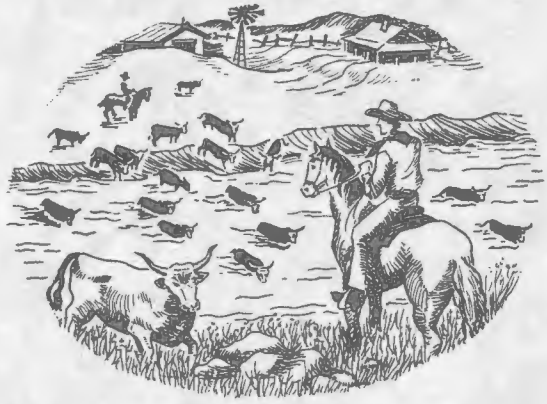
ARIZONA'S CHANGING RIVERS:

HOW PEOPLE HAVE AFFECTED THE RIVERS



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March 1997

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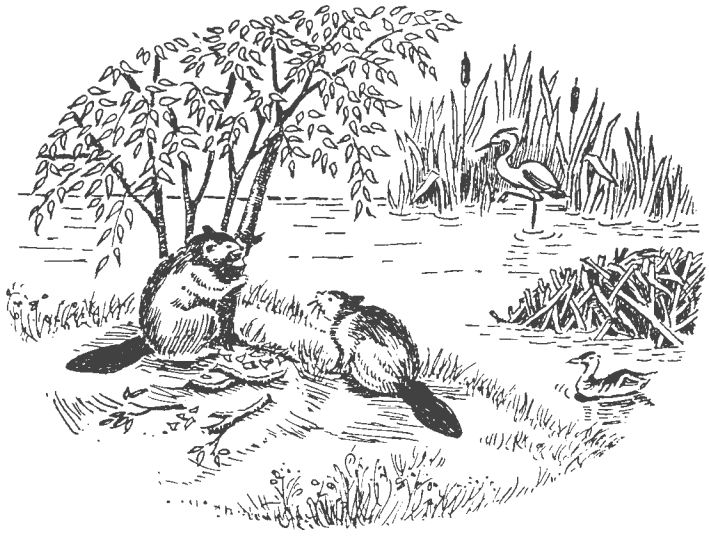

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ACKNOWLEDGEMENTS

This book is a synthesis of the works of hundreds of scholars who have studied Arizona history, archaeology, water law, hydrology, ecology and other topics. The most valuable sources are recognized in the "For Further Reading" section. This book is only a beginning. We welcome information from historians, from people who live along the rivers, people whose ancestors pioneered along rivers, and from experts in related fields.

Many thanks to the staff at the Arizona Historical Society and the University of Arizona Special Collections in Tucson, the Arizona Historical Foundation and Arizona Collection at Arizona State University in Tempe. We also thank Joe Gelt, Margaret A. Moote, Ana Rodriguez and Gary Woodard for helpful editorial reviews. Thanks to Patricia Oogjen, Tempe artist, for the cover drawings and other drawings throughout the book.

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FOR THEIR CAREFUL REVIEW OF THE MANUSCRIPT

AND MANY HELPFUL SUGGESTIONS

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FEATURE SECTIONS, MAPS, GRAPHS & ILLUSTRATIONS

Feature Sections

Maps

Graphs

Illustrations

Some Suggestions for Reading this Book

This book is organized unlike other books about rivers. Even the Table of Contents looks different. Rivers are interrelated into the lives of people and wildlife. Historical events are related to other events and many kinds of activities affected more than one river. For these reasons, the book is organized into history chapters alternating with chapters about specific rivers. The history chapters contain information needed to understand impacts on the rivers. They are not intended as a thorough history of the state. The river chapters contain information specific to each river, with frequent references to the history chapters for information common to several rivers. Short feature sections contain information on specific common topics. We have attempted to avoid technical terms, but those that are used are defined in the glossary. Similarly, we have used common names for plants and animals. Readers interested in the scientific names will find those in a special section of the glossary.

The chapters are designed so that readers can start almost anywhere in the book and read chapters without having to read what went before. As you read the chapters, you will find a pointing hand symbol at the bottom of the page pointing to related materials on other pages. You will also find a hand symbol with an $\mathcal{M}$ *inside that indicates that a relevant map is located on the page indicated.*

Some readers may prefer to read the chapters in a different order than we have presented them. People knowledgeable about Arizona history can start with the river chapters, while those with little historical background may wish to read all the history chapters before the river chapters. Readers primarily interested in a specific part of the state or a specific topic can start with those chapters.

While this format may appear confusing at first, we hope it will serve to make the reader aware of how, as the Navajos say, everything is related to something else— or as Norman Maclean said "All things flow into one and a river runs through it."

Related information symbols

Map symbol

CHANGING RIVERS

Rivers are Always Changing

Rivers are constantly changing. An ancient Greek philosopher pointed out that a person never steps in the same river twice. The water is always moving—moving itself, the soil and rocks. In years of high rainfall and snowmelt, the river may spread out over its normal banks, tearing out vegetation and rocks. In years of low rainfall and snowmelt, the banks of the river may move closer together. Vegetation and wildlife may suffer. In the long run, more typical years prevail.

Rivers change along with the seasons. During the late spring, full of snowmelt, they may rush forth, while in the summer and fall they may be shallow and slow. Many plants and animals take advantage of these natural cycles. Cottonwood trees produce seeds in spring when the high flows are receding. The seeds germinate in the moist soil, then flourish as the soil dries out in the summer, the roots still reaching water. Young fish may be born in the high waters of spring, then adapt to life in deep pools in summer.

Hayden's Ferry across the Salt River in the 1890s.

An informative description

"[The Rillito River] is insignificant at this point, but its bed enlarges as it descends to join the Santa Cruz, nine miles north of Tucson. Its waters cease to run above ground about a mile below the camp, and do not rise again until they join the Santa Cruz. The Rillito also receives an underground tributary near the post, its water coming from the cienega or swamp in the southeast portion of the mesa and about 23 miles distant from the camp. The cottonwood grows at intervals on the banks of the Rillito and Santa Cruz, and in some places attains considerable proportions. ...." U.S. Surgeon General, 1875.

People Change Rivers

Arizona's rivers tend to be fragile. In many rivers flash floods may occur—the river dry or nearly so one day and full of rushing water the next. The loss of stabilizing vegetation in the uplands and along the rivers can lead to downcutting, floods and formation of arroyos. Some human-caused changes to rivers are short-lived. A severe pollution incident may change a river radically killing fish. But if the incident is not repeated, the river may recover.

People, however, often change rivers in ways that make recovery difficult or even impossible. Once a river is dammed, for example, it becomes very different regardless whether rainfall is low or high. The new cycles of the river may be determined not by rainfall but by demand for electricity by distant cities. This often causes more water to be available at times when flows would naturally have been low, with less water available during natural high flow periods when the dams are filling to store water.

Groundwater pumping and surface water diversions remove water from rivers, completely changing them and their vegetation and affecting wildlife. Even human activities on nearby land may change rivers. Paved city streets, parking lots and roofs on homes can worsen downstream floods because of increased runoff. Great quantities of water rapidly enter a river, sometimes causing banks to give way. When banks are stabilized to protect buildings along the rivers edge, the force of the floods moves downstream creating further damage. Overgrazing may remove vegetative cover so that sudden, heavy rains tear away the unprotected soil, pouring soils into the river and spreading erosion.

Humans have been changing Arizona's rivers for centuries, but the changes that have occurred since the mid-19th century are more profound than most earlier changes. The great dams on the Colorado River are the most visible of those modern activities. Arizona's population explosion of the 20th century accelerated those changes, many of which are probably irreversible.

The history of Arizona and the history of Arizona's rivers are inextricably linked. All wildlife, plants, and humans need water to survive in an arid environment such as Arizona's. Within a desert, sources of water are oases of life; they are the centers of commerce, art, settlement, and recreation. From the first settlers thousands of years ago until the twentieth century, people have settled near sources of water. Farming was possible only near rivers. Miners needed a dependable water source and often transported water away from the streams.

Only in the twentieth century has technology allowed people to be independent of rivers, as groundwater pumping provided the means for cities and farms to develop by using water deposited underground thousands of years ago. Technology makes it possible to transport water hundreds of miles from its natural source to be consumed at a distant location. The Central Arizona Project is an example of such a technological feat.

An exaggerated claim

"'Where you can tickle the land with a hoe and make it smile with a harvest.' The soil in the Gila River Valley [north of Gila Bend] is equal in fertility to any found in the most famous garden spots of the world, not excepting the Valley of the Nile, the Polders of Holland or the Black Lands of Russia. ..." Gila Water Company, 1920.

A vague description

"The whole country traversed from the San Francisco mountains was barren and devoid of interest. It consists of a succession of mountain ranges and desert plains, the latter having an average height of about 5,000 feet above the level of the ocean. The larger growth, almost exclusively of cedar, was confined to the mountains; and the scanty vegetation of the plains, parched by a long drought, furnished few specimens for the botanist." Capt. L. Sitgreaves, 1853.

Interpreting Historical Sources

Trying to determine what rivers were like in the past is not easy. In some cases Indian oral tradition provides clues, as do histories of their way of life. We have other clues starting with the early Spanish travelers' accounts of the 16th century. Unfortunately, those accounts often do not give us much detail about the rivers. Father Kino, for example, often wrote about his welcome to a village and what the people wore, but seldom wrote about a river. Early 19th century Anglo beaver trappers experienced the rivers firsthand, but few of them kept journals. James Pattie's journal of travels in Arizona contains a great deal of detail, but is often obviously exaggerated, especially his encounters with wild animals. By the mid-19th century the U.S. government was sending out surveyors whose job was to describe the country. Many of these reports are very useful, but some are distressingly vague.

Some 19th century works are surely the writing of promoters—people trying to impress the folks back home or bring thousands of new people to Arizona. Other writers stressed the terrible hardships of the cross-country trip and compared the

An opinionated description

"There is a small creek that runs through the town. The water is alkaline and warm. The hogs wallow in the creek, the Mexicans water their asses and cattle and wash themselves and their clothes and drink out of the same creek. ... It never rains there, only in the rainy season and sometimes not then. There is very little air stirring, and if hell is any hotter than this, I don't want to go there." Phocian Way, 1857, describing the Santa Cruz River at Tucson.

desert rivers unfavorably with their green homeland. Many writers, however, wrote vivid and careful descriptions of what they found. Balduin Mollhausen, for example, wrote in detail of the castle-like beaver dams he found on the Bill Williams River.

From these descriptions and from other sources of information, historians have pieced together fairly detailed pictures of what places were like in the past. With knowledge about the many large old trees that were cut to provide fuel for the mines, for example, the historic forests can be envisioned. Bones of large edible fish in archaeological remains along rivers that are now dry tell of rivers that once flowed deeply. Tales of encounters with grizzlies and wolves, hunters' or fishermen's descriptions of their catches (even if exaggerated, in the way of hunters and fishermen) tell of animals that inhabited regions where they are not seen today.

We have barely discussed one important change —change in water quality. Except for a few major pollution incidents, water quality is scarcely mentioned. This is not because water pollution is unimportant but because little has been written on the subject. A separate study is planned for the future.

The Purpose of this Publication

Some people claim that 90 percent of Arizona's rivers have been altered by human activities. For example, a recent Forest Service visitor handout says, "It is estimated that 90 percent of the original riparian habitats of Arizona have been lost through diversion of the water and abuse of the lands." Some people say that 90 percent is excessive. Others believe this figure underestimates the damage and that, in fact, there are no unaltered rivers in the state. We do not believe a precise figure can be determined. And so instead of attempting to quantify river changes, our aim is to describe what changes have occurred and what caused those changes.

This is a series of sketches about Arizona's major rivers, written from a river's perspective. It asks how have human activities changed rivers? This is not a history which centers around the people, but a history of the major rivers as people affected them. Many histories of Arizona have been written over the past century, all of them focused foremost on the people. The reader is encouraged to supplement information presented here with a modern history such as Tom Sheridan's very readable *Arizona: a History*, published in 1995.

This publication does not bemoan losses of the past or pass judgment on the value of pristine rivers versus the forces of change. Rather, the purpose is to try to understand what caused the many changes that have occurred. In some cases, most people agree that mistakes were made that led both to changed rivers and to other problems for humans. In other cases, tradeoffs were made. A flowing river became a lake or a dry streambed in exchange for millions of dollars worth of crops or cities that house millions of people. Whether the tradeoffs were worth it is a value judgment.

Arizona's rivers were looked at to answer the questions: How much have our rivers changed over the past several hundred years? What are

A fictional account

Steamships on the Santa Cruz River? Back at the end of the nineteenth century, an enterprising land speculator promoted sales of property at Calabasas (now Rio Rico, north of Nogales) with brochures showing ocean-going steamships moored at a busy Santa Cruz River wharf. The Tombstone Epitaph described the brochure which advertised a busy port, ideal for commercial ventures. The story persisted for years that steamships had plied the river. Anyone who came to see the busy wharf was destined to be disappointed in the shallow marshy creek, unable to support even small boats except in flood season.

the greatest changes? What brought about those changes?

