acre, irrigated it for $8.15/acre, and then sold it back on own terms. Under the current laws this was perfectly legal and the courts would have to defend them when lawsuits were brought against them. The mass development and ownership of state land by few big companies threatened governments and it was agreed to use public

funding. A productive result was a good victory, but the allocation of public funds was a just a small battle in a large and complicated war.

Each state has its own situation and issues to deal with. The main problem and source of irritation for these congressional meetings was that each state wanted to solve its own problems, but no one had the funding to do anything. They needed Federal money, but had unique problems and ideas of how it should be spent. The Irrigation Congress met several more times throughout the 1890s in different cities to discuss the same issues with new solutions and compromises. In 1900 however, they met in Chicago and a new sense of impatience was felt throughout the convention.

Meeting so much closer to the wealthier and more economically stable eastern half of the country, and to Washington D.C. where decisions are made. Some argued for Federal projects to control flooding and to regulate irrigation while others were more concerned about preventing monopolies. It was unanimously decided that corporations could not be trusted and that only the government at the federal level could handle these enormous tasks.

In 1902 it was back to square one when the issue of federally funded Western reclamation came up. As with the 1st Irrigation Congress that met in 1891, most representatives were concerned about controlling monopolies. They had already been burned by the railroad companies in the 1850s when land was given to them so they could construct and finance expensive public projects that they weren't willing to pay for. This lead to huge monopolies and this congress did not want to be responsible for this happening again. President Theodore Roosevelt finally stepped in and made it known that he did not like how large cattlemen were able to obtain huge amounts of land on the Great Plains and wanted to make move to prevent monopolies in West. On June 17, 1902, Roosevelt's bill became the National Reclamation Act.

3.4 25 Years of Reclamation Service

Two years prior to Reclamation Act efforts had already begun by the California Development Company to divert water for use in Imperial Valley. Since the Colorado's riverbed lies at such a high elevation, diversion by simple ditches to small farms was a cheap and easy method that was widely practiced with the water that was now available. The Imperial Canal brought in much more water than could be used by the growing farm community, however, and the excess was captured by a depression at its end, thus creating the 150 square mile Salton Sea. While this is the extreme case of poor

Figure 6: Early gravity-irrigation ditches in Imperial Valley WY. (*The Grand Colorado: The Story of a River and Its Canyons*, p.162)

planning and what can happen as a result, mistakes and oversights were very typical of privately funded water projects.

The Colorado was out of control as it changed its course at least once every year. Floods would frequently overrun the 1st and 2nd stages of levees built by most towns and communities, and then proceed to destroy towns without at least a third set to contain it. On top of needing a minimum of three stages of levees, the river deposited silt every year during flooding, could leave up to four feet, which required the existing levees to be raised as much to keep the river at bay for the next flood. It was estimated that at the turn of the century, towns in the Southwest were spending $250,000 every year on flood prevention.

Regardless of the obvious situation at hand, states argued that new land to be reclaimed was far away and projects overseen and funded by the Federal government would overlook immediate needs of farmers and dangers of floods; Theodore Roosevelt saw things differently. At this time, the states in the West had dismal economies and in themselves unable to take on the planning and construction effort that was necessary for

such projects. As proof of this Roosevelt simply pointed to the lack of enforcement of the 160-acre law and the failure to properly regulate water withdrawals. With the reality and scale of the task at hand, Roosevelt made Western reclamation the center of his domestic policy

From the Reclamation Act of 1902, the Reclamation Service was formed as a branch of US Geological Service. Under the Reclamation Act, it was the sole responsibility of the Reclamation Service to oversee the design, inspection, and maintenance of dams along the Colorado River System. Actual construction, however, would be contracted out to private companies (the same is done today with highways).

In 1905 the situation along the Colorado proved increasingly desperate as it overflowed the banks of the Imperial Canal and easily put the Imperial Valley community and its crops under 6 feet of water. Even though the Imperial Canal was responsible for diverting all the water that caused damage that took two years and $3,000,000 to repair, it was still considered an engineering wonder of the time. The simple fact was that the river was that powerful.

Times were proving tough for the Reclamation Service as well. With 25 projects planned and authorized by 1907, constant clashes with state officials were stalling the process. It was accepted by state representatives to allow these Federal projects, as long as they worked within existing outdated state laws. Another source of frustration were politicians not directly benefiting from proposed projects and owners to water usage upstream and downstream who continuously stalled the process by rejecting requests for water allocation to projects. State control and water ownership ('prior association') were the main two decentralizing factors the Reclamation Service had to constantly deal with.

By 1907 the Reclamation Service had run out of money. The funding for the 10 projects currently in progress was supposed to come from the sale of land in the West to settlers, but it was not enough. With the Reclamation Service unable to work within their budget, Congress took back right to authorize projects and moved the Service to the Department of the Interior. Funding would now come from the sale of water and Congress could keep a closer watch on Reclamation Service activities.

In the next three years, authorization was granted for 20 new projects. With the increase in power granted to the Reclamation Service from the move to the Executive Branch, the Federal government would take 150 mil acres from states. The Yuma Project was dedicated in 1910 as the Reclamation Service's first project. The Laguna

Dam was the first dam on the Colorado River just 13 miles north of Yuma. Through a sophisticated siphoning system, water from its reservoir was moved from the California side, under the river, and over to Arizona for the irrigation of 68,000 acres in Yuma Valley.

The Reclamation Service's first multipurpose project was completed in 1911 on the Salt River (a tributary of the Gila 300 miles east). The Theodore Roosevelt Dam and Powerplant on Salt River and the Granite Reef Diversion Dam downstream were state of the art and not only produced hydroelectric power, but also diverted water for irrigating Salt River Valley. The Roosevelt Dam is considered the Reclamation Service's first great structure and set its own precedent to live up to.

By the end of the 1920s, the Reclamation Service had a handful of projects completed and were committed to tens of millions of dollars. The money was not coming in however. Only 10% of the loans given to farmers had actually been paid back, and 60% of the loans given to private irrigation projects were also in default, even though they were all interest-free. Constantly over budget, the engineers in charge simply began committing themselves to projects without funding in place. Once a project was started, excuses would be made on unforeseen cost overruns, and the money was soon granted for completion.

Even with the obvious problems, there were still calls for more projects and signs of them being needed:

- When the river changed its course in 1910, even though it was blocked by the Laguna Dam it still managed to flood towns in the surrounding areas.
- The Federal Government was still giving out millions of dollars to build new levees along the river, only to have them leveled in the next flood.
- Doing business in the region was still considered dangerous as towns that had been untouched by floods for years could suddenly and unpredictably be leveled the next.

Concerns over the worsening social conditions in the region were also brought to the attention of the Reclamation Service. 1/3 of the population in the Southwest was made of landless, seasonal laborers and Mexicans. The 160-acre law was also not being enforced by local and state officials:

- 99% of the nations melon fields were owned by 56 people who each owned 667 acres of land.

- 90% of the lettuce that was grown for sale came from only 67 people who each owned 336 acres of land

The towns that workers lived in were little more than ghettoes as landowners ran absentee corporations were they lived far away from their fields and weren't affected by the living conditions of their workers. The Southwest had become a farming industry rather than a farming community.

Relations with Mexico were worsening in the chaos as the American farmers used and wasted a lot of what they considered to be their share of the water. The Imperial Canal built by the California Development Company was responsible for diverting over 400,000 acre-feet of water from the Gila. Most of the Canal ran through Mexico before it looped back into the United States and into Imperial Valley. After several years of drought, temporary dams had been built to divert even more water into Imperial Valley. But in the winter of 1915-1916, these dams diverted water into the town of Yuma to completely wipe it out, and created floods in regions of Mexico located far away from the Colorado River with no previous history of flooding.

Most of the floodwater came from a diversion off the Imperial Canal made to irrigate more than 830,000 acres on Mexican soil owned by company in Los Angeles. In 1904, the United States had agreed to give Mexico half of the water carried through the canal since more than half of it ran through Mexico. This dispute grew so intense that in 1916 United States' troops invaded northern Mexico, bringing relations to their lowest since the Mexican-American War of 1846.

3.5 The Colorado River Project: Looking to the Future and Covering up the Past

In 1922 action was taken to bring the Reclamation Service under control. The problem with the Reclamation Act of 1902 and the creation of the Reclamation Service was that its original purpose was to solve social issues in crowded cities and isolation on small farms. Government officials understood these problems at the turn of the century, but didn't know how to deal with them. Social reform is tough and building dams is rewarding. Dams are great signs of accomplishment and give hopes of prosperity. When submitting a proposal or allocating money to such projects, there was no 'human' factor to deal with.

Unlike increased funding for schools or social reform, everything the Reclamation Service did was material, it had a dollar value, and results were immediate. There was a

problem and something was being done about it. For 25 years the Reclamation Service had been looked upon as an expendable tool and came out looking brilliant when they were given projects. The Reclamation Service needed Congress for money, and Congress needed the Reclamation Service for their public and local images. The same short attention span American public that craves quick results that still exists today saw these dams being built and praised them for their accomplishments.

The Reclamation Service hired and attracted the country's best engineers in so that they could build large dams. In 1902 the Colorado River was seen as a technical problem. Problems with dams and reservoirs could be calculated and fixed; social problems and future oversights were tougher. For the 25 years dams were designed to be bigger and better simply because they could be. These engineers pushed technology to its limits and were very proud of their work. Lack of foresight, sense of responsibility, and a trial and error mentality was paid for in homes destroyed or even lives lost.

The Colorado River Project first proposed in an attempt to create a water basin management system to organize and sensibly determine which future projects would be most effective in preventing floods and providing power to all seven states. The upper basin states wanted to capture the water early for more control over the release of water and to prevent the possibility of downstream flooding. The lower basin states claimed that they needed closer access so that expensive and inefficient canals wouldn't be necessary. Of course Mexico was worried about their supply and were against any development.

This plan was debated and compromised over the next 10 years, and even brought before the Supreme Court by Arizona, until it was finally passed on September 29, 1931. Under Colorado River Project, the annual 20.500.000 acre-feet of water in the Colorado River was to be divided between the seven basin states, royalties from the generation and sale of hydroelectric power would be given to Arizona and Nevada, and money was assigned for the construction of the Colorado River Aqueduct (to divert water to Southern California), Boulder Dam, Parker Dam, Imperial Dam (including a desilting station for water supplied to Imperial Valley), and the All-American Canal. Mexico was allocated 16,000,000 plus whatever the United States wasn't able to use. The final result of the Colorado River Project that is worth mentioning was the renaming of the Reclamation Service to the Bureau of Reclamation to help shake off the previous notoriety of lack of foresight and causing more floods than it prevented

Financing for Boulder Dam was very important in this deal since it would be needed to protect workers and regulate water during the construction of the Imperial and Parker Dams. It was also necessary to have a large dam to supply the power needed to lift over 4,000,000 acre-feet of water 1600 vertical feet yearly for the Colorado River Aqueduct. Aside from this, it would be the largest dam in the world, an American dam, an engineering feat, and very good for the Bureau of Reclamation's new public image.

3.6 Bureau of Reclamation and a New Era

The jump-start that the new and improved Bureau of Reclamation needed came in the form of the Great Depression. Under Franklin Roosevelt's New Deal, the Bureau expanded very quickly and had lots of work to do with the new big projects it would soon be responsible for. The Hoover, Shasta, Bonneville, and Grand Coulee Dams were all being built simultaneously, and would become the five greatest structures on earth when they were completed. The construction of Hoover Dam is worthy of particular interest since it became the prototype for large, multi-purpose dam construction. Other dams built shortly after may have been bigger, but none still hold back more water or supply more power.

The actual sight for construction of the Hoover Dam is where the Glen Canyon Dam stands today. Being 300 miles closer to the quickly growing communities in Southern California, Black Canyon was chosen instead. Construction began with the 3,000-foot long, 50-foot diameter diversion tunnels which would reroute the river from its ancient riverbed during the building of the dam. Workers in these tunnels were subjected to regular daily temperatures of up to and exceeding 140 degrees and poisonous carbon monoxide levels. Each of the four tunnels was started from four separate directions without the aid of complicated Global Positioning Sensors, or laser surveying equipment. One year ahead of schedule, all 16 crews connected their respective ends and completed the tunnels. After 12 million years of carving its own path through the desert, it only took 18 months for construction workers to change it. With the tunnels complete and the river diverted, it was time for dam construction to begin.

With the technology available at the time, what was accomplished by not only successfully completing this dam, but two full years ahead of schedule is still a marvel. Some quick logistics will help the reader appreciate the shear scale of this undertaking:

- The highest recorded temperature in the canyon during construction was 152 degrees.
- The 3,250,000 cubic feet of cement used would be enough to make a 4-foot wide sidewalk around the earth at the equator.
- 3,000,000 board-ft of lumber was used.
- If poured solid, the dam would have taken 125 years for the cement to cure and temperatures in middle would have cracked it. 220 blocks were poured so they would be stacked on top of each other to prevent this.
- To quicken the curing process and regulate the temperature of the cement, a refrigeration plant was built next to the dam at the bottom of the canyon and pumped cold water through 662 miles of copper tubing set in the blocks. Without this plant, workers would have had to wait for the bottom blocks to fully cure before the next could be poured.
- The cement plant built near the dam made 6,600 cubic yards of concrete every 24 hours (enough to make a stream 25-feet wide, 1-foot deep, and 1 mile long, every day)
- For 22 months dump almost one bucket per minute into the dam site (1 bucket = 16 tons of concrete).
- Four 395-foot intake towers were built like skyscrapers to provide the water flow necessary to power the massive hydroelectric generators within the dam.
- The final measurements of Hoover Dam after completion in 1936: 726.4 feet tall from its base, 45 feet thick at its top (now a two lane road for cars and trucks), and 660 feet thick at its base.
- Lake Mead holds two years of water flow from the Colorado River and is backed up 118 miles from the Hoover Dam.

Figure 7: Hoover Dam construction site in 1922. (*The Grand Colorado: The Story of a River and Its Canyons,* p.185)

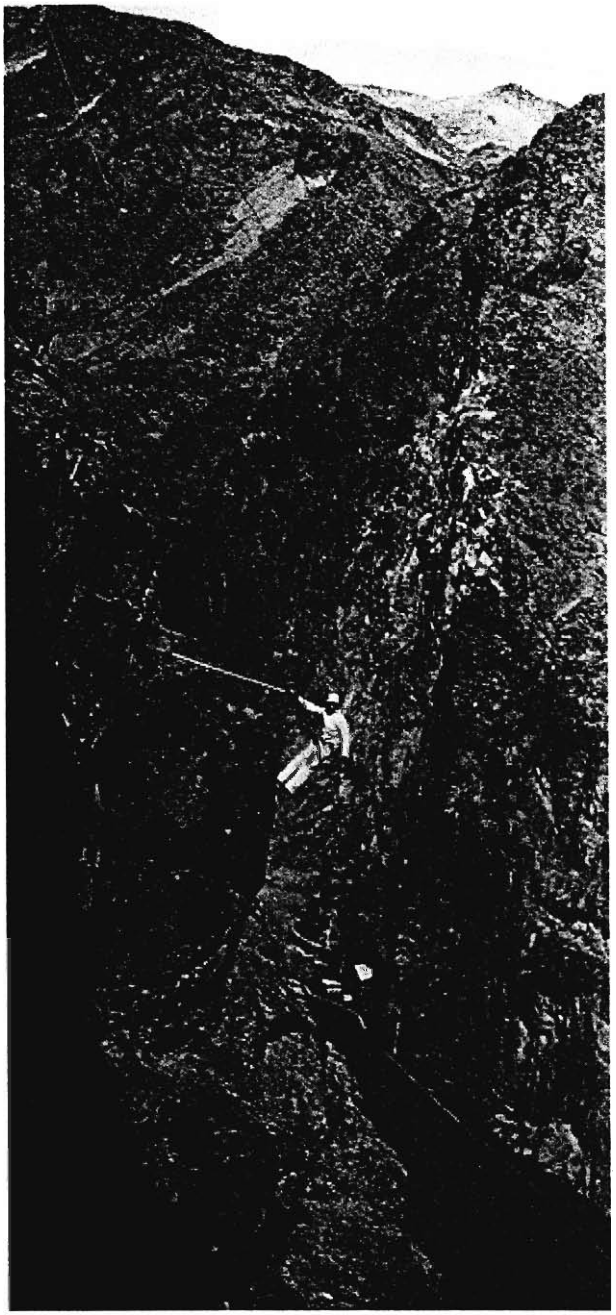

Figure 8: Wall scalers worked to remove loose rocks from the canyon walls that might fall once dam construction began. (*The Grand Colorado: The Story of a River and Its Canyons*, p.184)

Figure 9: The monumental task of running a construction site from the bottom of a 1,000 foot deep canyon. (*The Grand Colorado: The Story of a River and Its Canyons,* p.186)

4 EFFECTS OF DAMS AND WATER PROJECTS

4.1 Introduction

Dam construction in the United States was slow until the 1930s as only 1600 had been constructed and in use. By 1970 that number had increased to over 45,000. Some clarification of the details of dam construction can provide the reader some understanding of why there was a big push for large and small dams from the 1930s to the 1950s, and why there isn't the same push today.

Advances in data collection systems and technology have made predictions and justifications more accurate and easier to make decisions with to a skeptical public.

4.2 Dam Criteria and Consequences

> *"This dream, like most technological dreams, had the power to diminish as well as enrich the quality of man's life. The conquest of the Colorado stands as an embodiment of what we are capable of destroying even as we create."* [8]

When approached from an engineering point of view, the purpose of all water is to improve conditions for man. By establishing a list of selection criteria, the qualification of a possible dam site or design can be determined:

Selection Criteria

- Economic factors (cost vs. benefit)
- Dam functions
- Physical factors
- Environmental concerns
- Social considerations

The economic potential of water is usually never seen without the construction of a dam or diversion. From an economic standpoint, water acts as an intermediate good used to generate power and irrigate fields and as a final good when used for recreation and navigation. In either case, the final good can be directly and indirectly measured by the amount of happiness or utility that can be produced. It is much easier to assess an intermediate good, however, since there is a final product with a material worth or value. This can also lead to arguments about who will be the final beneficiary of the final goods that will be produced by the construction of such a water project.

Dams built with Federal tax dollars are considered by most to be a means for a few to get rich at the expense of many. However, this short sighted observation should be taking into consideration that fact that the government collects taxes not only on the goods produced from these final projects (i.e. products created through irrigation, industry, and municipal uses), but also on hidden items and sales that did not previously exist (i.e. gas for boats used for recreation, and cars that carry people to work at their new jobs, fishing licenses, food). When looking at the big picture, it becomes obvious that the economy of the entire region in which these projects are built will benefit both directly and indirectly.

Dam functions must also be determined as the construction of a diversion dam in an area that could also benefit from the production of electricity is extremely wasteful. Multi-purpose dams have a wide range of possible uses and can open markets and opportunities in places that they never existed:

Possible functions

- Steady water supply (municipal, industrial, domestic)
- Irrigation and drainage
- Flood control
- Upstream navigation within reservoir
- Recreation
- Hydroelectric power (noise and air pollution free)
- Salinity repulsion in river deltas
- Water quality improvement
- Fishery maintenance/improvement

Sufficient water storage for a steady supply, irrigation requirements, flood control, upstream navigation within reservoir, and recreation will depend on the site at which it is located and the current and future needs.

Hydroelectric power can be easily implemented in the construction of a new dam is be an enormous benefit to the surrounding region. The International Commission of Large Dams (ICOLD) reports that the 36,000 dams worldwide with height of more than 15 meters (50 feet) are responsible for the production of 20% of electricity, or 7% of all the energy used (including energy produced by means such as oil, coal, solar, and wind). Hydropower is much more efficient when considering space required when compared to solar and wind power, and of course there are no gas emissions as with the

use of oil and coal. It is a renewable resource that will never be used up, and there is also no noise pollution during power generation.

As sediment collects at the mouth of a reservoir it can form a delta that can be used for salinity repulsion if designed properly. The fertilizers and heavy metals that are typically the waste products of irrigation and industry can collect in these waterways as the river slows and they are deposited. Plants that grow will take in the excess fertilizers and other byproducts leaving the water entering the reservoir much cleaner at little to no cost.

Additional water treatment facilities located at dam sites can make use of the water stored in the reservoir by eliminating the need for it to be pumped. Dams are large structures and designs can easily accommodate water treatment facilities if necessary.

Fishery maintenance and improvement can increase the recreational capabilities of the reservoir as sport fish such as bass and trout can be added frequently to attract anglers and promote the usage of boats and water sports.

The location of sources of human consumptive and non-consumptive uses must be first classified so that it will be known if the limitations of a site will be within the planned use for a dam:

- Instream: navigation, hydroelectric power, recreation, waste dilution
- Offstream: municipal, agricultural, industrial

Instream uses of water committed to a project are beneficial in that they do not consume the water; the water is there before it is used, and is still there after it has been used. Offstream uses are consumptive, however, and are the source of concern as withdrawals can cause problems downstream for those who would be using it, or could use it in the future. Early classification of these of usages may prove a dam site impractical for construction.

The first physical factor to determine is the necessary size for accomplishing economic and functional goals:

Dam size criteria

- River must be able to fill and maintain adequate reservoir levels (including fluctuations in withdrawals and losses)
- Ability to withstand/dissipate flooding
- Sufficient storage during dry seasons
- Must contain wind-tides and waves
- Losses through evaporation and seepage

- Sedimentation

Many project proposals along the Colorado River have been rejected during the last 40 years because there simply wasn't enough water to maintain necessary reservoir levels due to upstream usage and downstream requirements. Water storage capacities are very important to the size requirements of the reservoir, and thus to the dam itself. Keeping with examples from the Colorado, in 1986 the spillways on either side of the Hoover Dam were used for the first time in its 50 years of operation due to unusually high flood levels during the spring thaw. The Glen Canyon Dam was almost lost as well when flooding occurred in 1991 in the upper basin, which would have been a catastrophic failure of proportions never seen before. Along with maximum storage capacities, minimum storage capabilities must also be determined. Once water supplies have been established and are in full use, people depend on them and they must continue during dry seasons. Hoover Dam retains two years of water flow from the Colorado River.

The containment of wind-tides and waves must not be overlooked as unusually high winds can cause nearby flooding and unplanned stresses to reservoir walls. Tides and waves pushed into the dam can also cause unplanned stresses and fatigue which can lead to failure.