How Have the Rivers Changed?

All of Arizona's major rivers and their major tributaries have changed to some degree. Even stretches of the Gila River with adequate water have changed because of the introduction of the exotic saltcedar tree. The Colorado River has changed from a highly variable flowing river to a series of dams and reservoirs, with progressive loss of water through municipal and agricultural diversions of water. The Gila River which used to flow most of the time all the way to the Colorado, now is generally dry below Ashhurst-Hayden Dam, except for effluent flow from the Phoenix area. The Santa Cruz once was a series of marshy areas alternating with flow for much of its length through the Tucson area. Groundwater pumping has mostly dewatered the stream north of the Mexican border, except for effluent flow from both Nogales and Tucson. The Salt River no longer flows through the Phoenix area, because of upstream dams and water diversion for agricultural and municipal use. The Verde River has been affected by water diversions, sand and gravel mining and dams. The Little Colorado River has lost most of its riparian character downstream of Lyman dam, because of water use and historic overgrazing which led to massive loss of soil. The San Pedro River upstream of St. David is recovering from historic changes, but faces a serious challenge from population growth in the Sierra Vista area. Aravaipa Creek has changed less than the other rivers—it has no dams or major water diversions. All of these rivers and others are discussed in the chapters that follow.

Fort Yuma and the Colorado River Crossing in the 1880s.

CHANGING RIVER NAMES

Rivers have changed over time and so have their names as new explorers and residents named them. These are some of the names that Arizona's rivers or sections of rivers have had over the years.

Bill Williams
- Hah-weal-ha-mook
- Hah-cu-che-pah
- Rio de San Andrés
- Bill Williams Fork
- Santa María
- Cottonwood Creek

Colorado
- Poketto
- Hakoti
- Pahaweep or Pah Gaiv
- Ahamcave
- Hahweal
- Hah withlcha cohut
- Javil
- Buqui Aquimuri
- Gritetho
- Firebrand River
- Tizón
- del Coral
- Río de la Conversión de San Pablo
- Río de los Martyrs
- Río de Buena Guia
- Río Grande de la Buena Esperanza
- Río Colorado del Norte
- Grand River
- Red River of the West
- Red River of California
- Red River

Gila
- Hahquah Saeel
- Jela, Jila
- Xela, Xila, Xelay
- Río de Nombre Jesus
- Río de Apóstoles
- Río Grande de Hila
- Spine Fluss
- Florida
- Poison River

Hassasyampa
- Aziamp, Assamp
- Haaviamp
- Ah-ha-seyampa
- Hesiampa

Little Colorado
- Tol Chaco
- Rio Bermejo
- Colorado Chiquito
- Río Jaquesila
- Río de la Alameda
- Río de San Pedro
- Río de Lino
- Colorado
- Flax River
- Salt River

Rio Puerco
- To Nizhoni

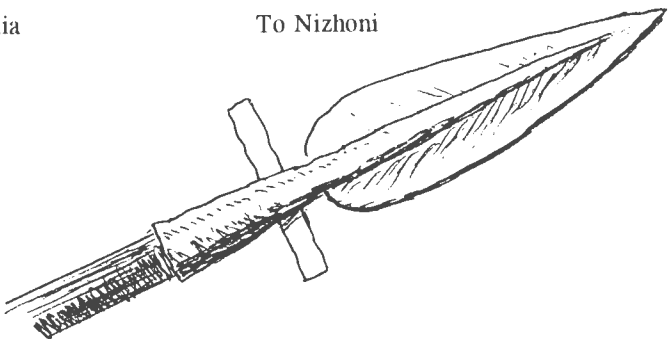
Salt River
- Río de las Balsas
- Río Azul
- Salinas
- St. John
- Salada
- Río de la Asunción
- Black River
- San Mateo

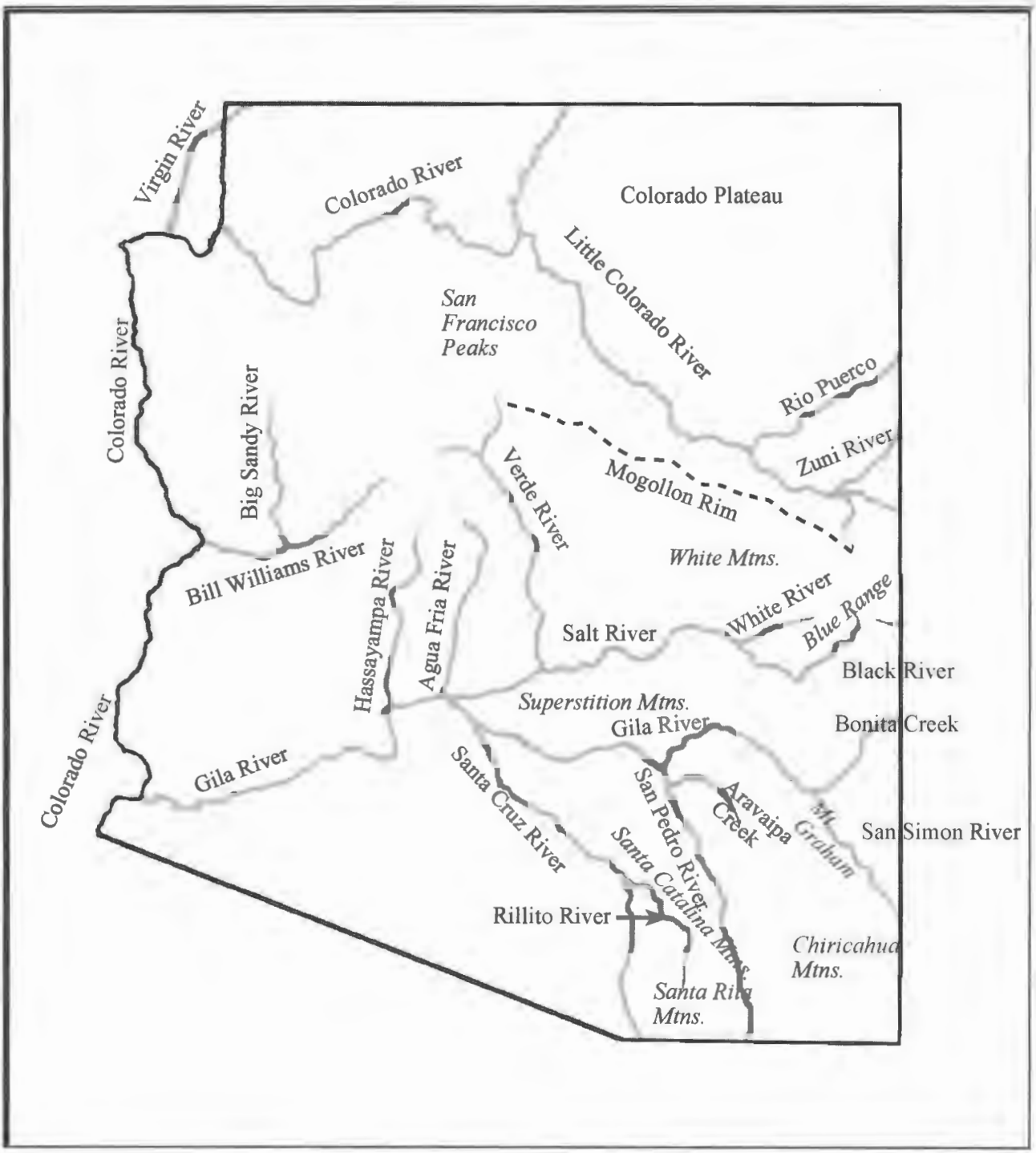
San Pedro
- Nexpa
- Sobahipuris
- Hiburi, Quibiri
- San Joseph de Terrenate
- José Pedro
- Santa Ana de Hiburi (Quibiri, Kiburi)
- San Juan
- Babocomari
- Beaver River
- Dirty River

San Simon
- Rop de Saiz
- La Ciénega Salada
- Valle de Sauz

Santa Cruz
- Río de Santa María del Pilar
- Río de Santa María de Suamca
- Río de Tubac
- San Lucas

Verde
- San Antonio





Arizona's major rivers and tributaries.

CHANGING LANDSCAPE AND PEOPLE

Dinosaurs and Ice Ages

Much of what is now Arizona once was under water. Fossils of sea creatures are found where deserts now prevail. About 150 million years ago dinosaurs such as the Diplodocus and Allosaurus roamed the area. The forests were dense, filled with evergreens, palms, ferns, rushes and mushroom-like fungus. Flowering plants and hardwood trees did not yet exist. Central Arizona along the present day Gila River was swamp land, with an ancient river running about two miles wide. A shallow sea lay to the west covering the area now known as California. The present location of the Colorado River was a seacoast.

About 100 million years ago, the land to the west and north of Arizona slowly rose above sea level forming a huge inland sea, stretching from Utah to Alberta, Canada. The lower shores of the sea flowed into the Gila watershed in central Arizona, creating a large tropical swamp.

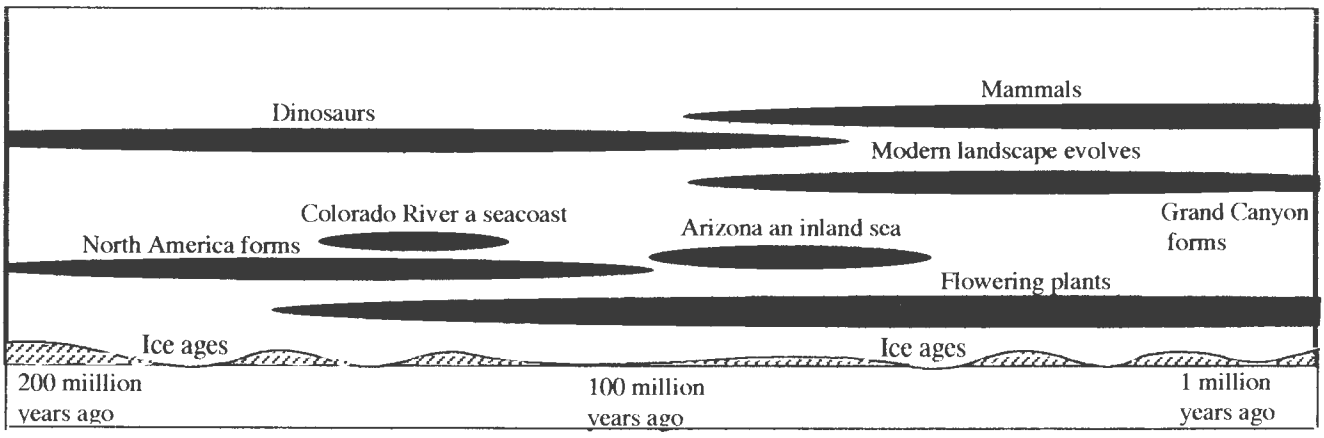
About 60 million years ago, the present landscape of Arizona began to take shape. The sea receded and the Rocky Mountains and Sierra Nevadas began to rise. What was once swamp land became an arid basin as the Sierra Nevadas rose and blocked most Pacific winds and rainstorms. Early in this period, mammals such as camels, peccaries, deer, mammoths, and Eocene horses replaced dinosaur-like reptiles.

For the next 50 million years, the landscape continued to evolve into the high mountains, low valleys, desert and range characteristic of Arizona today. Forces of erosion and uplift formed the Grand Canyon and the Mogollon Rim.

Modern humans appeared in the world one million years ago, but hundreds of thousands of years passed before they reached the Americas.

The area was much cooler and wetter in the distant past than it is today. Pinon, juniper and oak woodlands dotted the lower elevations. Desert grasslands, joshua trees, beargrass and yucca grew in the lower valleys. The mighty saguaro, a now-famous symbol of Arizona, grew only to the south in Mexico.

About 10,000 years ago, as the last Ice Age receded, the region became drier and hotter and the Sonoran Desert (with new plant and animal species) crept north. The climate grew warmer but wetter in the summer while winters became drier. Plants that needed more water were concentrated near rivers and springs.



Some plant and animal communities moved upwards in elevation, in some cases becoming stranded species on mountain "sky islands" such as Mount Graham in southeastern Arizona. New species moved in fairly gradually and co-evolved with other species. Natural predators tended to appear along with their prey species. By 2000 B.C., the landscape and climate essentially resembled modern conditions.

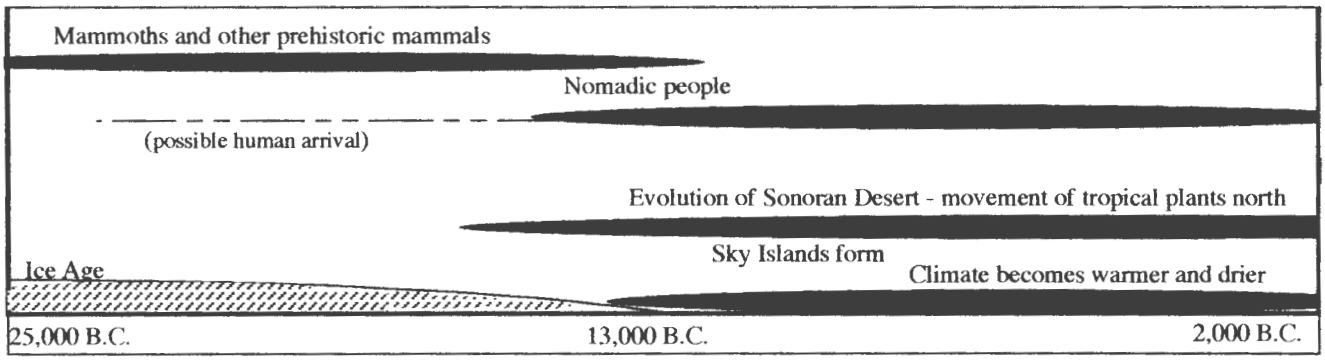
As the climate became hotter and drier, temperatures rose and patterns of precipitation changed. Many streams across the state began to dry up. More snow and rain occurred in the winter, but less in the summer. Animals, as well as humans, became dependent on the remaining free-flowing streams, springs, and seeps. Riparian areas, which became isolated environments in the desert, became important habitats, providing corridors and nesting areas for many kinds of wildlife, as well as places for the early residents of the area to hunt and settle. Today, less than four percent of Arizona's land surface is covered by rivers or lakes, but these areas are necessary to more than 75 percent of Arizona's wildlife species.

Early Inhabitants

Some 15,000 to 20,000 years ago, the first in a series of migrations brought people from the north to Arizona. The first people to discover Arizona will never be known, but it is known they were skilled hunters who could bring down the mighty mammoth with primitive weapons. Some of these people passed through Arizona to migrate farther south. Others remained, always moving to new locations in the area using temporary dwellings. These people were few in number and had little direct impact on the rivers. By about 8000 B.C. most of the large animals, such as mammoths, had died out. Some scientists believe over-hunting played a role in the demise of these animals as well as the animals that fed upon them. Others believe the climate changed at the end of the Ice Age and those animals could not adapt. If the hunting theory is correct, humans would have indirectly impacted the rivers by eliminating some important species from them.

At least three other major migrations brought people south to Arizona over the millennia. By about 1000 B.C. some of those people began to settle in permanent communities where they grew crops to augment their hunting. These communities were near dependable water sources. People used wood for cooking, heating, and building their homes—the first major way humans began to affect the rivers directly by altering the vegetation.

Four major civilizations dominated Arizona rivers at different times between 1000 B.C. and about 1450 A.D. The Anasazi used the Little Colorado and parts of the Colorado River basins, while the Mogollon occupied the high country in the upper watersheds of the Verde, Salt and Gila rivers. The Sinagua occupied the Verde Valley. The Hohokam used the Salt, Gila, San Pedro and Santa Cruz basins.



In the driest part of the state, the southwest corner away from the major rivers, people for millennia have lived using widely separated water sources, "tinajas." They were skilled in finding isolated water sources and using them to sustain life. All of these civilizations used their environment intensively for farming, hunting, food gathering, and woodcutting.

The Anasazi People

The Anasazi primarily occupied the Colorado Plateau. Until the middle of the sixth century they were primarily nomadic, living in the lowlands in the summer and moving upland in the fall. Climate change in the sixth century improved conditions, enabling them to settle in more permanent agricultural communities. They built diversion dams to control runoff for fields where they grew corn and other crops. The civilization reached its peak in the twelfth century, utilizing extensive water distribution systems with terraces, checkdams, irrigation ditches and masonry-lined reservoirs.

Chaco Canyon in northwest New Mexico was the leading trade center for a large area extending into central Mexico. Traces of trade routes extending for miles from Chaco still can be seen. Anasazi architecture required the use of thousands of wood beams. More than 200,000 beams were used in multi-storied pueblos in the canyon. Over the years people had to go farther and farther from home to find big enough trees. Chaco Canyon residents deforested the area for miles around, leading to erosion, more damaging floods, arroyo cutting, and loss of good farming soil. This probably contributed to the settlement being abandoned at the end of the 12th century. The Anasazi in other areas increased their use of check dams, reservoirs and irrigation and were temporarily able to feed and house a growing population in the face of disasters in Chaco and elsewhere and were able to prolong their way of life for another century or so.

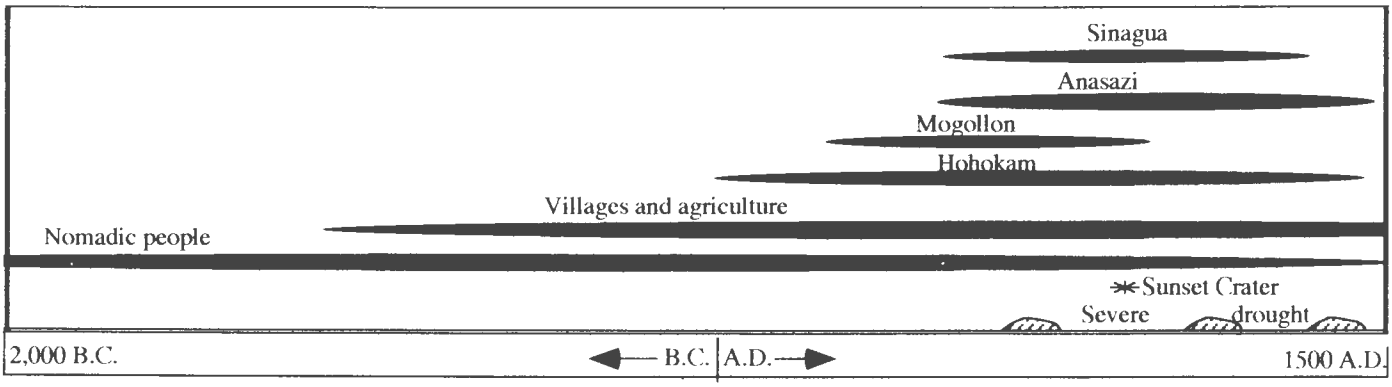
The Mogollon People

The Mogollon people also began as nomadic groups living in the highlands of the Arizona-New Mexico border. They eventually settled into communities and developed farming techniques suitable for their area. They are best known for their fine pottery which depicts with great artistry stylized bighorn sheep, bats, birds and human forms.

After 750 the role of the Great Kiva (a major religious structure) increased and by 1000 the society was at its height. This lasted only about 100 years, however, and the Mogollon pueblo society had nearly disappeared by 1150, for reasons not fully understood, but probably related to climate change.

The Sinagua People

The Sinagua settled around the Verde Valley and up into the San Francisco Peaks region. In the 8th century they, too, shifted to an agriculture-based economy, growing crops such as corn in the floodplains and agave in the uplands. These people traded extensively with the Anasazi and Hohokam, as far away as Chaco Canyon and with tribes as distant as the Pacific coast. Tuzigoot



Approximate territories of ancient cultures.

(now a National Monument), a hilltop structure near the Verde River, was built in the 14th century and is a prime example of how these people lived and farmed. Over the years they developed the Palatkwapi Trail, a 150-mile long major trade route to Hopi Villages.

People used irrigated crops such as corn, squash, cotton, and tepary beans. They grew agave on drier terraces. Something happened within a century of these achievements. By 1400 there was a high rate of infant mortality, and about 25 years later the Verde Valley was abandoned. The people moved to the northwest. Archaeologists do not agree on the reasons for this.

The Hohokam People

For about five hundred years from 900 to 1400 the Hohokam intensively farmed the Salt River Valley, the Santa Cruz River, the San Pedro River, and other river valleys in Arizona. They practiced irrigated agriculture in the Santa Cruz Valley as early as 500 B.C. They lived in small communities, and in many places built mounds whose purpose is still debated. They may have been food warehouses, living quarters, military structures, religious structures or administrative centers for running their complex agricultural systems. In the Salt River Valley mounds were at about three-mile intervals along the major canals. The Hohokam at times farmed most of the good land in the valley using well-engineered canal and reservoir systems as well as water harvesting systems in the smaller drainages.

The Hohokam served as middlemen between the Anasazi and civilizations farther south and traded all the way to the Pacific Ocean. They, too, used their environment intensively. The peak of Hohokam civilization lasted almost 400 years, until about 1450. When the first Spaniards arrived in the late 17th century, they found only ruins. Modern Tohono O'odham and Pimas consider themselves to be descendants of the Hohokam.

Why Did the Great Cultures Disappear?

No one theory can explain the failure of the ancient cultures—separated in time and space as they were. Archaeologists do not even fully agree on just when they failed or what happened to the survivors.

Climatic factors were undoubtedly important—major droughts affected all three cultures at different times. Concentration of large numbers of people in small areas, made possible by years of normal or above normal rain probably made it difficult to replace lost crops with gathered food supplies when the rains failed. The people may have over-exploited resources such as timber and soil, making their lands less fertile. In some areas, years of irrigation probably led to salting of the soil, making it difficult to grow crops. Occasional large floods temporarily damaged irrigation systems. Some archaeologists believe that when the Chaco civilization failed in the north, its trading partners (especially the Hohokam) also suffered, contributing to the decline of their way of life. Other archaeologists believe that the amount

of governmental control needed to maintain the complex irrigation systems of the Hohokam led to revolt of the "working classes." Some wonder if the spread of European diseases such as small pox reached Arizona even before the Spaniards themselves did, which caused people to die of new diseases to which they had no immunity. Even if this were true, the societies were already in decline. Some scholars, however, believe Hohokam civilization lasted into Spanish times.

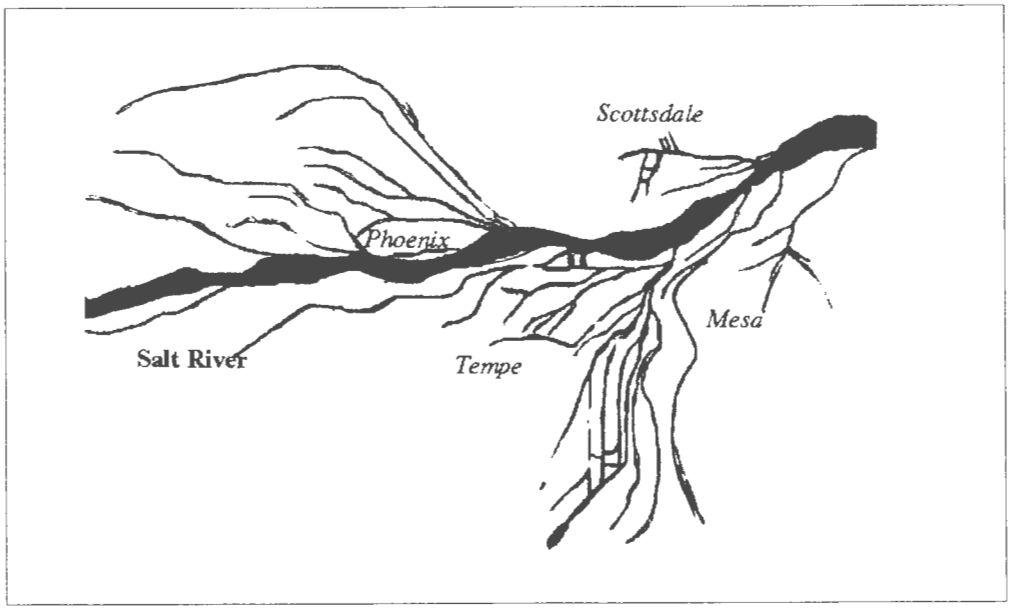
Hohokam Agriculture Along the Salt River

Of all the early civilizations, the Hohokam probably had the greatest impact on the rivers. Their irrigation system was the most extensive in North America. Their effect on rivers has not been thoroughly studied by archaeologists or hydrologists, but some generalizations can be made about one large urban center. Ways in which the Hohokam impacted their rivers were probably duplicated on a smaller scale by the other civilizations.

The Hohokam developed a complex and sophisticated irrigation system in the Salt River Valley. Much of that system has been recycled into modern canals or destroyed by modern agriculture and cities so that fully understanding many important details is difficult. We do not know how large the population was, what the maximum area under irrigation was or the exact impact this civilization may have had on the Salt River and other central Arizona rivers. It is certain they did impact some rivers to a relatively large extent, for at least a few hundred years.

In 1903 H.R. Patrick described what was known about the canal systems at that time. Many ruins had already been destroyed, but some were still standing in the Phoenix area. He determined that many of the modern canals followed the alignments of ancient canals. He believed that there were about 135 miles of canals, irrigating 120,000 - 130,000 acres and supporting as many as 200,000 people.

In 1929 Omar Turney published an exhaustive survey of the ancient canals and other structures, looking at ruins, reading old descriptions and talking with people who had themselves knocked down buildings or plowed over canal systems. His map had enough canals to account for 200,000 irrigated acres and up to 250,000 people. Later researchers put the acreage at up to 400,000 acres, not all of which would have been farmed at the same time. The most recent estimates are that between 100,000 and 200,000 acres were farmed through 185 miles of canals. The maximum population was between 50,000 and 200,000.