Losses through evaporation and seepage prove to be beneficial or detrimental to a reservoir. It is estimated that in the United States alone over 25 million acre-feet of water is lost to evaporation every year. Losses are desirable if flood containment is the sole purpose of the dam, but there is no technology available to prevent this and the extent to which evaporation is going affect a reservoir will depend on the climate of the environment of the dam site (attempts to coat the surface of Lake Mead with an oil-slick type of coating proved futile as it was quickly broken up by wind). Seepage can be predicted by taking the type of material of the retaining walls which will hold back the reservoir. Sometimes seepage is desirable to recharge ground water supplies and for flood control. But typically it is avoided as ground water levels can flood septic systems and can undermine dam and retaining wall bases. Economic losses are also the result of large amounts of seepage as the water draining from the reservoir is not producing hydropower or irrigating crops. Fixes include linings, grout, etc., but are enormous tasks which are time consuming, costly, and there are no guarantees that they will work.

Silt carried by a river is typically the determining factor for the life-expectancy of a dam by filling and reducing the storage capacity of the reservoir. Sediment can be

carried into a reservoir in two forms: suspended and bedload. Suspended sediment is usually the finer sands and debris that is carried by fast moving water and settles as the water slows and becomes still. Bedload is the big debris, such as boulders and tree trunks that is carried and deposited at the entry to a reservoir. Either way, the usual process of sedimentation is that a delta forms at inlet and grows toward outlet (which can also cause upstream flooding). Some methods of dealing with sedimentation are sediment detention basins (such as those in Lake Mead and lake Powell), small dams can be dredged and low level outlets can flush out their reservoirs regularly most, but for the most part dams are planned to withstand 100 years of sedimentation as there are no economic means of removal before requiring replacement.

Several results of sedimentation in these 100-year dams can prove to be beneficial however. Reduced seepage losses through the buildup of substance along bottom of the reservoir can improve operational efficiency. Fish breeding ponds and waterfowl refuges at the inlets where deltas have formed can also bring in added recreational benefits. Careful planning of how to use or avoid sedimentation can be crucial to the longevity and cost-benefit results of a dam

These concerns account for the butter and guns point of view as to whether or not a water project should be built. As technology improved and life in America became easier socially and economically toward the 1950s, the environmental movement began and with it, a dramatic decrease in dam construction. Also, there has been a change in mentality toward what is important as opposed to what was important for the first half of the century. The people involved in water projects during the first half of the century did what they felt needed to be done. But the facts are that dams cause a huge impact to the surrounding environment and the results are very obvious:

Environmental concerns

- Fowl migration routes and spawning grounds disappear
- Less sediment downstream (no replenishment of wetlands and beaches)
- Downstream water polluted, increased salinity, and/or poor oxygen
- Recreation
- Scenic
- Land that isn't/couldn't be used for forestry, agriculture, roads, etc.)
- Archeological/Historical

Plants and animals that are indigenous to the region must learn to cope with the dramatic change to their setting with the construction of any dam. Through the economic benefits of recreational use of the reservoir, the introduction of wildlife that is not indigenous to the area will also challenge and make its presence in the area as well. Regular floods also leave sediment, replenish wetlands, and flush out areas downstream and local ecosystems depend on this.

The downstream water quality typically suffers as well after sitting in a reservoir. Polluted runoff from industrial, municipal, and agricultural usage typically occurs near the water storage and makes its way back into the reservoir. The increase in fertilizer and heavy metals in the reservoir makes large amounts of algae to take over which can deplete oxygen supplies and choke off the local habitat. Oxygen is also necessary for the oxidation of salts, chemicals, and animal and vegetable wastes and decay. In a reservoir, the water is still and unable to oxidize these natural and unnatural by-products through the gaseous venting and recharging that occurs when it is moving.

Other factors are related to human usage and appeal and are considered social issues. The effects on a natural habitat from a reservoir created for extended recreational use can have can be devastating. Along with the effects on the natural environment, there are also factors such as what a reservoir is going to have on the natural scenery and land that could be used for forestry or the construction of new neighborhoods and roads will be lying idle under several thousands of gallons of water. Archeological and historical relics will also be flooded behind the dam and lost forever.

At beginning of the 21st century, human life is considered extremely valuable. Factors that are known and not known with these projects are also better understood, not only by those constructing them, but also by the general public. However, even with all the advances in technology that are currently implemented for monitoring usage, it is still not known where all the water from the Colorado River goes. What used to reach the Gulf of California is known, and how much flows through the dams, diversions, and canals is also known. But while calculations are constantly run to determine evaporation losses, but little to nothing is recorded on ground water.

4.3 Logistics of the Lower Colorado River System

The Colorado River has been split into two regions to improve the efficiency of project planning and river management: the Upper Basin which is based in Salt Lake City, UT, and the Lower Basin in Boulder City, NM. The Lower Colorado River Basin is

where most of the water projects have taken place. The Lower Colorado (LC) joined the states of Arizona, California, New Mexico, Nevada, and Utah together so that water projects and planning could be made with all five being taken into consideration without the complications of state borders separating them. This also accounts for the last 688 miles of the river and 7.5 million acre-feet of water per year.

The scale of the use of the last half of the Colorado River to support life and a strong economy is staggering. The river is responsible for supplying water to some of the largest, and definitely the driest areas in the United States. 30 million people, or 1 in 10 Americans, get their water or power from the Colorado (3 of 4 Arizonians) through a complex network of dams, diversions, canals, aqueducts, and water pumps that can best be described by simply listing out the numbers:

- 322 reservoirs are formed by diversions and dams on or near the river.
- 350 diversion dams deliver over 900,000 acre-feet of water, of which 450,000 is returned to be used again.
- 11,700,000 acre-feet pass through Hoover Dam every year, but only 3 million make it to Mexico.
- 15,000 miles of canals.
- More than 50 hydroelectric powerplants produce 10 billion kilowatt-hours of electricity.
- Over 150,000 farms require 4 million acre-feet of water every year for the irrigation of 1.8 million acres of land in the middle of the desert.
- 60% of the vegetation and 25% of the fruits and nuts grown in the United States comes from crops irrigated by the Colorado River's water.
- In Arizona only 0.32% of the land is covered by water, yet there are 190,000 pools, 150,000 boat owners, and 325,000 anglers.
- 1.5 million acre-feet of water is diverted for use by the Central Arizona project through 336 miles of canals and tunnels, and must be pumped 4000 vertical feet to reach remote locations.
- Water delivered by CAP to Phoenix contains 650ppm of dissolved solids. By comparison, the Verde River, which is considered a clear mountain stream, regularly contains 80ppm, 150-250 during the spring runoff. Tucson claims to have a TDS (Total Dissolved Solids) of 265ppm, but water has been tested with more than 500ppm.

- The Colorado River sustained over 30 million Americans who use water for domestic purposes:
    - A typical load of laundry takes 40 gallons of water.
    - The average pool takes 25,000 gallons.
    - Flushing a toilet once uses on average 2-3 gallons.

In the summer months, where not to long ago was a half mile wide delta that was not navigable as the tides were changing, it is not unusual for the Colorado River to dry up in the sands of Mexico long before it ever comes close to seeing the ocean. With water usage so thorough over the course of its 1700-mile journey and no plans to increase the amount of water in the river, the efficiency of its usage must be improved to make more water available.

4.4 Evaporation Data Collection

According to the U.S. Supreme Court Decree of 1964 in *Arizona v. California*, data of the use and distribution of diversions, return flows, and withdrawals is to be collected, and recorded annually, and logged with the Bureau of Reclamation. As a result, the lower Colorado River Accounting System (LCRAS), was formed in the late 1980's, and the first final report was delivered to the Secretary of the Interior. Reports have been made from 1995-1999, however, at the time of writing only a copy of the 1997 report was able to be obtained (currently efforts are being made to give public access to these reports at the lower Colorado River Basin website: www.lc.usbr.gov) .

Of particular concern to the overall project sponsored by Professor Theodore Crusberg, of which the information obtained in this report will be a part, is data concerning evaporative losses. This data will serve as an example of how LCRAS records and calculates losses within the Colorado River system.

LCRAS calculates the evaporation rates from the surfaces of several lakes along the Colorado River to adjust the water balance equation used to determine inflows and outflows from Hoover Dam to Davis Dam, Davis Dam to Parker Dam, Parker Dam to Imperial Dam, and Imperial Dam to Mexico:

$$Q_{res} = Q_{dif} + T_{rm} + T_{rum} - Q_{ex} - E - CU_d - ET_{pht} - ET_{crop} - \Delta S_r - \Delta S_a$$

Where:

Q_{res} = Residual flow

Q_{dif} = The difference between measured flow at the upstream boundary and the downstream boundary.

T_{rm} = The measured inflows from tributaries.

T_{rum} = Unmeasured flows (based on previous data)

Q_{ex} = Water withdrawals from CAP and the California Aqueduct.

E = Evaporative losses

CU_d = Domestic, municipal, and industrial withdrawals

ET_{pht} = Estimated phreatophyte evapotranspiration (specific crop class)

ET_{crop} = Estimated crop evapotranspiration (corn, cotton, tomatoes, etc.)

ΔS_r = Change in reservoir storage

ΔS_a = Change in aquifer storage (no wells are used as of yet to determine ground water levels, will be studied in the future)

Calculations for open water evaporation rates are calculated daily from AZMET or CIMIS stations along the river. These stations subtract monthly precipitation from the averaged evaporation rate and multiply it by the surface area of the immediate body of water to obtain results measured in acre-feet. Losses from the All-American Canal and CAP are not included in this data, but factors and processes are currently being determined so that future determination of their contribution to overall evaporative losses will be included.

The graphs in Appendix D were created from raw data obtained by the Bureau of Reclamation from several checkpoints, and are an example of how such data can be used to help determine the evaporation rate of the River. As can be seen, a slight increase of evaporation rates can be seen on average over the course of 30 years, as suspected.

5 WATER DISTRIBUTION LAWS

5.1 Introduction

This section will prove that existing water laws are a result of local and state economies, not aridity. The idea of prior appropriation and the foundation upon which water laws in the West were created by actually began in New England in the early 1800s. Increasing numbers of farms and ranches stressed downstream water supplies and shortages were becoming a growing problem; a system was needed to regulate consumption. The idea of 'prior appropriation' delegated rights to water use to owners of land bordering streams according to who had been established the longest (first come-first serve). This system proved to be sufficient as farmers and ranchers in the northeast didn't require large diversions to compensate the relatively wet climate, unlike that in the west.

Section 5.2 of this chapter will focus on the history of how concepts and processes of water usage delegation in the southwestern United States grew from these laws in the East. Shortly after these laws were in place, their shortcomings became obvious and the threat of overnight monopolies urged an unsuccessful attempt at reform by the newly created Reclamation Service, as described in Section 5.3. Most importantly, it will be shown in Section 5.4 how prior appropriation can be good for starting local economic development, but works against the common good in the long run.

5.2 Creation of Water Laws

The early 1800s showed a changing economy in New England as the young country began to prosper after its initial political ambiguity. The number of cotton mills was growing quickly and views of existing laws were seen as unchangeable, and different interpretations by numerous judges gave inconsistent rulings on who was entitled to use and consumption. Owners of land bordering waters upstream reduced downstream flow by constructing small dams for cotton mills and irrigation systems, while those downstream doing the same slowed upstream flow by creating reservoirs and often flooded available land for water storage. Between 1820-1831, cotton mill production in New England grew over 600% and there were still no laws that explicitly

stated who was entitled to water usage and development along streams and rivers. From 1824 to 1833, more water right cases were heard in courts than the rest of history of common law combined, and gradually favoritism shifted from small farmers to industry and commerce. The quick economic benefits of granting rights to big businesses put political and social pressure on local judges, and proved to be the beginning of an argument that is still being fought to this very day.