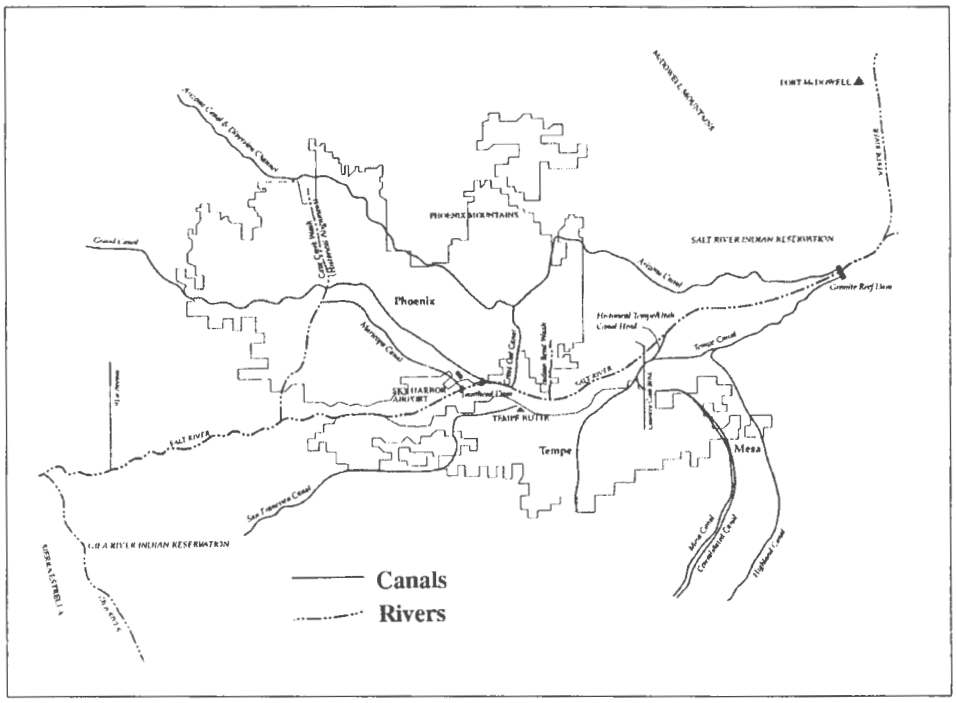


Ancient Hohokam canals in the Salt River Valley.

Two Agricultural Styles

What are the differences between the peak of Hohokam society and twentieth century agriculture in the Salt River Valley? In 1920 the population probably was roughly the same as the population in 1420 and the number of irrigated acres probably approximately the same. They both used canals to irrigate fields in about the same places. Use of river water was probably roughly comparable.

There were, however, major differences. In Hohokam times, beaver dams were common throughout the watershed as well as many smaller dams and water harvesting projects. In modern times almost all the beaver and small dams are gone. In their place are six large dams and some smaller dams. Beaver dams hold back water throughout the system, while modern dams create a few large lakes.



Modern Salt River Valley canals.

The Hohokam grew many spring-summer crops, but no winter crops until the Spanish introduced wheat. Thus, Hohokam land was left fallow in the winter while modern agriculture continues all year long. The Hohokam probably used all the summer flow for irrigation, and little water flowed downstream of the fields during the dry period. In the winter, however, the river flowed normally and was able to recharge the water table. This would have been adequate for most riparian vegetation. In modern times the river through Phoenix is dry all year long except for big flood years, because of dams and diversions.

Flooding would have been quite different in ancient times. While the Hohokam had buildings, ball courts and other structures, they had no paved streets or parking lots. Most of the rain would have soaked into the ground. In modern times, the high amount of paved surface sends more water into the streams when rainfall is heavy. This leads to occasional high run-off that lasts only a short time, but leads to erosion. Occasional huge floods devastated Hohokam canals and fields. These floods caused enormous damage that had to be repaired, but also brought silt and nutrients to the farmlands. More importantly, the floods also would have helped leach out salts in the soil. Modern farms are seldom flooded and canals seldom seriously damaged.

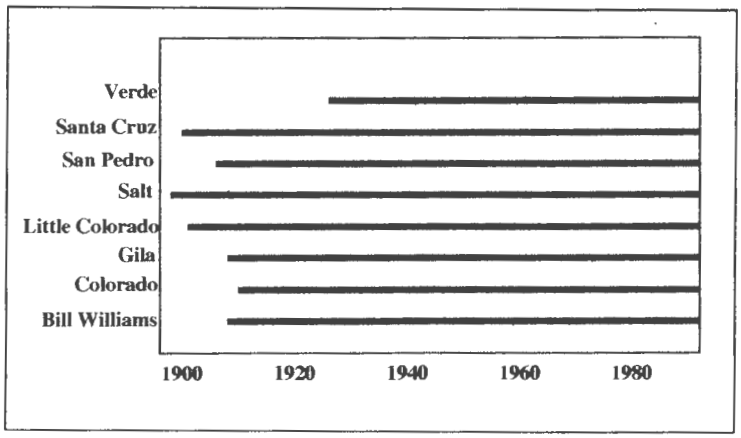
One of the biggest differences is the ability of modern people to pump water from deep underground and the ability to transport water great distances. Life in the Salt River Valley in 1920 depended both on the Salt River and groundwater. The Hohokam could dig shallow wells that basically used the same water that fed the river—river water in another form. Because modern farmers can use groundwater, their total water use was undoubtedly greater in 1920 than in 1420, and less water was wasted. The Hohokam had to depend on streamflow for all their water needs.

The Hohokam would have collected and cut wood for their fires and homes. In many cases they probably left vegetated strips between fields and harvested by cutting branches rather than taking whole trees. Before the introduction of electricity, the Anglos harvested wood extensively and cleared whole forests, leading to erosion and loss of soil which changed the rivers.

Climate and Geologic Change

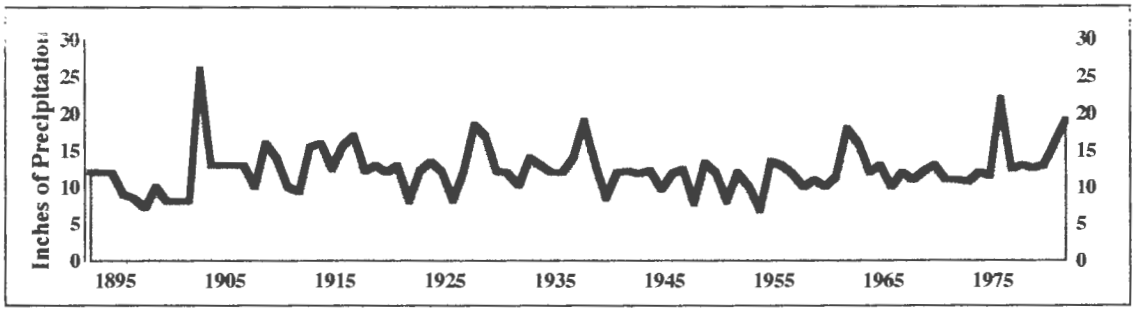
Climate

Arizona has a highly variable climate. Droughts and floods, scorching heat and freezing temperatures occur in the desert lowlands. Upper elevations also experience dramatic variations in temperature and rainfall. The state has a wide range of geological zones with very different climates. In general, however, Arizona is an arid state; about one-half of Arizona receives less than ten inches of rain a year. Parker gets an average of only 2.26 inches of rain a year, while Prescott gets more than 12 inches, and the mountainous areas may get more than 30 inches. High temperatures of 120 degrees occur in the summer along the Colorado River, while low temperatures of -23 degrees are reported in Flagstaff, with temperatures in mountainous areas falling even lower.



Extent of official streamflow records.

Learning about past climate is not easy. The first official weather stations in Arizona were at the army forts as early as 1879. The first continuous weather stations, operating to the present day, were established in 1892. Newspaper accounts of major weather events provide a limited record for the previous 50 or so years. To go farther back, scientists study tree rings to determine which years were drought years (when the rings were small) and which years had plenty of precipitation (when the rings were wide). Farther back than that, scientists look at evidence of past vegetation. Fossil pack-rat middens tell scientists what plants grew in the vicinity of the nest in the past. If there were plants requiring a cooler climate than today's, they infer that the climate then was cooler. Another method is to study pollen records in ancient lake sediments. Floods can also be inferred from geological records.



Arizona statewide mean annual precipitation.

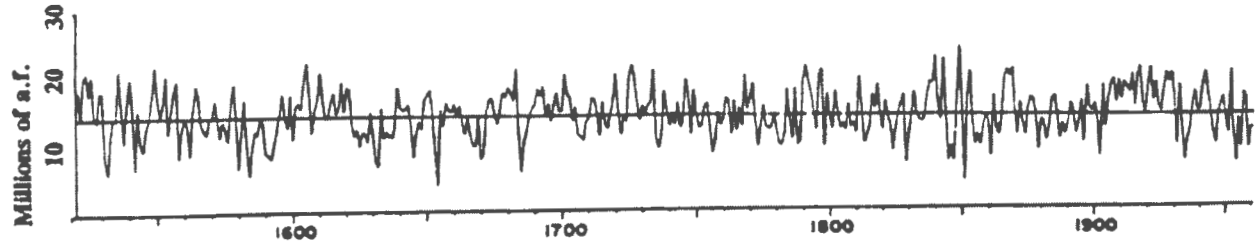
"The country through which we traveled for several days was not altogether new to me. I had passed through it before during a tour of exploration among the Southern Indians in 1860. But how different was it now. In former years the magnificent valleys, stretching all the way from Los Angeles to the borders of the Colorado Desert were clothed in the richest verdure. Vast herds of cattle roamed over them rampant with life. ... Now, after two years of drought, all was parched, grim and melancholy. ... For hundreds of miles the country was desolated for want of rain. ... Thousands of cattle lay dead around the black, muddy pools. ... No more pitiable sight ever disturbed the eye of a traveler in this lovely region than the dreary waste of dead and dying animals." J. Ross Browne, 1864, describing drought in southern California.

Drought

Among the most important climatic factors affecting Arizona's rivers is the variable pattern of rainfall. Much of the history of Arizona's rivers has been cycles of flooding and drought. These variable patterns of precipitation have affected human settlement from prehistoric times to the present. Different cultures at different times have been affected by sudden, changes in climate.

Precipitation varies greatly from season to season and year to year throughout the Colorado River Basin. The longest statewide drought of historical record lasted 76 months at the beginning of the twentieth century when annual rainfall was consistently at least two inches less than average. The longest drought period affecting Arizona rivers is found in tree-ring records and lasted from 1579-1600 when the annual flow of the Colorado River (throughout the basin) is estimated to have been less than 9 million acre-feet per year. But droughts affected Arizonans even earlier. Drought conditions affected prehistoric civilizations in the eighth century, the thirteenth century and the fifteenth century. A lack of water made it difficult to grow crops, and have adequate drinking water. It even affected the plants and animals that could be gathered to supplement meager food supplies. People who could not find adequate food or water supplies moved or did not survive.

The years after the early twentieth century drought were particularly wet ones, when Colorado River flows of more than 15 million acres-feet were common. Using those recent flow records, the water of the Colorado River was divided between the Upper Basin states (Colorado, Utah, New Mexico and Wyoming) and the Lower Basin states (California, Arizona and Nevada), with upper and lower basins each allocated 7.5 million acre-feet annually. If negotiators had the tree ring records when they calculated river flow in the late 1920s, they probably would have allocated far lesser amounts. A drought as long as the one in the sixteenth century probably will again affect the river.



Annual flow of the Colorado River at Lee's Ferry, reconstructed from tree-ring records.

17 55 94 109 139

"Tucson Gets an Earthquake.
Buildings Rock Like Ships at Sea.

... It was only a moment until the streets were filled with terror stricken people. ... The court house dome moved back and forth like a tall tree. ... great slices of the [Catalina] mountains gave way and went tumbling down into the canyons, huge clouds of dust or smoke ascended it to the blue sky, high above the crest of the queenly mountain. ... Great boulders or little mountains, wrested from their seats by the shock came thundering down into the valley. ... [May 4]

"... A peculiar feature of the earthquake ... in the Sulphur Springs Valley ... was the opening up of hundreds of water veins. ... the dry parched earth beneath our feet was opening up in every direction around us and water was spurting up in some places as high as 10 feet above the surface. ..." Arizona Daily Star, May 6-7, 1887.

Flooding

Flooding also is common in Arizona. Flooding, while inconvenient for modern desert dwellers, is a natural part of the hydrologic cycle and is an important part of a river regime. Cycles of plant and aquatic life are tied to annual floods. Less frequent large floods move soil and rock, create new beaches, fertilize floodplains, and clear out old vegetation to make way for new trees and shrubs. Major flood years often have followed drought periods, with extremes occurring within a few years of each other. In the twentieth century, floods have occurred on an average of about every ten years.

One way in which modern society has attempted to even out these extremes of flood and drought is to build dams to store water in times of plenty for release in times of drought so that people could occupy the floodplains. Occupation of the floodplain, however, has led to repeated flooding problems for people who build structures in places destined to flood or be eroded.