In 1844 Massachusetts courts determined that the first to dam a stream or river for irrigation or mining had usage rights over upstream and downstream landowners. This attitude of prior appropriation made water a property that was separate from the land and facilitated monopolies over its use. Large corporations with extensive financial resources could build larger dams and other water projects than small groups of local farmers, and the short-term benefits were quickly justified. However, the idea of equal access and the American way was compromised because of this, and future decisions would be complicated by this early decision.

In the West, prior appropriation proved both convenient and troublesome at the same time as prospectors quickly claimed rights to existing water supplies. Hydraulic mining used in the late 1840s and well into the 1850s was extensively used as dreams of gold and thousands of prospectors poured in. Diverting water to wash away top soil exposed existing and ancient riverbeds and was much quicker than the panning method of sifting for gold. The mining industry needed its own use of water, and constant arguments between miners and farmers over usage made it necessary for the State to step in and make a universal ruling on ownership. In 1857 the California Supreme Court finally recognized the lack of an established water rights system and adapted prior appropriation.

Congress had still not voted on the states' use of prior appropriation laws simply because they knew nothing of mining or the Western water issue, and the law making process was stalled for these very reasons. In 1866, 1870 and 1877 laws were passed allowing the use and diversion of water through public lands for mining, agriculture, and other uses. States all across the Union were already upholding prior appropriation, and Congress had no alternative but to support them. It was common knowledge that prior appropriation was more of a necessary evil than a practical, long-term solution, but big companies had the courts tied up with loopholes and extensive resources devoted to this

purpose. It was a solution, however, and no one could come up with a better answer. Despite rejections from people such as John Wesley Powell against Prior appropriation, Powell claiming that it would take "generations" to take rights away from water use owners, it became law.

By the 1870s-1880s, Western engineers began to warn about the shift of water usage from mining to agricultural purposes, and how this would affect the local and state economies. Prior appropriation was creating short-term monopolies within an area and was doing little for the long-term planning of new communities. Prices for renting or obtaining usage privileges are set by the owner and can be changed at will as he or she pleases. Typically, large companies would come in and claim huge amounts of water ownership, and would carry little regard for the communities which used the water that they were renting out. For a small farming community where the appropriators also used the water for their own purposes, chances are that efforts would be made for long development of canals, irrigation ditches, etc. The problem with having large companies as the appropriators is that they are dissociated from the immediate problems of the communities (and disinterested), and do little other than collect the rent due to them for their water.

The California, Colorado, Arizona, and other basin states have economies based on mining and farming, and even back at the turn of the century it proved to be difficult to take away or modify prior appropriation rights. Reform was attempted on three separate occasions during the 1870s-1880s to give more control to the states and to bring some of the money in that was going to these big businesses through sale and lease of existing water rights.

The first attempt came with the Congressional acceptance of prior appropriation when details laid out determined that it was the responsibility of the states to run dams and canals along waterways, and therefore their right and responsibility to sell or lease this water to individual consumers ('equal access'). California feared both big government and big business, but at the same time didn't have the financial capacity to run and maintain the system. This plan appeared to take care of this situation from both ends, but was fought the whole way by businesses and was never fully implemented.

The next attempt came with the California legislature's adoption of the Wright Act in 1887. Through this plan, the state would be organized into districts, and taxes collected within each would be used directly to maintain or build new dams, irrigation systems, canals, etc. This plan was never meant to end the big investment firms or their tactics, but it did put a lot of pressure on the courts in favor of the smaller farmers. District planning and projects were given more exposure, and judges were now able to make decisions.

The final attempt was more of an issue of the amount of paperwork necessary for prior appropriation. Paperwork is, without a doubt, a friend of big business when lawsuits are concerned. Large law teams were formed even back in the late 1800s to tie up courts and prosecutors in paperwork and loopholes to delay a decision or to even win a case. Without such steps in reform, the prosperity known in the West today would not exist.

Prior appropriation is a great economic incentive and opportunity, but it is just too inefficient to split up this limited resource: the only requirement was that whomever was granted the right to use an amount of water was that they be able to put it to "beneficial use." Manufacturers, farmers, power companies, miners, and cities all claimed more water than they needed to secure as much of a supply as they could for future use. This system did nothing to encourage or enforce efficient use consumptive practice. Farmers were given more or less water based on such things as political friends and how much they *thought* they might use or expand in the future. Even the notorious 160-acre rule had its loopholes in that farmers were given the rights to enough water to irrigate 160 acres of land, but were only responsible for the development of 60 acres. The very nature of capitalism would almost demand that one in this situation sit on that additional 100 acres and sell the extra water. The government, of course, was sitting on all this wasted resource and letting others get rich off of it, but cries of big government prevented adequate funding and human resources that would have been made possible by increased taxes to set up a large scale management of this prospect and a system that was more fair and provided equal opportunity.

The courts were the other stumbling block in this situation. Lack of financial resources and research meant that courts had no knowledge of stream flow data, how much water was actually being used by farmers and others, or how much was even

needed for different crops and mining techniques. The word of 'interested witnesses' and parties involved were all that was available, and since record keeping was not of paramount significance, different courts gave different amounts of water for the same crops. By the late 1880s, Colorado River water was given out for five times the amount of the capacity of all the ditches along its length. Of course the courts didn't allow anyone to divert an entire river or stream, but a lot of water was wasted and more times than not farmers and miners were forced to take matters into their own hands with violent results. It had been time for change for a long time by this point, and several new developments helped to convince Congress and people back east to change the way that water rights were distributed and accounted for in the West.

The drought of 1889-1890 in the Great Plains proved how important it was to the United States that irrigation become an established and reliable resource in the West. The decrease in the cattle ranching industry was shifting new and increased interest in agriculture and more people were applying for and complaining about the unfair practices and reduced opportunity being caused by prior appropriation and ignorant courts. Then new attention was brought from Congress from California's Wright Act and John Wesley Powell and United States Geological Service's report on arid West and their warnings about the fragile nature of the environment.

The nationwide depression that lasted from 1893-1897 also put Americans in fear of a class war and revolution (as discussed in Chapter 3). William Ellsworth Smythe, editor of *The Irrigation Age* magazine and big advocate of reclamation, had this to say about the time:

> "*We are in the midst of a world-wide depression that will be historic. Industries are in total or partial idleness. Millions of people who have formerly added something each Saturday night to their savings accounts are drawing today upon their principal. Tens of thousands are menaced by the real hardship…it almost seems as if there were too many people in this world-as if there were more mouths to feed than food with which to satisfy them. Whether we have reached the crisis of our social and industrial woes, or whether even more dangerous than any yet encountered are still before us, no one can tell. But it seems plain that the world demands some new field for the profitable employment of human*

energies, some field which will not only absorb labor, but reward it, at least, with the means of a living." [9]

Most saw farms as the key to true happiness, much in the same way as the nation looks now to its 'Bible Belt' or 'Heartland' region. Big business was being blamed for the breakup of the family unit and for hurting the chances of small businessmen, and most of all for the nation's non-landowning class. Over 90% of the population was living east of the Mississippi River and overcrowding was becoming a big issue. Hopes were that the irrigation projects that would make life possible and successful would also build a sense of community with locals paying for them as a community, and holding maintenance, repair, and everyday operation as a community (common water supply/system). This would lead to common banking, markets, manufacturing; pure capitalism with no government involvement. New methods of *intense agriculture* would make 20-25 acre farms capable of offering a sustainable living, and problems such as loneliness and isolation would cure themselves with these close-knit societies. Irrigation was seen as the key, and word of the abuse of the system in place in the West was slowly making its way back East.

5.3 First Attempts at Reform

The first funding for policy reform came for crop irrigation studies in the 1890s. Most of the problems with the courts estimating the water required for distribution was that not even the farmers knew how much they should be watering particular crops. These studies also looked into the irrigation systems in current use. 19th century irrigation systems were very inefficient in that huge amounts of water were lost to seepage and evaporation. As can be imagined, it was quickly verified that the longer and smaller canal is, the more water would be lost. In 1903 the Secretary of Agriculture estimated that canals of 100 cubic feet per second (cfs) lost 1% of their volume per mile, and for 25-50 cfs, that number jumped to over 5%.

While the findings of such studies did help to streamline the water delivery and allocation processes, it did little to change the way that water rights were bought, sold, and hoarded by big businesses. Several alternatives to prior appropriation had also been proposed during this time, including a system that would mimic the fairer Mexican approach to distribution, but these were all fought viciously and defeated one by one.

The length of time of the legal process behind the distribution of water was taking precedence over efficiency or justice, especially in the summer and during dry seasons when the need for water in the arid regions were desperate. The idea of being able to create one Federal law became slim at best as huge variations in climate, geography, soils, and crops planted, plus most in Washington D.C. were from the East and had no idea about desert or life in the parched region.

Elwood Mead, head of the Office of Irrigation Investigations within the Department of Agriculture knew of the situation from first hand experience as he had lived in the West his entire life. He believed that drastic updating and overhaul of the current system would cause an economic crisis in the developing economies of these young states, but at the same time fought to keep the ultimate power of water right distribution at the state level. He worked with states within the existing guidelines and pushed for the start of state engineering offices to keep and maintain records of water ownership, and the use state employed "Watermasters" to distribute water, keep records of its use, and to settle disagreements according to new commissions like the ones he formed when he drafted Wyoming's water code in 1889 and 1890.

President Theodore Roosevelt did not support any policy that either put the entire control of water regulation, distribution, and projects in states' hands, one that would let states decide where there was a need for Federal reservoirs, or for one that would let the states design Federal projects, but regain control over the water after they were finished. States argued that new land to be reclaimed was far away from Washington D.C. and Federal projects in the region would overlook existing and future needs of farmers and the dangers of floods. By 1902 only Colorado, Wyoming, and Nebraska would have formal procedures on water regulation and distribution, and of them only Wyoming and Nebraska would have the administrative ability to resolve conflicts between users. On top of these problems, there was still no credible knowledge of the amount of water available from the Colorado River still. Data was in the process of being collected, but this raw data and the methods used to collect it were still debatable, if they had been correctly filed in the first place. There were a lot of farmers who 'owned' much more water than they could productively use, and there were a lot of court cases between them and people who wanted to use that water without having to pay for it.

The 1902 Reclamation Act was signed in so that it would obey and enforce federal and state laws that were already in place, and in the process put the U.S. Reclamation Service in a tough situation. The Reclamation Act stated that neither the state or Federal Government could give a farmer more water than needed simply because his ancestors secured rights and called for conservation and fair distribution, but never produced much for results with it. The Reclamation Service went so far as to threaten to take control of some or all of Western water surpluses, but politicians, land developers, and farmers fought back saying that this would lead to a government monopoly of control over their fates. Most states needed Federal funding and resources, however, to build and maintain water projects such as dams and canals, but felt that they couldn't give up control once in place (this was the process used for the railroads and industry back in the East, what was the difference here?).

The fact that the Reclamation Service had to work within these outdated state laws meant that no one could be denied if they wanted to use the water for 'economically useful purposes'. Big companies used most of the water in the summer when everyone else needed it too. Conflicts such as these couldn't be fixed from the Federal level because states had already written laws and had been administering water rights for years. Up until the Civil War, all land within the United States' boundaries was considered to be property of the Federal Government, but the states had already made their claim to the water and the Reclamation Service was left with no other option but to give them an ultimatum: resolve all the existing conflicts or it wouldn't be able to build any projects.

In 1903, Nevada came forward saying that they were willing to cooperate at all costs. The state economy had been on a steady decline since the end of the silver rush, and teaming up with the Reclamation Service brought hopes of preferable treatment in the future when deciding new water projects. Nevada created its own state engineering office and appointed a state engineer recommended by the U.S. Geological Service (USGS) and the Secretary of the Interior. Increased efforts were made to determine the state's surplus water and to make detailed lists of water appropriators for the state's records. As a reward, Nevada was awarded the first Federal irrigation project to be completed (Tuckee-Carson Project, 1905), but also gave up much of its control over its own water supply in the process. No one else jumped on the Federal bandwagon

immediately, but in August 1904 Washington and Oregon asked the Reclamation Service for help revising their outdated water laws.

While attempting to help Washington and Oregon, the Reclamation Service set out to draft a water code for the entire arid West, and formally proposed when it had been asking for the entire time: a state engineer's office, centralized records of all water ownership, and to give authority to the courts to resolve conflicts. None of the states were willing to accept this proposal since it both threatened the current order of things, and gave up the state administration's power to solve conflicts (the fear in this was that if the courts were given this power, then the Reclamation Service could then bypass the state in the decision making process). By 1907 the Reclamation Service was out of money and had yet to secure enough water for 25 irrigation projects that were already planned and authorized. They were getting nowhere in the courts and found no convincing the federal and state governments of their ideas on reform, so they began looking for loopholes.

Loose interpretations of the General Appropriations Act of 1897 were first on the hit list. This law stated only that the water in forest reserves and protected land could be used for "domestic, mining, milling, or irrigation purposes, under the laws of the state wherein such forest reservations are situated or under the laws of the United States and the rules and regulations established there under." [10] This basically meant that Congress never gave up its control to the states. Another convenient find of the Reclamation Service was the result of the 1899 U.S. Supreme Court ruling in *United States v. Rio Grande Dam and Irrigation Company* that determined "a State cannot destroy the right of the United States, as the owner of lands bordering on a stream, to the continued flow of its waters; so far at least as may be necessary for the beneficial uses of the government property." [11] Even the Desert land Act of 1877 clearly stated that "for the appropriation and use of the public irrigation, mining, and manufacturing purposes subject to existing rights," but does not say anything about giving up federal sovereignty. [12] It was clear that the progression of ownership of water is from the Federal Government to the individual, and that even though the states didn't own the water, it was their responsibility to maintain records for the Federal Government.

Even with these findings, however, the Reclamation Service still wanted to win political support in the West and only used them to make their intensions clear. In 1904

the Reclamation Service made a public statement that "the States are recognized by the Federal Government as in control of the regulation of the use of water merely because the Federal Government has not undertaken to regulate such matters...the court in the Rio Grande case made it plain that the State laws must give way if ever the Federal Government undertook to resume control." [13] The Court did not say that the Federal Government could claim the entire surplus of a river, or that it could divert waters to another basin, and it was decided not to pursue this issue deeper.

The Reclamation Service continued to closely monitor and participate in any case that was in any way related to water ownership, development, or distribution. While all this was going on, they had managed to buy up a considerable amount of land, which was in direct conflict with what they were entitled to, but it was insurance for the event of some unfavorable rulings that could easily happen in the near future. Through this purchase of land, it was possible for the Reclamation Service to stall state and private irrigation projects by not allowing them on these 'public lands' and making blanket claims on water surrounding potential sites. Over 40 million acres had been purchased between 1902 and 1904, and even though plans were calling for the use of only 3% of this land, the primary reason for it purchase was to block the projects of anyone who could be considered competition (which it was able to do along the Rio Grande and the Colorado River until the late 1920s). These were not popular ways of doing business as the Reclamation Service quickly gained legal rights to ten times the average annual flow of the Colorado River, even though they were not doing much with it.

By 1913 only 20% of these Federal Lands were being irrigated, and the it was obvious that it was time for more water projects and reservoirs. By the late 1920s, the trend of states granting land and water to the Reclamation Service for large projects became common, but so did the legal battles afterward over final control. The Reclamation Service's funding came from the selling of this public land (not from the Treasury), and as the anticipation of projects and Federal control over them came and went, and more and more farmers began defaulting on their loans to the nation, serious money issues became their problem as well.

5.4 Use of Prior Appropriation Continues

The Reclamation Act had been made during the Depression of 1893-1897, and now that the depression was over, there was more interest in the East to save the 'landless men' rather than simply shipping them out West. Reclamation had been seen as a tool for social reform as many saw the simpler farm life as the key to the idea society. "It sought to reclaim 'worthless' lives along with worthless desert soil, and it provided an excellent opportunity for social engineering." [14] The initial failure of the Reclamation Service to obtain land and water use was only one of the reasons that it was not possible to reform the methods of prior appropriation in the early 1900s.

The battles erupted several times during the last century, and really heated up in the 1970s and 1980s, but the 1902 Reclamation Act still ties the hands of the Bureau of Reclamation to this day, and this method of private purchase and sale of water in the West has become a big business. With companies specializing in each state according to specific laws and codes, reform of this practice seems less likely than ever.

5.5 Conclusion

By gaining control over the Colorado River and increasing the usable supply through new technology and construction methods, social focus that was concerned with more immediate/small-scale development and prosperity quickly shifted to a much bigger scale as the initial damage caused by these near-sighted projects caused new problems. It is now possible to concern oneself not only with his or her own immediate chances of survival in this harsh land, but with the overall good of the community as well.

Prior appropriation does nothing to encourage conservation. If a landowner does not use all the water allocated to their purposes, then they risk loosing some of it. The results are waterlogged fields, the build up of salts from over-irrigation, exhausted fishing and recreational streams which in themselves can do wonders to boost a local economy, increase the ground water which can float septic tanks in the surrounding areas, and the increased runoff takes with it important pesticides that must be reapplied to ensure adequate protection to crops. The excuse of looking for economic development as the 'means' to obtain freedom 'ends' is also an outdated concept that is beginning to wear thin with a lot of Americans.

Laws are created with the intensions of having them modified with the changing times. Courts and legal aids make their decisions by looking at rulings in the past along with current law and senior appropriators have been extremely effective in using this to stall reform for the sake of quick returns on the water rights market. The economies of most of the western states' economies are still small in comparison to those in the East, and money for infrastructure and development is harder to come by when compared to the small areas and dense population in the East. However, these numbers are beginning to grow much closer together now, and the dangers of an economic crisis started by the changing of water distribution policy is growing less likely.

CONCLUSION

Technology continues to influence the way society justifies its actions and situation. As the Spanish first came and brutally conquered almost everyone they came in contact with, it was justified because they were strong militarily. The exact opposite was true for the Pueblos who concentrated entirely on developing technology for their survival rather than battle. As a result, they were the ones who were able to survive and flourish in the desert, not the Spanish.

As the American settlers pushed west in the 1800s, there was no refrigeration, motorized transportation, and little if any communication with others. The survival rate was dismal because of their inability to warn each other of flash floods, or to get help when their farms were failing. By the turn of the century big changes were coming quick as the start of the Industrial Revolution encouraged large scale projects with improved steel and concrete production facilities and farther reaching railroads.

The new engineering power that managed to overwhelm man even as he used it also gave him a sense of paranoia toward it. The amounts of money, power, and control that were being produced by the industrial machine made it possible for the annual incomes of individuals to rival that of entire nations. The public began to look again to the simpler life of farm communities to restore the values and decency that many had known not too long before. But there was no stopping the advancement of science and technology, and within a matter of decades, moving to the arid lands of the American deserts became no more difficult than moving anywhere else in the country. Without the Bureau of Reclamation and the water projects they developed, the West would know none of the prosperity that it does today.

From 1945-1990 the population grew from 590,000 to 3.67 million, and this number is quickly rising. An article in a 1933 issue of Fortune magazine called the West, "...as parched and barren a patch of wind-swept rocky desert as can be found." [15] If he were able to see the migration to the region that is still happening today, then he might take back that statement. Following these technological and scientific successes and failures, the public attitude began to shift in a different way for the first time in history.

Perhaps the Indians were the real environmentalists since they were able to survive with nature and didn't feel the need to constantly do battle with it. The aggressive nature of the Western civilization was completely the opposite in that for the

Europeans to survive, they had to be able to defend themselves against constant attacks from nomadic tribes and hostile neighbors. Great advances in technology used for military purposes has always proceeded ahead of those which merely promoted survival, such as that by the Indians in the West, and because of this basic survival of the white man was compromised. By the 1950s, Americans in the West finally had survival figured out for the most part and began to focus on environmental concerns. Advances in dam building, and industrial and agricultural practices made lives more comfortable and freed up time for people to look around. In today's increasingly vicious capitalist economy, technology is making great strides in manufacturing and innovative sources of entertainment. However, if Hoover Dam were proposed today, it would be wholeheartedly rejected by environmental activists who would point out specific unknowns such as the increase in water in the air from evaporative losses and what kind of effects they may have in areas east of the Colorado River.

FUTURE CONSIDERATIONS

Future projects may want to look further into the evapotranspiration losses of crops in the Southwest for a more accurate estimation of the total amount of water lost through evaporation (used with surface evaporation data was available for this report). Contacting Paul Davidson from the Bureau of Reclamation may be useful in this search as he is responsible for supplying the evaporation data used in this report.

The other key consideration that will be made for future project groups is to keep the focus of the report as narrow and detailed as possible. This will allow the project group to explore a certain aspect of this material in much more detail than time allowed on this particular paper.