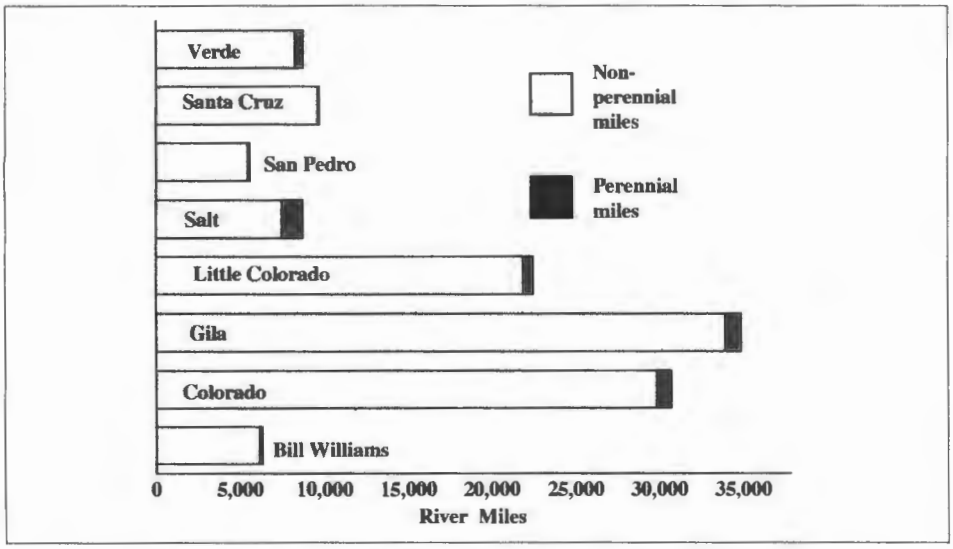
The seven-day release of water from Glen Canyon Dam in March 1996 was the first major dam release with the intent to mimic past flood conditions to help restore the downstream ecosystem. The release is expected to allow some restoration of the ecosystem by restoring beaches and scouring backwaters for habitat for young native fish. "Flood" levels were much lower, however, than in pre-dam times.

Geologic Changes

In relatively recent times, the state also has experienced natural geological events including an earthquake and a volcanic eruption. In 1066 AD, Sunset Crater, in northern Arizona, erupted. It caused short-term devastation, but also spread a layer of rich ash over the landscape which conserved soil moisture and increased the agricultural productivity in the area.

Another dramatic geologic event was the earthquake of May 3, 1887. Its epicenter was located just south of the border near San Bernardino Ranch in southeastern Arizona. It was about as powerful as the San Francisco Earthquake of 1906 . The quake damaged many of the buildings in St. David and elsewhere in the San Pedro Valley, including the remains of the abandoned town of Charleston. It also caused swamps and cienega areas in the St. David area to disappear. Many existing and newly-dug wells began to flow under artesian conditions. In fact, artesian wells in the area were first discovered in the 1890s when water flowed temporarily from a ground fissure opened up by the great earthquake.

Bavispe, Mexico was destroyed in the 1887 earthquake.



Perennial and non-perennial stream miles in river basins.

Of Arizona's 113,508 square miles of land surface, only 492 square miles are covered with water today. Lakes comprise the great majority of these "wet" areas, leaving less than .01 percent of the land area covered by streams. The vast majority of Arizona's streams are non-perennial, either flowing only after rains (ephemeral) or flowing in some sections and going underground in others (intermittent).

SANTA CRUZ RIVER

The Santa Cruz River figures prominently in the history of the Southwest and Mexico. Spanish missionaries used the Santa Cruz River Valley as their primary avenue for expansion to the north, and it was the first part of Arizona they settled. The Gila Trail followed the Santa Cruz River and so did a good number of argonauts, or '49ers, who traveled through the valley on their way to seek gold in California. Agriculture has been practiced along the river for thousands of years.

The Setting

The Santa Cruz River has its headwaters in the San Rafael Valley, where numerous springs and creeks are found. After a 32-mile loop through Mexico, it re-enters Arizona about five miles east of Nogales. From here it continues north-northwest to its confluence with the Gila River near Phoenix.

The Santa Cruz River once was mostly perennial from its headwaters in the San Rafael Valley, through Mexico and north to about Tubac, often as a series of cienegas rather than a flowing river. At Tubac the geology changes, and the water went underground surfacing near the mission of San Xavier del Bac outside of Tucson. After a short perennial reach, the river was often a dry streambed until it surfaced near Tucson's "A" Mountain. Springs from San Xavier to Rillito Creek created cienegas and added to the flow. The last dependable water was at the Nine-Mile water hole at the north end of the Tucson Mountains.

"... the banks of the river, and the valley itself, are covered with poplars and willows, ash-trees and plantains, oaks and walnut trees. ... Some portions of the valley are of such grand, rich, and simple beauty, as for instance Tumacacori and San Xavier del Bac, that they would be remarkable in any part of the world." Julius Froebel, describing the Santa Cruz River in 1859.

From there, springs or water holes were the only water available until the Gila River. The trail in Pinal County was called the "Ninety-Mile Desert." The channel in the area was for the most part insignificant, except during floods, and many old maps showed the river ending in the desert miles before the Gila River.

The Santa Cruz watershed encompasses about 8,200 square miles. Within this area are a number of tributary streams with perennial sections. Nogales Wash, Sonoita Creek, Rillito Creek, Cañada del Oro and the Avra-Altar watershed are the most prominent of the tributaries.

Early Inhabitants

The Santa Cruz River Valley is broad and fertile, with moderate winter temperatures. It is not surprising, then, that the valley attracted farmers, starting as early as 1200 B.C. Stable farming communities were in the Santa Cruz Valley by at least 600 B.C.

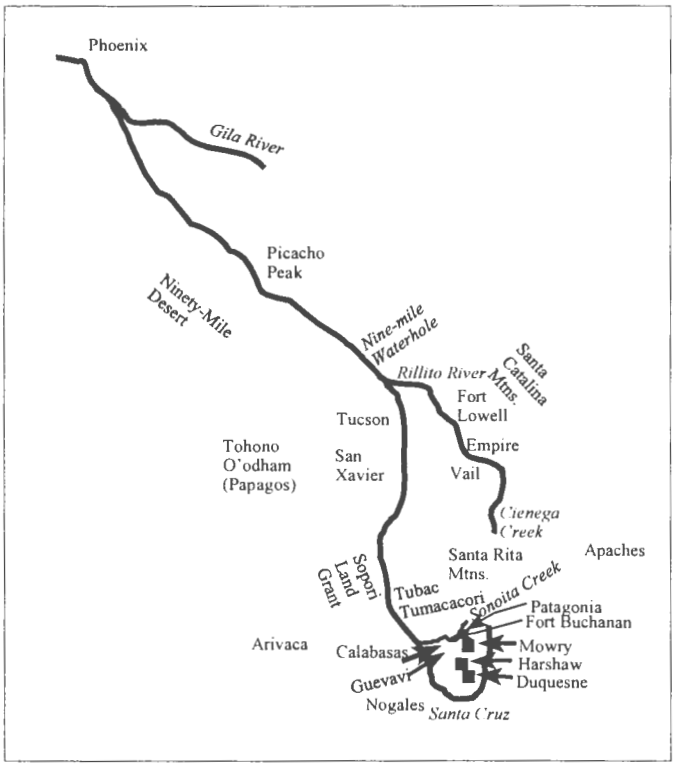
These early Hohokam farmers grew corn, tobacco, and possibly cotton and agave. The crops were raised during the rainy season or were irrigated with surface waters from the Santa Cruz River, diverted through ditches. The Hohokam ate fish caught in the river.

The Spaniards

The early Spanish explorers missed the Santa Cruz Valley. Coronado may have entered the San Rafael Valley in 1540, but the first real Spanish penetration was by the Jesuit missionary Father Eusebio Francisco Kino in 1691. Although the Spanish had settled throughout Mexico, the Santa Cruz River Valley was the first area in Arizona that the Spaniards colonized.

Father Kino was active in the Santa Cruz Valley until his death in 1711. He traveled north along the river from Santa Maria de Soamca, later known as Santa Cruz, Sonora. His influence in *Pimería Alta*, the northern frontier of New Spain, was widespread. His labors help found missions over the next century at Guevavi and San Xavier del Bac. He had *visitas*, or smaller missionary posts, at San Agustín del Tucson and Tumacacori.

Father Kino introduced a new religion to the natives, as well as new agricultural crops and livestock. His missionary endeavors also brought European diseases.



Historic sites along the Santa Cruz River.

"The Indians were alarmed because the Padres pastured so many cattle that the watering places were drying up." Father Kino 1691.

The native Indian population in the Santa Cruz Valley decreased drastically in the eighteenth century, partially due to the introduction of new diseases by Spanish explorers and missionaries like Kino.

Kino usually offered livestock as gifts when establishing a new Jesuit village or mission. In this way, the fertile grasslands of the Santa Cruz Valley eventually became the grazing grounds for thousands of cattle, sheep and goats. Not only did this provide food for the native people, it also supported Spanish settlement in the valley. Many Spanish settlers prospected for minerals or practiced ranching in the area, often depending on crops grown at the missions. Another method the Spanish government used to encourage settlement was by offering land grants. The result, which to some degree persists today, was to establish grazing as the primary use of a large portion of the Santa Cruz River Valley.

Soon after missionaries entered the valley, the Spanish military began establishing presidios, or military posts, to protect the colonists. Captain Juan Bautista de Anza is one of the most remembered officers from this period. Not only was he the largest landowner in the area, with extensive ranching operations, but in 1775 he organized a group of about 300 people, with gear and livestock, at "his presidio" in Tubac. Traveling north along the Santa Cruz River and then across the desert, the group established a new city on the coast of California—San Francisco.

The Spaniards used water from the Santa Cruz River for livestock and diverted water for agricultural use. Canals brought river water to a garden at San Agustín del Tucson. The remnants of those canals were used in the 1800s by Solomon Warner at his flour mill near the base of Sentinel Hill, or "A" Mountain, and can still be seen today. The Spanish had extensive irrigation canals

"Today we passed through Tucson. ... Here we heard some awful tales of the route ahead of us [from Tucson to the Gila], dead animals strewing the road, wagons forsaken, human skeletons, who had famished for want of water etc." W. Hunter, 1849

near Tubac, employing Indians to grow crops for themselves, the missionaries, and Spanish miners.

Anglo Explorers and Travelers

Mexico went to war with Spain and gained independence in 1821. After the U.S. defeated Mexico in 1848, Mexico retained the Santa Cruz Valley temporarily. Soon after the 1849 California Gold Rush, the United States purchased all of southern Arizona south of the Gila River (The Gadsden Purchase), or most of the Spanish frontier of *Pimería Alta*. So, just as minerals were becoming scarce in California, a huge new land mass was added to the American domain.

The Gila Trail, which followed the Santa Cruz River along most of its course from the town of Santa Cruz in Mexico, was a primary route for travel to California. Not surprisingly, many of the argonauts found the Santa Cruz Valley to be a suitable alternative to the chaos of California.

The expansion of travel and settlement in the Santa Cruz Valley created the need for a city to supply travelers, and Tucson, which had remained a very small town for centuries, rose to the occasion. Although some small attempts at mining and agriculture were made prior to the American Civil War, Tucson's location along this major travel route, especially the railroad greatly influenced its growth.

Some early American explorers included surveyors of the international boundary in the 1840s and 1850s. Others included military companies, like the Mormon Battalion, which was exploring for a wagon road.

Mining

Mining in the Santa Cruz River Valley was practiced for centuries by Indians, primarily in small silver mines in the Santa Rita Mountains. Thoughts of gold and silver lured the Spanish, but copper has been the most important mineral extracted in Arizona in recent times.

After the arrival of the Spanish, some attempts at mining silver and gold were made. At this time any large-scale attempts at mining were infeasible. Not only was it difficult to haul the ore over the rugged terrain of the mountains, but Apache raids made it dangerous.

The "era of modern mining" in Arizona began in the Santa Cruz Valley in 1857 with the purchase of the Sopori and Arivaca land grants. The purchasers of the grants, including Charles D. Poston, formed the Sonora Exploring and Mining Company, and later the subsidiary Santa Rita Silver Mining Company. Most of the early mines in the Santa Cruz Valley were developed for gold or silver, but these metals were relatively scarce compared to copper. Despite considerable optimism about the richness of the mines, the operations didn't produce a significant profit.

The San Rafael Valley and nearby grasslands to the east were the sites of significant mining activity beginning around 1880. Over 1.9 million tons of ore were taken from about 40 large mines there, including the districts of Mowry, Harshaw, and Duquesne. Most mines were active for only a few years, but some were productive until the 1960s.

By the middle of the twentieth century, open-pit copper mining became a major land use south of the Tucson area, with smaller mines to the northwest. During the mining peak of the 1960s to the 1980s, groundwater pumping by the mines affected the water table from the San Xavier District to Tubac. In 1994, mining activity declined, with annual pumping by these mines just over 30,000 a.f., down from more than 50,000 a.f. earlier. Mining operations have led to pollution

"That portion of the valley which is generally watered ... produces, like southern California two crops a year. Last year there were 40,000 acres of land in cultivation in Santa Cruz Valley proper, and nearly 45,000 acres in the net-work of valleys and canyons adjacent." The Bulletin, 1879.

problems, especially on the San Xavier District of the Tohono O'Odham Nation, and contributed to lowering of the water table and dewatering of the river.