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FOOTNOTES

[1] *Cadillac Desert: An American Nile, Part II*

[2] Watkins, T.H., *The Grand Colorado: The Story of a River and Its Canyons*, p.76

[3] Watkins, T.H., *The Grand Colorado: The Story of a River and Its Canyons*, p.87

[4] Pisani, Donald, *Water, Land, & Law in the West: The Limits of Public Policy, 1850-1920*, p.151

[5] Espeland, Wendy Nelson, *The Struggle for Water: Politics, Rationality, and Identity of the American Southwest*, p.66

[6] Schnitter, Nicholas J., *A History of Dams: The Useful Pyramids*, p.43

[7] Schnitter, Nicholas J., *A History of Dams: The Useful Pyramids*, p.47

[8] Watkins, T.H., *The Grand Colorado: The Story of a River and Its Canyons*, p.165

[9] Espeland, Wendy Nelson, *The Struggle for Water: Politics, Rationality, and Identity of the American Southwest*, p.181

[10] Pisani, Donald, *Water, Land, & Law in the West: The Limits of Public Policy, 1850-1920*, p.43

[11] Pisani, Donald, *Water, Land, & Law in the West: The Limits of Public Policy, 1850-1920*, p.43

[12] Pisani, Donald, *Water, Land, & Law in the West: The Limits of Public Policy, 1850-1920*, p.44

[13] Pisani, Donald, *Water, Land, & Law in the West: The Limits of Public Policy, 1850-1920*, p.44

[15] Espeland, Wendy Nelson, *The Struggle for Water: Politics, Rationality, and Identity of the American Southwest*, p.180

APPENDIX A: SPANISH SHIPS FROM 15th and 16th CENTURY EXPLORATION

The ships used by the Spanish explorers to cross over to North America and eventually into the Colorado River were not as specialized as one might imagine. Much of the sailors' time was spent pulling the boats up rapids and dislodging them from unseen sandbars. Below are a few pictures and descriptions taken off the internet (http://www.heritage.nf.ca) so the reader can get a better feel of the problems that were encountered during the initial trips along the mighty River:

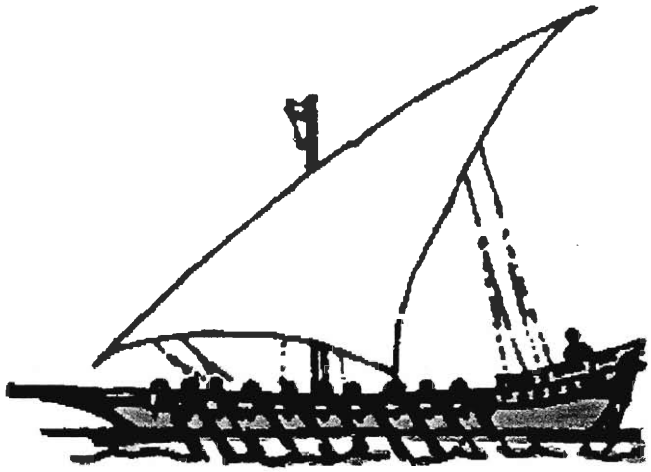


Figure 10: The Frigate was a quick, shallow-bottomed boat that allowed between six and twelve oars and between one and three masts making very quick and useful for scouting missions. *(http://www.heritage.nf.ca)*

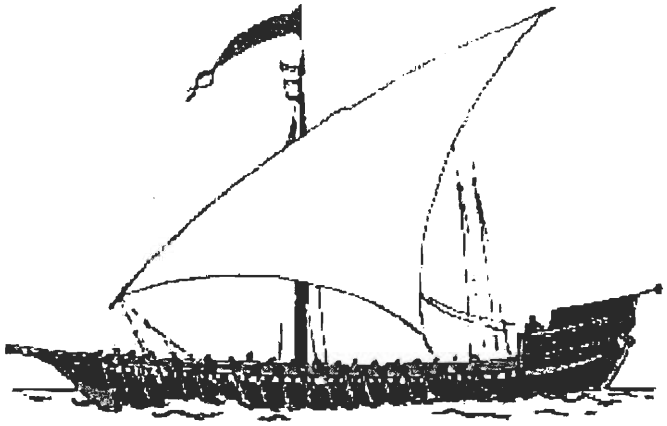


Figure 11: A Brigantine was a slightly larger version of the Frigate, but was partially decked and was widely used in shallow coastal areas due to its flat bottom (typical crew: two sailors to navigate and twenty-two soldiers to row). *(http://www.heritage.nf.ca)*

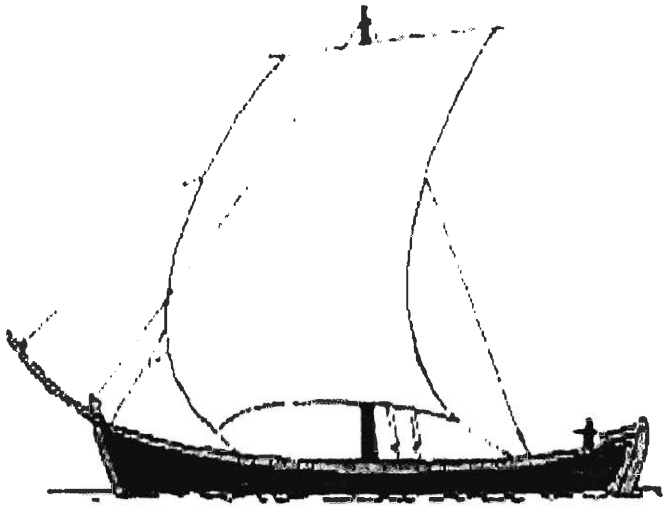


Figure 12: The Barca was used more as a merchant ship as it too had a flat bottom which proved good for shallow coastal navigation, but also because of its increased payload of well over 100 men. *(http://www.heritage.nf.ca)*

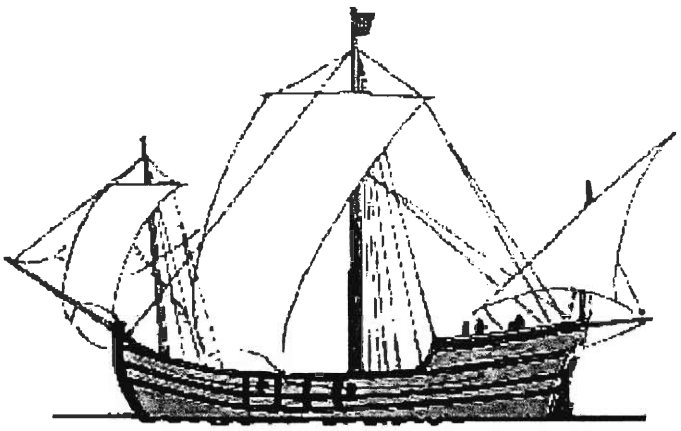


Figure 13: The Caravel was a strong boat (150-300 tons) used in extensive sea travel. Cargo space was limited but its maneuverability was remarkable for a vessel of its size and due to its flat bottom. The *Nina* and *Pinta* were two famous Caravels used on Columbus's maiden voyage to North America. *(http://www.heritage.nf.ca)*

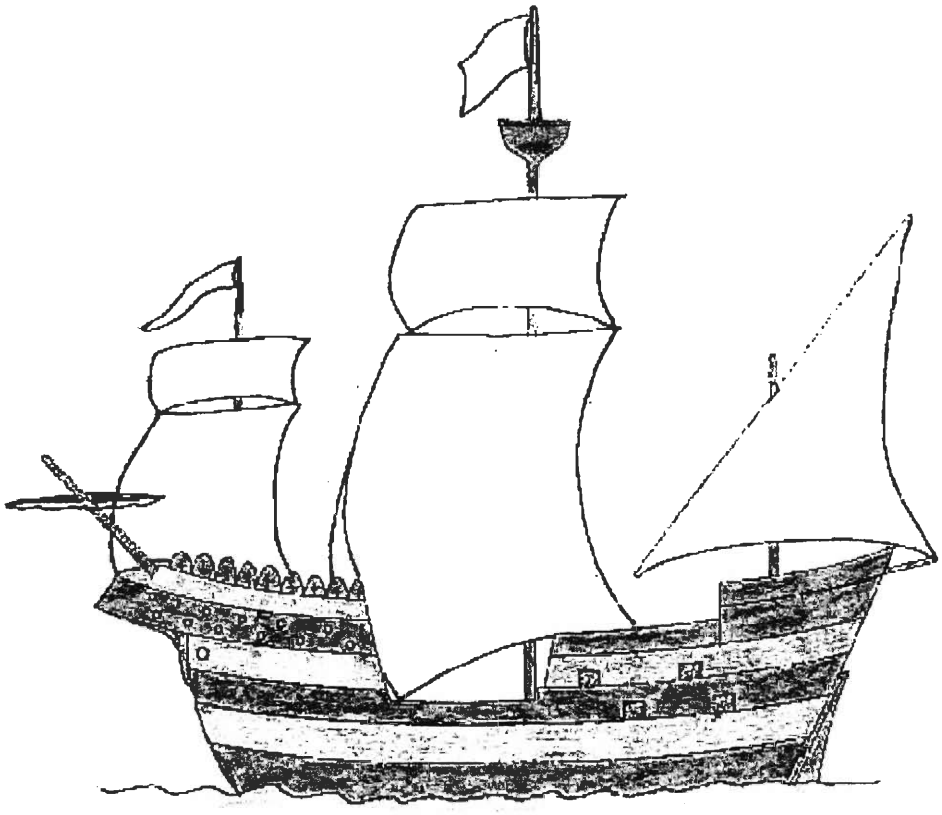


Figure 14: The Nao was another merchant ship which was considerably bigger but structurally similar to the Caravel (200-600 tons), but more closely resembled a Galleon in profile. Capable of carrying large loads of men and artillery quickly and nimbly made the Nao's great ships. The *Santa Maria*, again of Columbus's journey, was a Nao. *(http://www.heritage.nf.ca)*

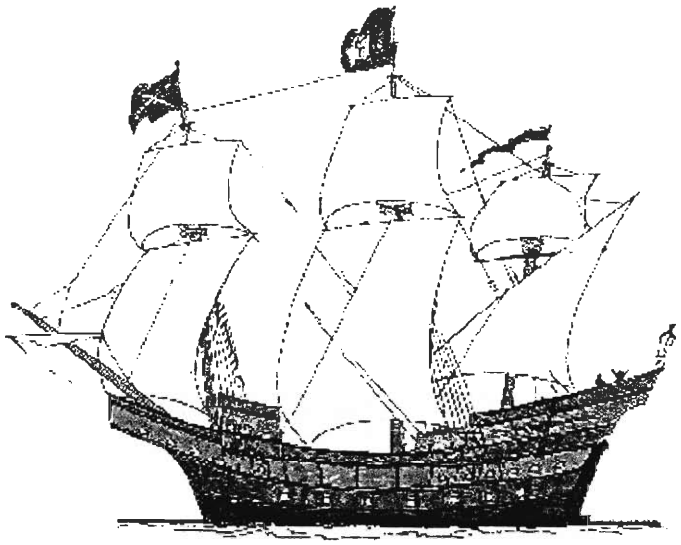


Figure 15: The Galleon became the pride of the Spanish fleet. Initially used for short trips to transport valuable goods (300-600 tons), the Spanish Galleons grew in size to almost 1,200 tons by the time of their North American conquests. ***(http://www.heritage.nf.ca)***

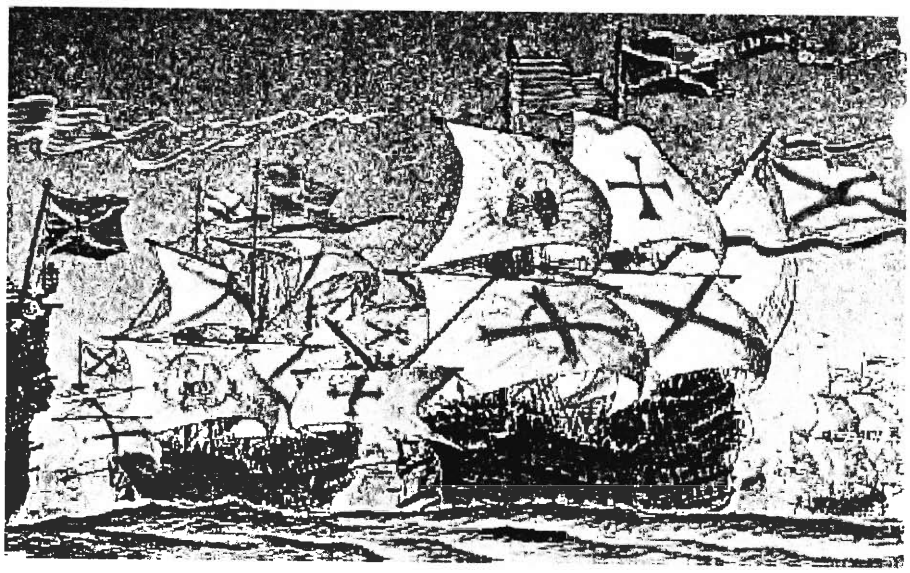


Figure 16: An artist's painting of the 15th and 16th century galleons. *(http://www.heritage.nf.ca)*

APPENDIX B: SPANISH MAPS FROM 15th and 16th CENTURY EXPLORATION

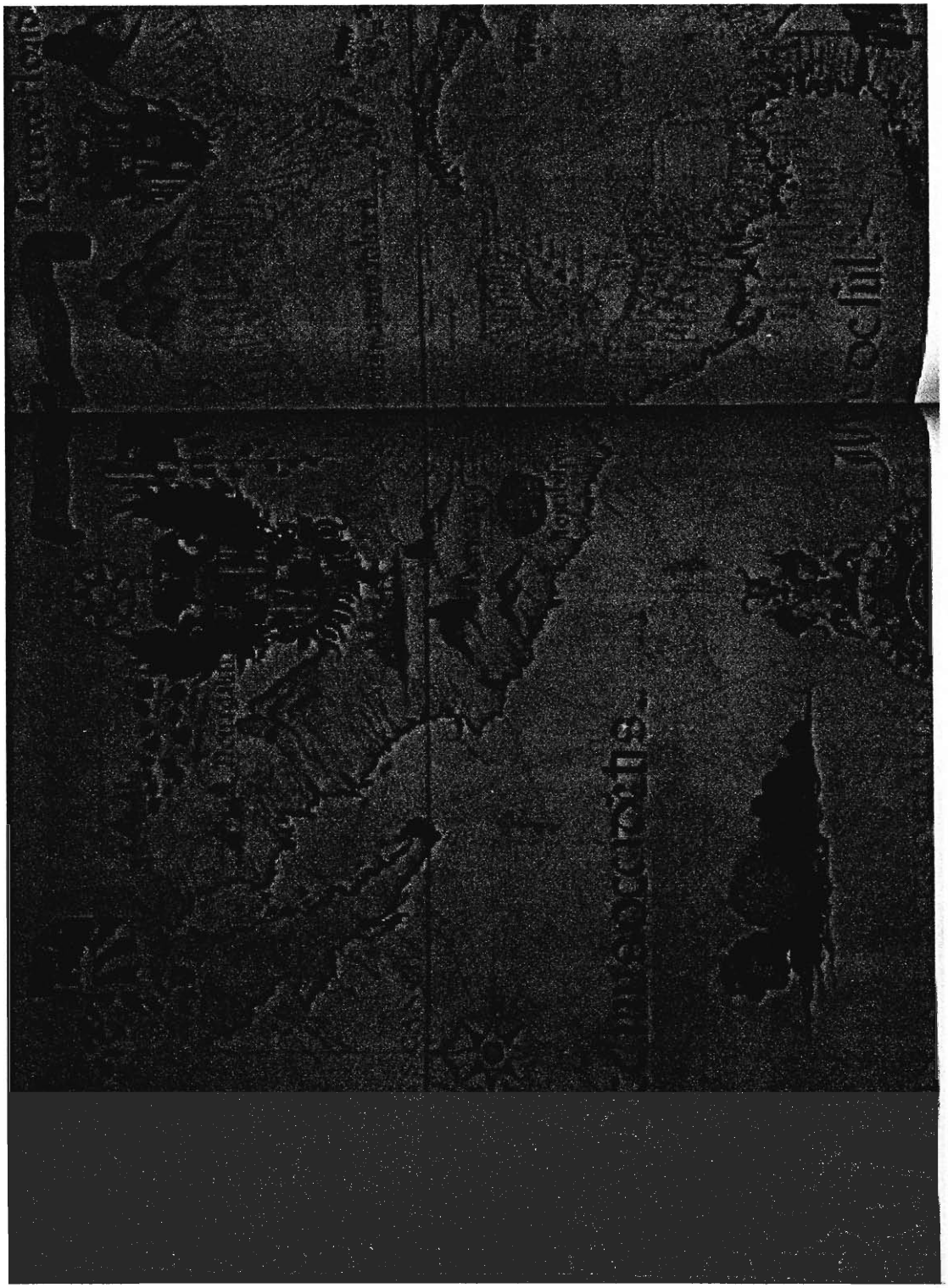


Figure 17 : Spanish map from the late 1500s of the new world. (*The Grand Colorado: The Story of a River and Its Canyons*, p.42-43)

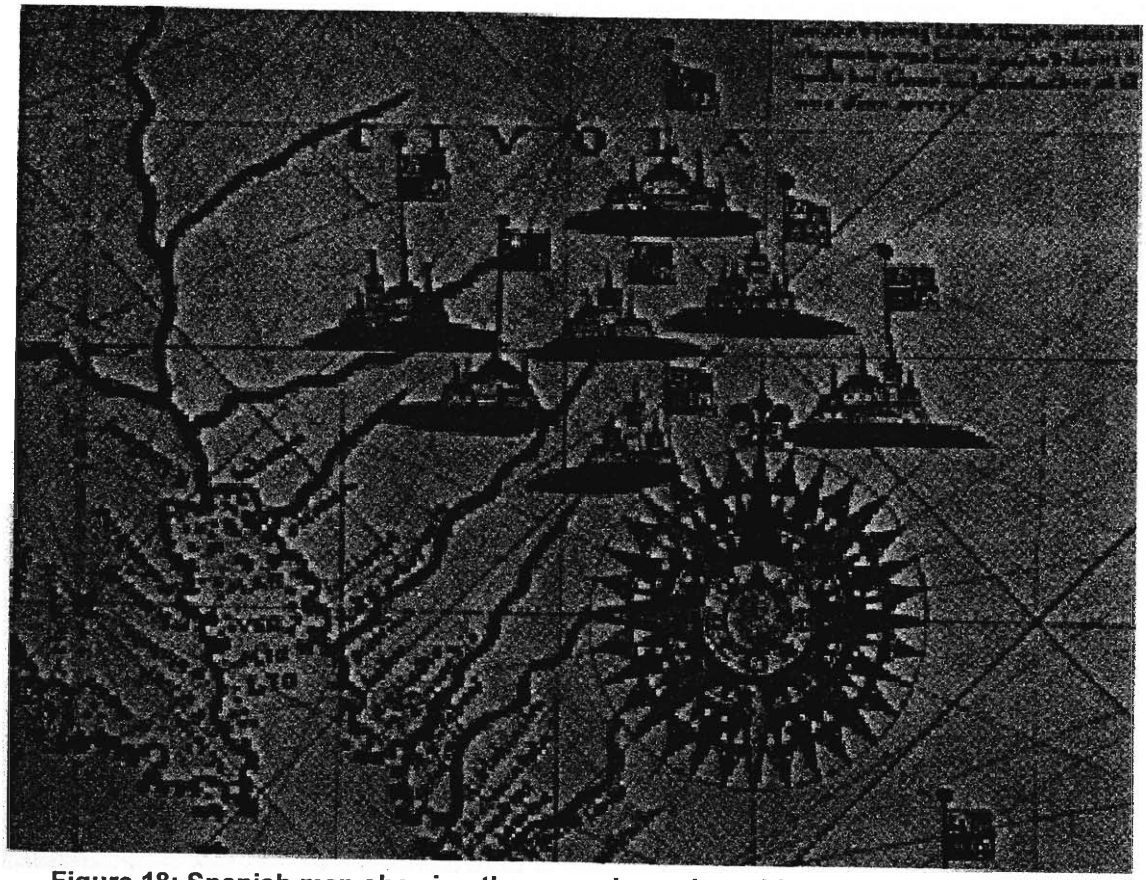


Figure 18: Spanish map showing the seven legendary cities of Cibola. (*The Grand Colorado: The Story of a River and Its Canyons*, p.45)

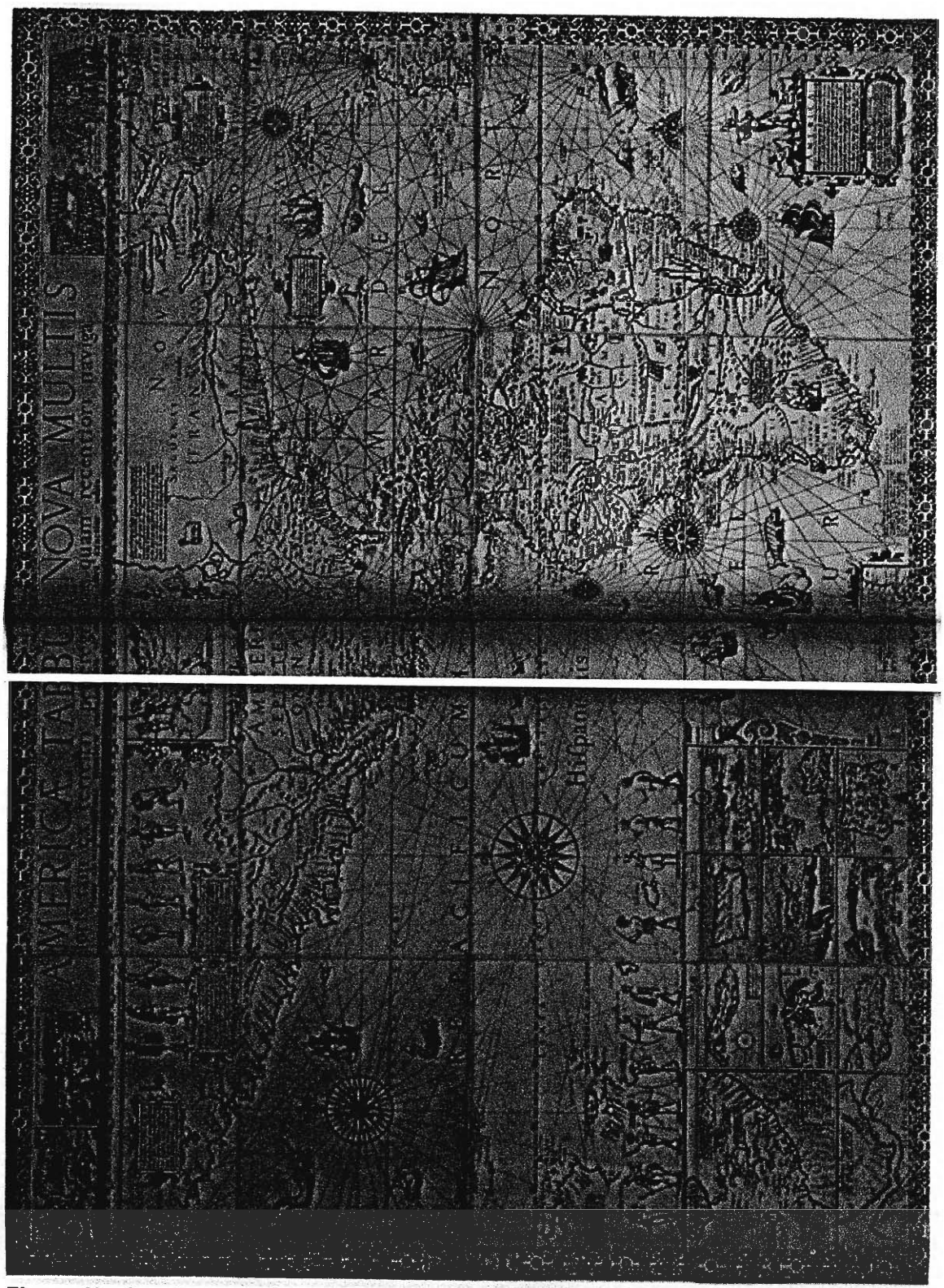


Figure 19 : Spanish map from the early 1600s. (*The Grand Colorado: The Story of a River and Its Canyons*, p.46-47)