Ranching

Droughts in California and Texas in the 1880s, coupled with the arrival of the railroad, brought huge numbers of livestock into Arizona. In the early-to mid-1800s, between 2,000 and 5,000 head of cattle grazed in the San Rafael Valley annually. In the early 1880s, two ranches along Pantano Wash near Tucson, Empire and Vail, had an estimated total of 6,000 cattle and 23,000 sheep. Sam Hughes, a Tucson pioneer, reported that Pima County had about 10,000 head of cattle in 1885, concentrated along streams.

Large numbers of livestock were grazing in the Santa Cruz Valley when severe weather patterns affected the area about 1885. A series of very dry summers and very wet falls, coupled with the overgrazing of livestock, left the valley in a precarious state. In the spring of 1890, the heaviest rains then recorded fell on the valley, washing away dams and other diversion structures along with ranches. Rather than encourage new growth on the damaged range, the heavy fall rains washed away topsoil. The damage to the grasslands was extensive. Within a year the livestock industry in the Santa Cruz Valley began its decline.

Some of the grasslands never recovered. Today most ranchers practice conservative grazing management. As a result, the San Rafael Valley is currently a healthy grassland system. It has less

On Tucson's need for new water development. *"Originally the well was but 18 feet deep and the process of sinking is still going on. Formerly the city supply came through submerged sluices in the river bed and to some extent these still furnish all that is necessary, but the company has been obliged to run their pump 27 months in the last two and a half years. To do this it required 1,782 cords of wood at an expense of $4500. Tucson uses an average of 13 million gallons of water per month."* Arizona Daily Star, June 13, 1895

Warner and Silver Lakes

Tucson in the 1880s was a growing community with a need for new industry and recreation. This need was partially fulfilled by the development of two lakes on the Santa Cruz River near downtown Tucson. Silver Lake was built in the 1860s by putting a dam across the Santa Cruz River about a mile south of Sentinel Hill, or "A" Mountain. In 1863, James Lee built a mill near the lake, grinding flour with power supplied by water from the lake. Warner Lake was built about one half mile north of Silver Lake by Solomon Warner in 1883-1884. Since all of the water from the Santa Cruz was impounded and diverted by James Lee, Warner built his dam far enough north to catch the waters seeping from the cienegas around the base of Sentinel Hill. Both of these mills ground grains to supply flour to the nearby community. Warner was fairly successful, so he added a three stamp mill to grind ore from local mines he was operating.

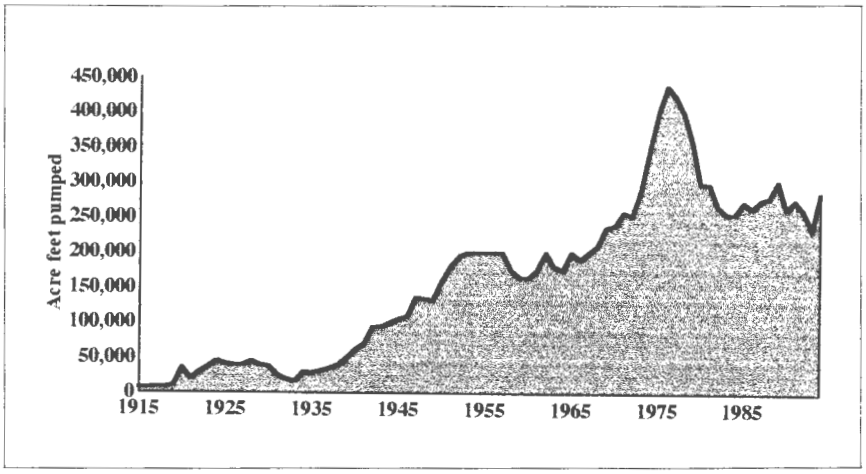
The lakes that had been built became popular areas for a number of reasons. First, local people began to picnic by the waters, and then to swim. Hunters bought the right to hunt the ducks and other waterfowl on the lake. In 1888, Frank and Warren Allison had possession of the lakes, and were harvesting fish to sell in Tucson. Bath-houses were built on the lakeshores, and for some time the lakes near Sentinel Hill were the most popular recreation spots in Tucson.

Silver Lake around 1888.

pressure from urban development than other areas within the Santa Cruz River Valley.

Agriculture

When the first Anglos began settling in the valley the population relied on crops grown by diverted surface water. This changed with the introduction of ground-water pumps. Woodburning pumps were brought into the valley by 1890, and this technology completely changed the nature of agriculture. The first pumps were inefficient and needed wood to operate, which was scarce in the desert. Within a few years, more efficient combustion pumps were invented, and Tucsonans became dependent on groundwater.



Groundwater pumping along the upper Santa Cruz River.

Once the groundwater table began to drop in the early twentieth century, some of the surface flow of the Santa Cruz River disappeared. To maintain irrigated crops without the use of pumps, subsurface diversion structures were placed in the river bed.

After efficient pumps made it economical to bring groundwater into otherwise dry lands, water-intensive crops were planted up and down the valley. Wheat, alfalfa, cotton, fruits and vegetables have been grown in the valley for decades. Green Valley's 7,000 acres of pecan trees use 30,000 acre-feet of water per year today. The Marana-Avra Valley area has been heavily farmed since the 1930s. When the City of Tucson bought some 10,000 acres of Avra Valley land in the 1960s and 1970s, farming declined but pumping continued to serve municipal demands.

The Growth of Towns

Although the Santa Cruz River Valley passed from Spanish to Mexican to American ownership, settlement in the area was retarded by persistent Apache raids. It was not until well after U.S. purchase of southern Arizona, in fact not until after the Civil War ended in 1865, that a military presence allowed relatively safe settlement of the valley.

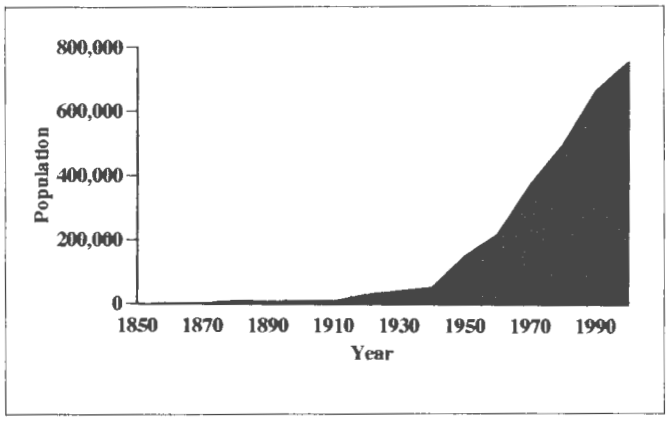
Prior to 1865, the population of Tucson remained relatively stable at around 250 people or less, although Tucson was the territory's largest town for many years. After 1865, the population of

Entrenchment of the River

Sam Hughes was an early Tucson pioneer. He was born in Wales in 1829, and after coming to the U.S. as a boy, he traveled throughout the West before settling in Tucson in 1858. He became a wealthy businessman, dealing in livestock and real estate, and was an important figure in the development of the budding city.

In 1887 Hughes saw a way to bring water from the Santa Cruz River to irrigate land north of town—he would crosscut a ditch into the river and divert subsurface water. Originally he planned to dig the canal about 20 feet wide and 15 miles long, on the east side of the river around St. Mary's Road. Such a large project would be expensive and Hughes could not finance it, so in 1888 he built a smaller version and hoped that the next year's floods would finish the cut.

Some moderate floods washed down the Santa Cruz River in 1889, but had an unexpected effect on Hughes' ditch. The water started eroding the channel of the river from the headcut to the south. By the end of August the arroyo had crept to Silver Lake, about 3 miles upstream. Within a year the river had cut a significant arroyo south to near Mission San Xavier del Bac. The big floods of 1890 worsened the situation. Today the river between Tucson and Sax Xavier is entrenched as much as 30 feet, in large part because of Hughes' ditch.



Population in Pima County.

the region began to grow quickly, mostly in Tucson. Other areas in the valley experienced population growth as well. Today the population of Nogales, Arizona is about 20,000 and Nogales, Sonora many times that. Farther north, Casa Grande developed as a railroad town in the 1880s, and as groundwater pumping technology improved, the town became the nucleus of a major agricultural area.

Urban development affected the river in many ways. Woodcutting for fuelwood deforested areas near the river. People who built homes and businesses near the river demanded flood control structures to protect their investments. Today, most of the Santa Cruz and Rillito rivers through the Tucson urban area are soil-cemented to prevent erosion. Streets, parking lots and buildings increased paved areas, causing less water to soak into the ground. Instead, flowing water rushes rapidly to the watercourses, often causing flooding problems and eroding streambanks.

The rivers also became convenient places to dump trash, either casually or in landfills. Wastewater from the sewage treatment plants also was dumped in the rivers, both from the Nogales International Wastewater Plant and from two large facilities in Tucson. This wastewater actually benefitted the river, once its water quality was reliably controlled, creating a lush riparian habitat from Rio Rico to Tubac.

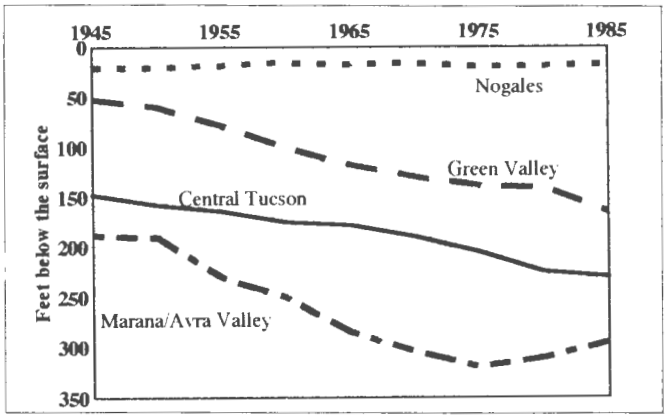
Water Use

Population increases placed pressures on the water supplies throughout the basin, but most of all in the Tucson area. To supply its water needs, the emerging city turned to the river. Homesteads and farms were established close to the river in the nineteenth century. Gardens and picnic areas lined its banks. In the late 1800s, Warner and Silver lakes were created near downtown Tucson by damming the Santa Cruz River.

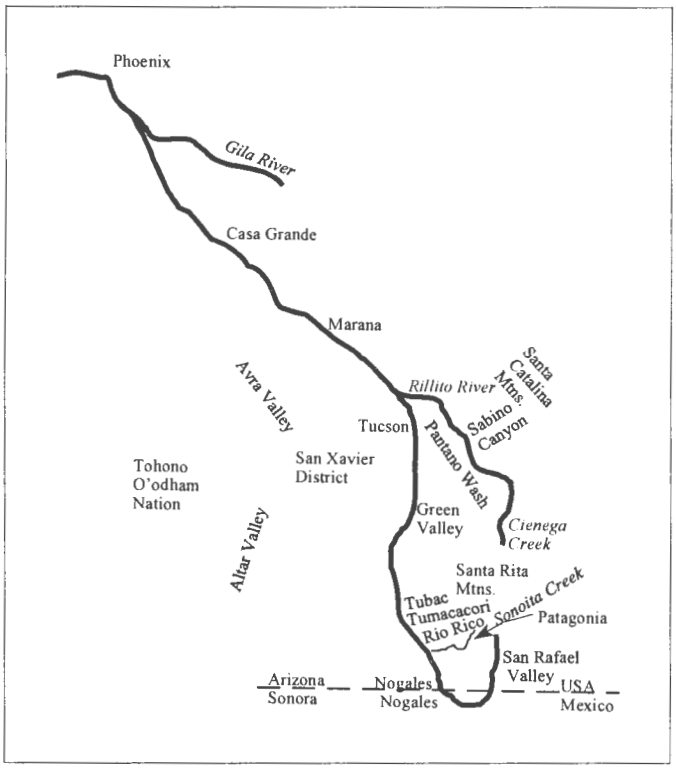
Groundwater pumping changed Tucson's relationship with the Santa Cruz River. In the days of Warner's Lake, reliance on the river's surface water meant that settlement did not often occur far from the river. The effects of groundwater pumps were two-fold: efficient pumps allowed development to proceed further away from the river; and groundwater pumping was the primary cause of the drop in water table and the loss of surface waters.

Groundwater pumping has for years been extracting more water from the Tucson Basin than is naturally recharged. Currently, agriculture accounts more than half the water use in the Tucson Active Management Area. The overdraft in 1990 was more than 207,000 acre-feet, or nearly 70 billion gallons. Pumping made it possible to bring water to places where there once was none.

The Central Arizona Project (CAP), a system of canals and pumps which brings water from the Colorado River through Phoenix to Tucson, is designed to relieve the groundwater overdraft and even provide flowing water for watercourses. Un-



Depth to water at selected locations.



Twentieth century sites along the Santa Cruz River.

certainties in public opinion in recent years have, however, delayed the use of CAP water and the groundwater supplies continue to be overdrawn.

Vegetation and Wildlife

The lower Santa Cruz River in Pinal County did not historically have a perennial flow of water. As a result its vegetation reflects a desert stream—no large cottonwood trees or lush grasses As in the upper Santa Cruz River Basin.