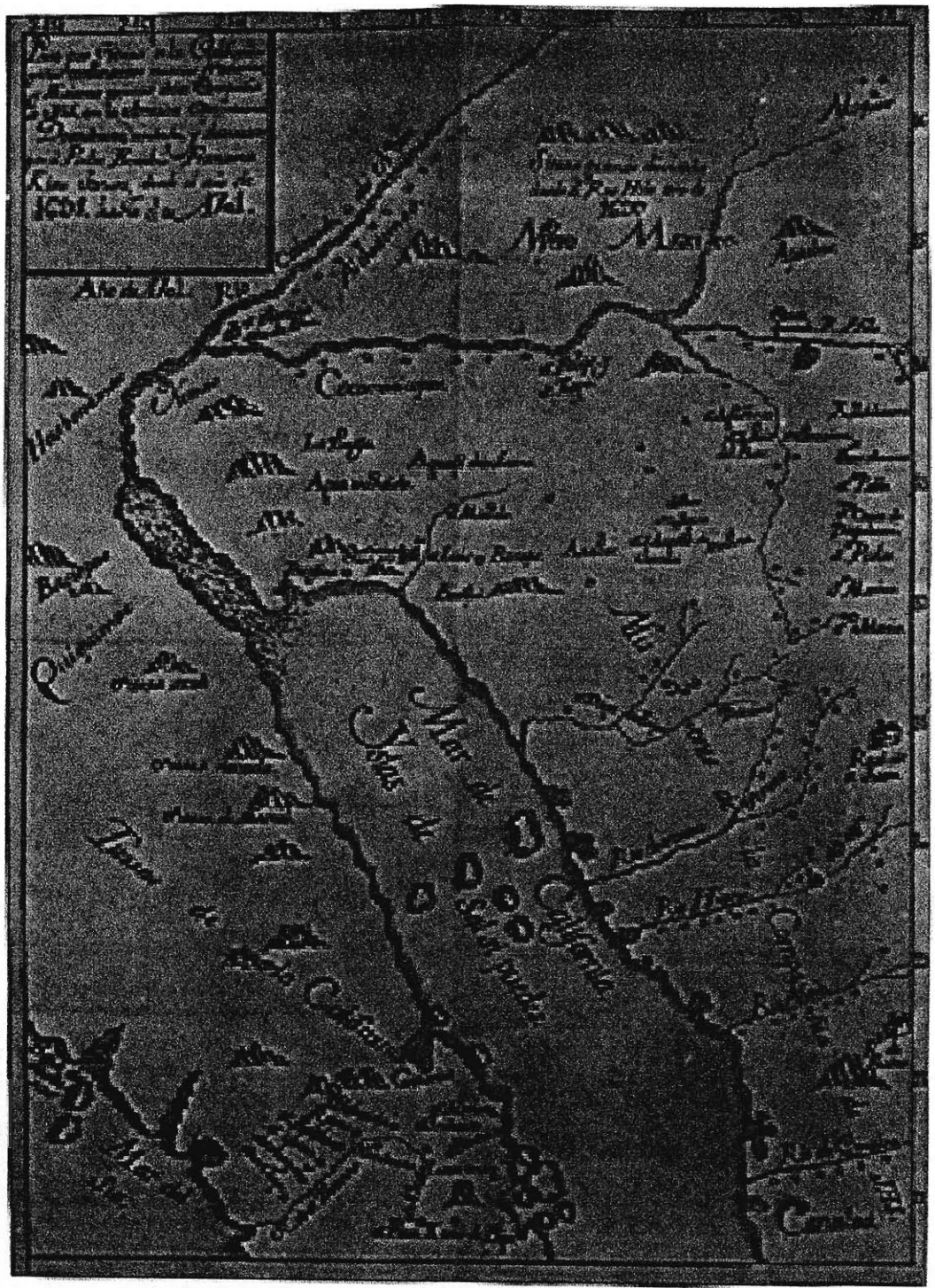


Figure 20: Early Spanish map of the mouth of the Colorado River. (*The Grand Colorado: The Story of a River and Its Canyons*, p.49)

Figure 21: Later version of the Gulf of California still showing California as an island. (*The Grand Colorado: The Story of a River and Its Canyons*, p.52)

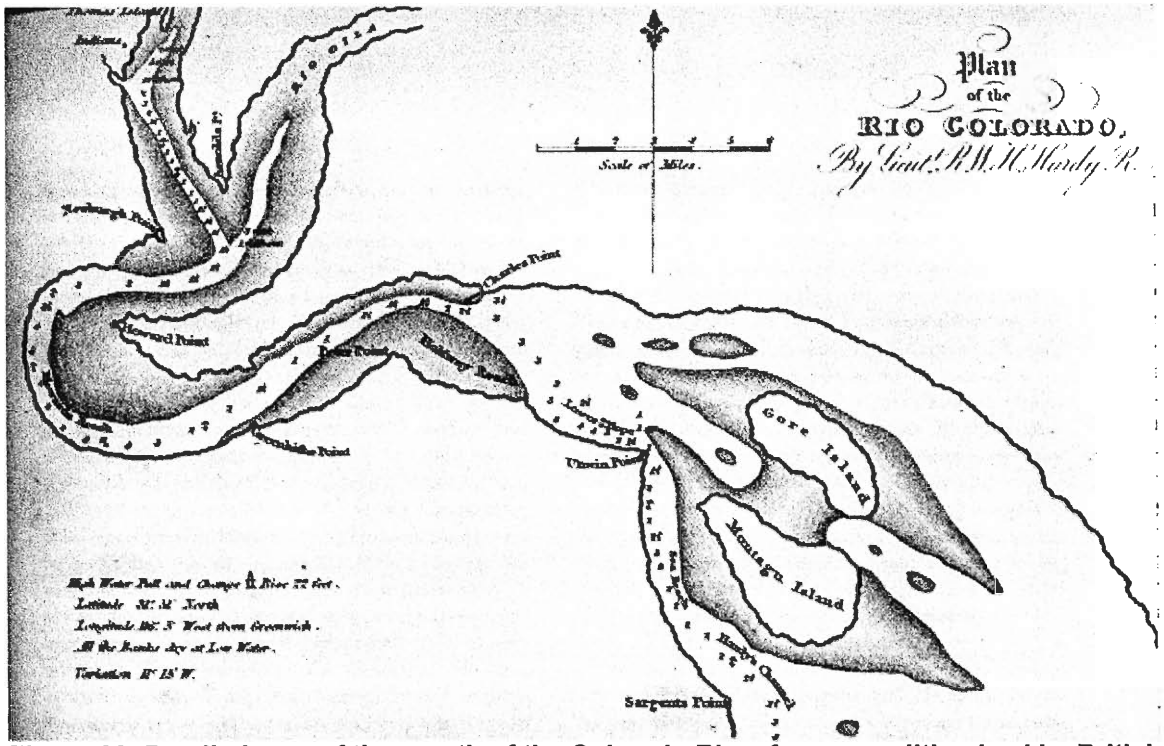
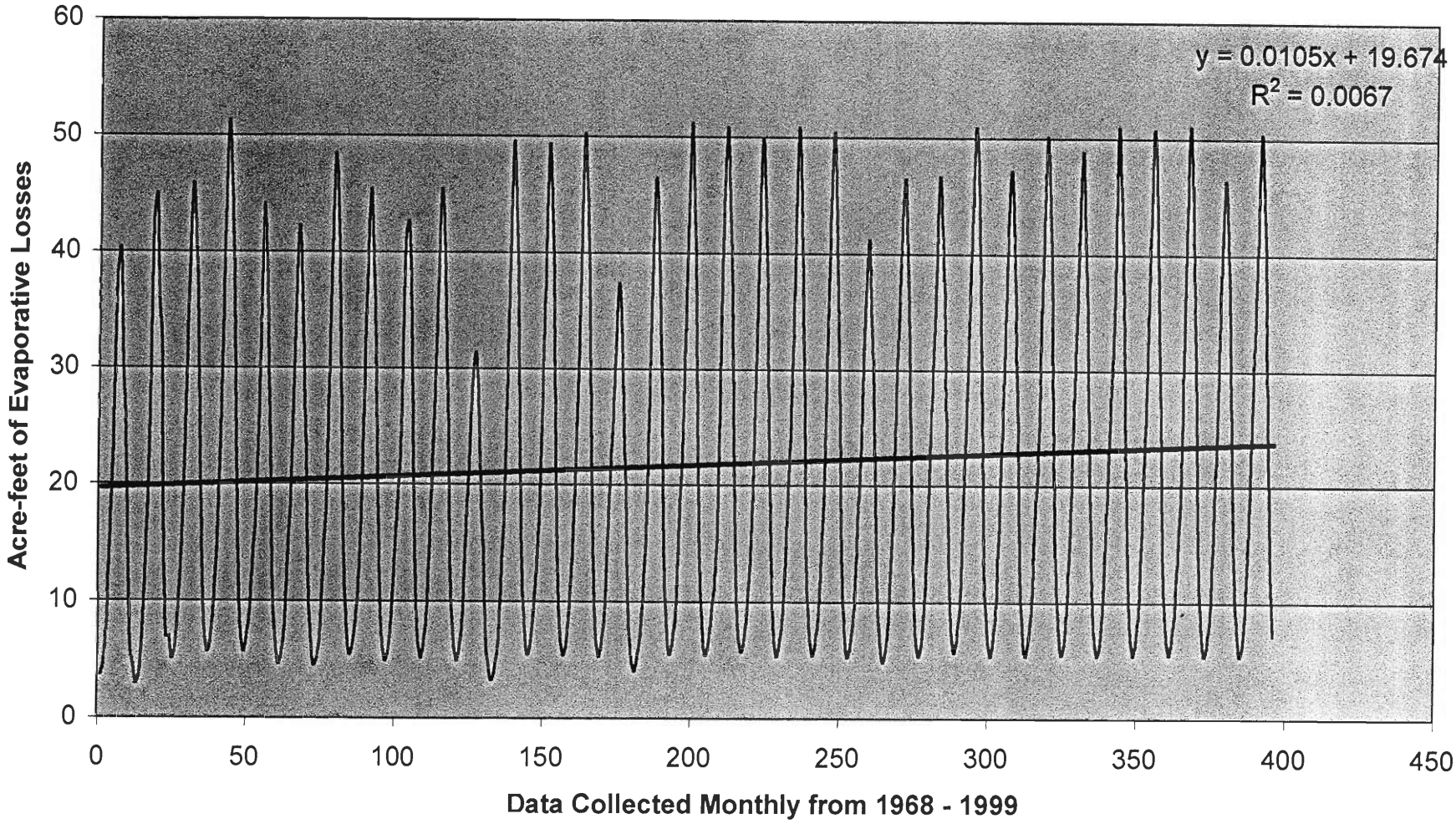


Figure 22: Detailed map of the mouth of the Colorado River from expedition lead by British Lt. Robert W. H. Hardy, 1829. (*The Grand Colorado: The Story of a River and Its Canyons*, p.67)

APPENDIX C: BLUE MESA RESERVIOR EVAPORATION DATA AVERAGED MONTHLY



APPENDIX C: BLUE MESA RESERVIOR EVAPORATION DATA AVERAGED YEARLY