In the early days of exploration and settlement, the upper portions of the basin, on the other hand, were described as lush and fertile with excellent grazing grounds, abundant grass, occasional forests of huge mesquite trees, and a river lined with riparian tress such as cottonwoods, walnuts, and willows.

Other riparian species existed in the cienegas, which were commonly found along the river and its tributaries. The Santa Cruz River at "A" Mountain in Tucson was a broad, swampy area fed by springs flowing from the base of the hill. Cienegas were found near Tubac and Nogales, .

Fort Lowell was established near a marsh on the Rillito River in Tucson. The soldiers were frequently ill with malaria, as were soldiers at Fort Buchanan, near present-day Patagonia. Other cienegas existed along Cienega Creek, Pantano Wash, Arivaca (in the Avra-Altar watershed) and the San Rafael Valley. All of these areas had lush aquatic vegetation and diverse wildlife.

The higher elevations in the mountains throughout the basin had large tracts of forest, most of which are still present. The valley itself was covered with grasses, shrubs, and riparian vegetation, from cottonwood-willow forests to the mesquite bosque. Much of the valley's vegetation has been altered by groundwater pumping, agriculture, urban development, and introduction of exotic plants and animals.

On the San Xavier District of the Tohono O'odham Reservation, early travelers described a very old and large mesquite bosque. Although most other bosques in the area had been cut down for firewood, this one lasted until the 1960s, when groundwater pumping and the resulting drop in the water table led to the loss of both this mesquite forest and a cottonwood forest on the banks of the river.

The diversity of the vegetation contributed to a great diversity in wildlife. The perennial water of the river supported fish and other aquatic species. Prehistoric farmers near Tucson supplemented their diet with fish caught in the river. Early explorers described the Santa Cruz As a crystal clear, and full of "fish and tortoises of various kinds." Beaver and muskrat were pre-

"Mr. Fuller had killed a tiger in my absence and he and Grosvenor had quite a chase after a bear that ventured near the camp. ... Bears are very numerous here of these species, the black bear, the brown or as it is called the cinnamon bear and the fierce and dreaded grizzly. ..." Phocian Way at Tubac, 1858.

sent, probably wherever enough water and vegetation could be found. Waterfowl were common.

Travelers and settlers also encountered large mammals. Diaries of many pioneers describe killing black and grizzly bears, wolves, coyotes, mountain lions and bobcats. Deer and pronghorn roamed the valley. One legacy of the Spanish period was a population of wild horses. Wild cattle were fairly common in the area, originating with the Spanish and later, cattle drives of the 1800s.

Once the human population began to grow, many species were pushed out of the area. The large herbivores, or plant eaters, like antelope, were not welcome in farmlands and were hunted.. Some of the large predators like grizzly bears and wolves are no longer found anywhere in the valley. Others became limited to upper elevations. Even now a hiker in the mountains near the Santa Cruz might be lucky to catch a glimpse of a black bear or mountain lion.

The aquatic species suffered the most. As surface waters were lost and cienegas drained, some animals were unable to survive. Estimating the number of species affected by the loss of riparian habitat is difficult. The Arizona Game and Fish Department, however, lists plants and animals thought to be in some danger of becoming extinct. In 1995, approximately 50 species were listed by the department in the Santa Cruz River Valley. The main cause of this displacement is loss of habitat, especially riparian habitat.

Changes in the River

In the Santa Cruz Valley today, the receding groundwater table has left much of the river dry. The San Rafael Valley is very much the same as it was before Anglo settlement, but the reliability of the surface flow at Tubac is dependent on wastewater from the Nogales Treatment Plant. The perennial reaches that existed at San Xavier and Tucson are now a dry, deeply entrenched channel, except where effluent flows. In other areas the channel of the Santa Cruz was purposely changed to straighten the meandering river or otherwise redirect water. Most of the banks of the Santa Cruz and Rillito rivers through Tucson have been soil cemented to prevent erosion. Artificial channels were constructed south of Mission San Xavier del Bac to join the East and West branches of the river, redirecting flow away from the Mission.

"In 1935 many a grand old patriarch still ruled here that had evidently already looked down on several centuries of desert droughts and savage storms. ... Here there are trees of historic dimensions; the bole of one stately specimen ... reached a girth of 13 feet six inches; and a diameter of more than 43 feet; while the height of another capitol-domed giant was calculated to be 72 feet ... in the apparently empty, arched aisles of the grand mesquite forest there have been drawn together from its rich seclusion a group of as colorful birds as may be enjoyed anywhere. ..." Herbert Brandt, 1942, describing the San Xavier mesquite bosque.

Many of the grasslands and desert areas in the Santa Cruz Valley were replaced by agriculture and towns so the vegetation in the valley is very different from pre-settlement times. Even the river in Pinal County, historically dry, is now surrounded by crops. Casa Grande is near some of the most productive agricultural land around

Restoration and Preservation

Reliance on the river has changed, but our fascination with it has not. Recognizing historical, cultural, and ecological values, many river miles have been preserved. Tumacacori National Historic Park and Tubac Presidio State Park both are remnants of the Spanish periods of exploration and mission-building. Mission San Xavier del Bac is a particularly famous attraction and is now a part of the San Xavier Indian Reservation. Many miles of the Santa Cruz and Rillito Rivers through Tucson have been purchased as parkland.

Some of the tributaries still have ecologically important perennial surface flow. Many of these, too, have been preserved by public ownership or through private initiatives. The Nature Conservancy, for example, maintains the Patagonia Nature Preserve on Sonoita Creek. Sabino Creek, which feeds into the Rillito, is within a popular Tucson National Forest recreation area.

A TIME OF CHANGE 1500-1850

By the end of the fifteenth century, the Hohokam, Anasazi, Sinagua and Mogollon civilizations had passed their peak and numerous smaller groups of people were spreading slowly into new areas. Two new groups of people moved into the Southwest to further change Arizona's rivers. Athabaskan speaking people (Navajos and Apaches) settled in the Southwest from the north, and Spanish speaking people moved in from the south. Since they were trying to occupy much of the same territory, some of which was already occupied by people such as the Pimas, Yumas, and Hopis that had been around for centuries, clashes were inevitable.

Indian Settlement—1500 to 1850

This 350-year period was a time of great change in Arizona. Not only did the Athabaskan-speaking people and the Spanish enter the area, but many groups such as the Maricopas that arrived much earlier settled in new areas. Territorial boundaries had always been fluid, especially for the nomadic and semi-nomadic people. People moved to where the resources were most plentiful or conversely were driven from such areas by other people. Rivers remained the focus of settlement.

In 1600 the area south of the Gila River (including the San Pedro and Santa Cruz rivers) was dominated by Pima-speaking people, the Pima, Tohono O'odham and Sobaipuri. Hokan-speaking people occupied the western section of the Gila River and the lower Colorado—the Cocopahs, Quechan (Yuma) and Mohaves. Pai-speaking people—the Havasupai, Walapai and Yavapai—occupied the highlands north of the Gila River, including the Verde Valley. Uto-Aztecan-speaking people—the Paiutes, Zuni, and Hopis (pueblo people)—were north of the Colorado and Little Colorado rivers.

By 1850 the Maricopas had moved eastward to areas occupied by the Pimas along the central Gila River. The Sobaipuri had left the San Pedro and been assimilated into the Tohono O'odham society along the Santa Cruz and farther west. The Navajos had moved into the area north of the Little Colorado River. The Apaches dominated the eastern part of the state, south of the Little Colorado River, including parts of the Salt, Gila, Santa Cruz and San Pedro rivers.

The Athabaskan Tribes

The latest migrations of tribes from the north moved south from Canada toward the end of the first millennium, spreading out in the Great Plains and eventually reaching the Southwest some time in the fifteenth or sixteenth century. Because these people were nomadic and did not leave permanent structures, archaeologists do not

Apaches crossing the Gila River at San Carlos in the 1890s.

Tohono O'odham women getting water.

know exactly when they reached Arizona or when they separated into distinct groups of Navajos and Apaches. Spanish and later Anglo-American ranches and farms were periodically begun and then abandoned throughout the San Pedro and upper Santa Cruz valleys because of Apache raids.

Navajos

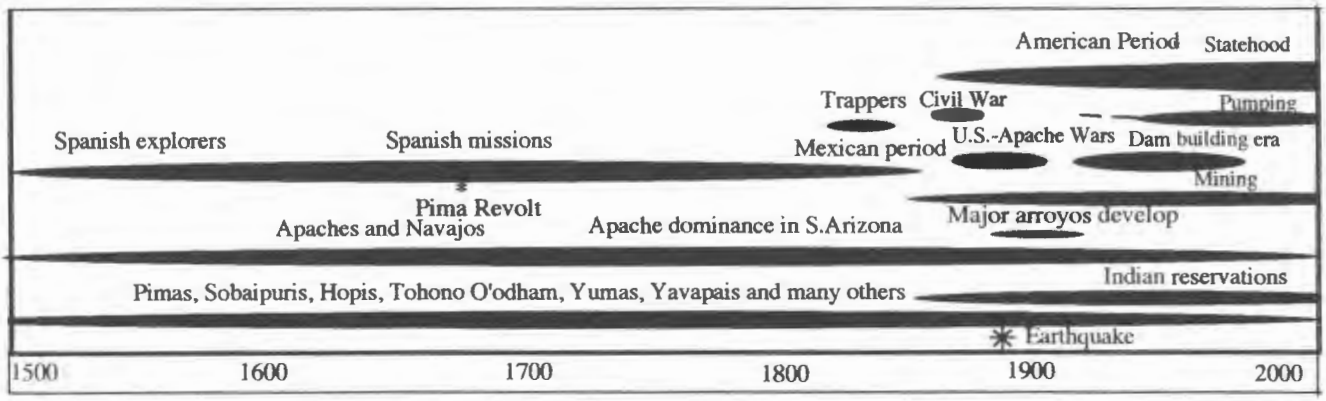
The Navajos moved through Utah and Colorado into New Mexico and then came west to northern Arizona. They mixed with pueblo tribes, began farming, adopted Spanish livestock, and developed a new way of life. By 1630, the Spanish in New Mexico were referring to them as "Apaches de Nabaju."

A revolt of the pueblo people against the Spanish in 1680 drove the Spanish out of northern Arizona. The Navajo formed closer bonds with pueblo people and adopted Spanish horses, goats and sheep for a new pastoral way of life. Sheep became important as a sign of wealth and a source of wool for the Navajo to be used in their new art of weaving. As the herds increased, overgrazing became a serious problem along the Colorado Plateau, increasing erosion and loss of soil to the Colorado River system.

Apaches

The Apaches developed a very different life style from the Navajos. Some scholars believe they were a small splinter group of the Navajos, uninterested in settling down in permanent communities. Their way of life remained largely nomadic until the late nineteenth century, although they did practice seasonal farming. Raiding other tribes, and later the Spanish, became a way of life. Apaches often dominated the highlands, raiding farms and ranches along the river valleys.

They, too, benefited from Spanish livestock, but did not develop an economy based on herding. In-



stead, they tended to raid other tribes and Spanish ranches from central Arizona to southern Sonora. Horses became important to their wide-ranging life style and allowed them to travel great distances. Several bands of Apaches settled in the area, some more sedentary than others. The Chiricahua Apaches were the most numerous and warlike band, and they prospered. As Tom Sheridan described it in his *Arizona: a History,* "They became the specters that rode through Hispanic nightmares for the next two hundred years."

The Spaniards

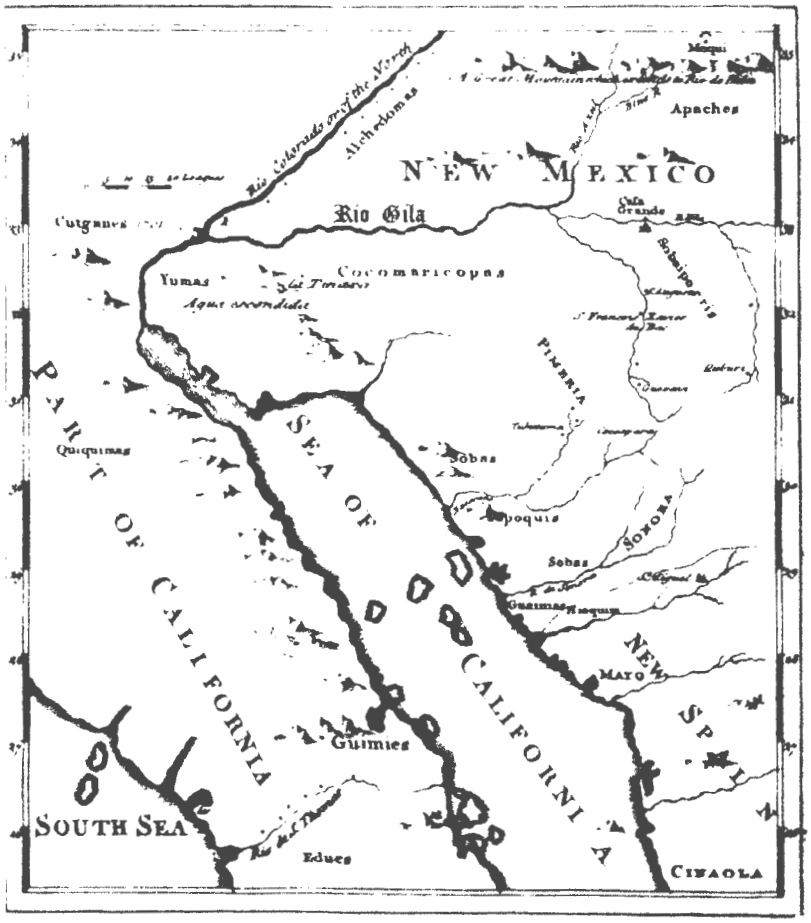
When the Spaniards arrived in Arizona, led by Coronado in 1540, they found only the ruins of the ancient tribes—Hohokam, Anasazi, Mogollon, and Sinagua Indians. They encountered a number of Indian tribes in the 1500s—the Pima, Maricopa, Tohono O'odham, and Sobaipuri Indians in central and southern Arizona; the Hopi, Havasupai, and Pauite Indians in northern Arizona; and a variety of tribes near the Colorado River, including the Mohave, Cocopah, and Quechan. The earliest explorers did not mention the Navajos or Apaches.

The first Spanish incursions in the 16th century tended to be dramatic short-term military events—swooping in and out, hoping to find gold or other wealth. Later as missionaries such as Father Kino arrived in the 17th century, permanent settlements became more common. These settlements were located near rivers or springs where people already were living. Missionaries attempted, with varying success, to "civilize" the Indians by forcing the Indians to adopt more sedentary lifestyles. Intensive agriculture and the introduction of herds of cattle were to provide the economic sustenance for the newly formed communities. Crops and livestock the Spanish introduced changed the lifestyles of the people.

Spanish Land Grants

During the Spanish and Mexican periods, the governments made land grants to individuals to encourage settlement of the Santa Cruz and San Pedro rivers in Arizona, the Rio Grande in New Mexico and other places. Some of the larger land grants along the Santa Cruz included: San Jose de Sonoita, 5,123 acres on Sonoita Creek; La Canoa, 46,696 acres to the north of Tubac; El Sopori, 141,722 acres between La Canoa and the Mission San Xavier del Bac; Arivaca; San Rafael de la Zanja; Tumacacori/Calabasas; and Los Nogales de Elias, 32,763 acres near Tumacacori. Much of the Santa Cruz Valley, from its headwaters to San Xavier was within one of these land grants. Grazing was a primary use of these lands and the effect, which to some degree persists today, was to establish grazing as the primary use of much of the upper Santa Cruz Valley. Because of Apache raids, however, many of the areas were used for only short times by the original grantees but increased in importance later.

After the Gadsden Purchase was ratified in 1854, the U.S. government had to decide how to deal with claims in the newly acquired land. Because of faulty record-keeping, ownership of many parcels of land was uncertain. For example one claim, the Peralta-Reavis, was for 13,000,000 acres of the Gila River Valley from New Mexico almost to its confluence with the Salt River. To deal with the litigation, the Court of Private Land Claims was established in 1891. Many land grants, including the Peralta-Reavis, were found to be fraudulent. Many of the land grants continue to play a role in land development patterns today. Green Valley and Rio Rico are both located on old land grants.



Pimería Alta.

While the missionaries met with some early success in the San Xavier area, the Pimas revolted in 1751, plundering missions throughout the area that became known as Pimeria Alta. Spanish *presidios* (military encampments), were established to protect missionaries and miners. Although the Spanish had missions on the Colorado Plateau and along the Colorado River near Yuma, these were short-lived and ended with revolt of the native people.

Spanish rule ended in 1821 when Mexico won its independence from Spain. Mexico again went to war in 1846, this time with the United States. The Treaty of Guadalupe Hidalgo in 1848 ended the war and the U.S. became the owner of all of Arizona north of the Gila River. The Gadsden Purchase in 1854 added the remainder of the land south of the Gila to the U.S., forming the current U.S.-Mexico border.

Impacts on the Rivers

The three centuries following the Spanish and Athabaskan migrations into Arizona were unstable times. The Spanish introduced new diseases that often devastated whole communities. The effect of disease was probably compounded by the Spanish system of gathering native peoples into population centers, where disease spread rapidly. Nomadic tribes were less affected.

The Spanish also introduced new crops and livestock, changing the lifestyles of both the farming and the nomadic tribes. The farming tribes gained winter crops for the first time, and were able to farm all year long. They also gained sheep, goats, cattle and horses. In some areas where livestock became numerous, the impact on the rivers was increased erosion and loss of soil.

The nomadic and semi-nomadic tribes gained horses, allowing some to become highly mobile. This in turn led to increased successful raiding of Spanish, Mexican and Indian settlements. The Apaches had some effect on the rivers, especially through their technique of using fire to keep some areas as grassland rather than mesquite-shrub dominated landscapes. But their greatest influence was through keeping sedentary peoples out. Apache raids rendered much of the San Pedro and Santa Cruz valleys uninhabitable for ranching and farming for about two hundred years, postponing the effects of overgrazing and heavy water use until the Anglo-Americans prevailed at the end of the nineteenth century.

San Pedro River

The San Pedro River is one of the longest undammed rivers in the Southwest. It has high value for migratory and resident wildlife as well as recreation. Its colorful history includes many boom-and-bust mining towns, ranching, farming, and the development of urban areas and military bases.

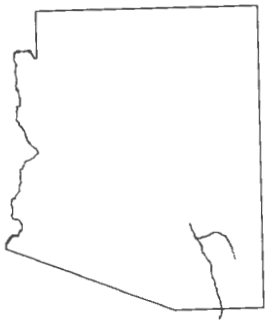
The River

The San Pedro watershed extends over 4,487 square miles and includes two main tributaries—the Babocomari River in the upper basin and Aravaipa Creek in the lower basin. The main stem of the river is about 193 miles long, from its headwaters in Mexico to its confluence with the Gila River.

The San Pedro River is surrounded by mountains ranging from 1,920 to 9,000 feet feet elevation. About 33 square miles of riparian habitat are found along the river and its tributaries.

Early Inhabitants

The San Pedro Valley has been inhabited for at least 12,000 years. The earliest people hunted mammoths and other animals and harvested plants. By 500 A.D. people were irrigating crops near the mouths of major tributaries. Population expanded between 850 and 1000, but by 1200 the civilization was in decline and by 1400 the villages were abandoned.



When Spaniards arrived in the sixteenth century, as many as 2,000 Sobaipuri lived in the area. They said they knew nothing about the previous occupants. Some consider the Sobaipuri to be ancestors of the Pima and Papago Indians. Apaches arrived in the area about the same time as the Spanish. Frequent conflicts arose among these three groups of people.

"... the Rio San Pedro it affords plenty good running water and runs north emptying I suppose into the Gila and seems to a bound with plenty of Fish. Our course was now down this River and quite a lot of salmon trout was taken, bands of wild horses were seen as also antelope and wild cattle. ... On the 11th of December while marching down the San Pedro a number of wild cattle I believe mostly bulls came running from the west and ran through our ranks plunging their horns into two team mules goaring them to death instantly and running over men." Philip St. George Cooke, 1846.

Spanish-Mexican Period

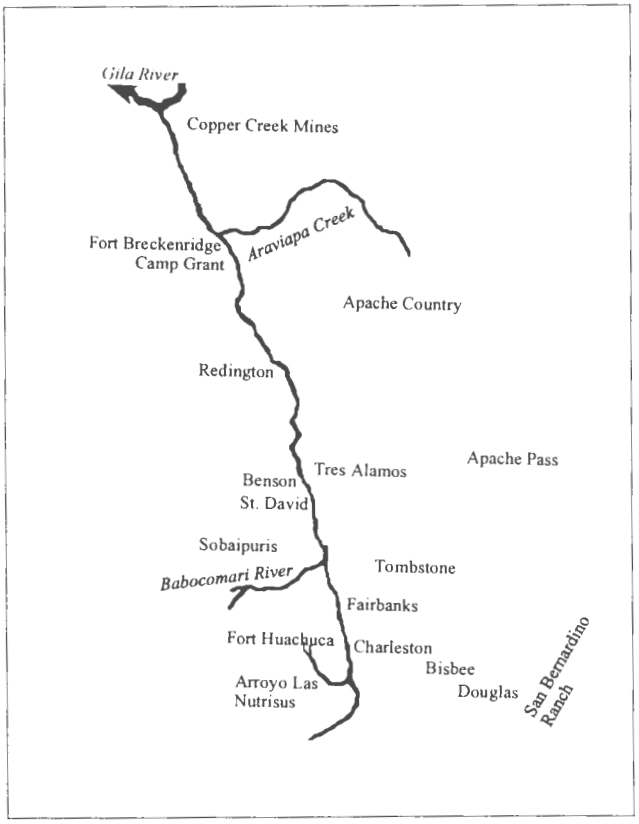
The San Pedro River has long been an important transportation corridor. Friar Marcos De Niza probably was the first European to pass through the valley in 1539 while seeking the "Seven Cities of Cibola." Francisco de Coronado brought over 300 Spaniards, 1,000 Indians, and 1,500 horses and pack animals through the valley in 1539-1540. Father Kino also came several times between 1691 and 1702, trying to establish missions and to introduce European livestock and crops. He noted that the Sobaipuri villages used irrigation to grow corn, beans, cotton and squash as well as peaches and other European crops, but that they moved often, probably because of Apache attacks.

Settling in the upper San Pedro Valley in the 1700s, the Spanish ran cattle, especially near the headwaters. Because of Apache raids between 1700 and 1830, cattle numbers fluctuated. By

1710, the Apache controlled land and water use in the San Pedro Basin. By 1736, many of the Spanish ranches were abandoned.

The Apaches also forced the Sobaipuris out of the area, putting an end to most agricultural activities. A Spanish military escort moved about 250 Sobaipuri Indians from the San Pedro Valley to the Guevavi Mission near the Santa Cruz River in 1762 to replace the Pimas who had died from epidemics and to protect that Mission from Apache attacks. In 1775 the Spanish tried again to settle the upper San Pedro Valley and placed a presidio on the west bank of the river near Fairbanks, but were driven out by Apache attacks in 1780.

Until the late 1870s, the Apaches controlled most of the San Pedro Basin. Not until the Indian wars and capture of Geronimo in 1886 was Apache control over the area broken.



Historic sites along the San Pedro River.

"In the gorge below (Tres Alamos) and in some of the meadows, the stream [bed] approaches more nearly the surface [of the floodplain], and often spreads itself on a wide area, producing a dense growth of cotton-wood, willows and underbrush, which forced us to ascend and cross the out-jutting terraces. The flow of water, however, is not continuous. One or two localities were observed where it entirely disappeared, but to rise again a few miles distant, clear and limpid." J.G. Parke, 1854.

Early American Explorers

The Patties, who trapped beaver along the San Pedro River in 1826, called it the "Beaver River" because the animals were so plentiful. Beaver dams formed a series of pools and grassy marshes. Pattie described the river: "Its banks are still plentifully timbered with cottonwood and willow. The bottoms on each side afford a fine soil for cultivation. From these bottoms the hills rise to an enormous height, and their summits are covered with perpetual snow."

The first "official" exploration of the area was conducted by the Mormon Battalion in 1846. Their leader, Philip St. George Cooke, left us some of the best early descriptions of the San Pedro. He described the San Pedro as a "marshy bottom with plenty of water and grass" and as "a beautiful little river"with an abundance of fine fish, which they caught. One type that grew up to three feet long was called "salmon trout." These were almost certainly Colorado squawfish. Some areas were dominated by cottonwood or ash forests. Cooke wrote, "In those days the grass grew so tall that one could see only the herds of antelopes that roamed over the valley in large herds." Cooke, the leader of the battalion, feared attacks by cattle even more than by Apaches.

Cooke was followed by other explorers—some searching for riches such as gold in California, some escaping religious persecution, and others beginning a new life on the Western frontier. Asa Clarke, who explored much of the valley in the 1850s, reported a gun battle with a grizzly

bear and, when he replenished his canteen from an old irrigation ditch, also noted that the valley had been farmed, but abandoned. He said trees were "becoming common on the river; its direction is indicated by them for a long distance. They are principally cottonwoods, with some sycamore, willow, and mesquite."

After the Gadsden Purchase, many more people arrived. Routes were laid out for stage coaches and later, railroads. In 1854, J.G. Parke led a surveying party along the Gila River to Tucson and then to the San Pedro River. At the site of present-day Benson, he reported "... the stream is about eighteen inches deep and twelve feet wide, and flows with a rapid current, at about twelve feet below the surfaces of its banks, which are nearly vertical, and of a treacherous miry soil, rendering it extremely difficult to approach the water, now muddy and forbidding. ..."

Also In 1854, James G. Bell traveled the San Pedro en route to California. When he reached the San Pedro he "found plenty of water." Traveling up the river, he described the San Pedro as the "most hospitable place" he had seen since San Antonio. He noted: "The valley through which the San Pedro passes is a desirable location for ranches. The hills on either side are covered with timber, huge loose stones and a good quality of grass ... some portions of these hills are very pretty."

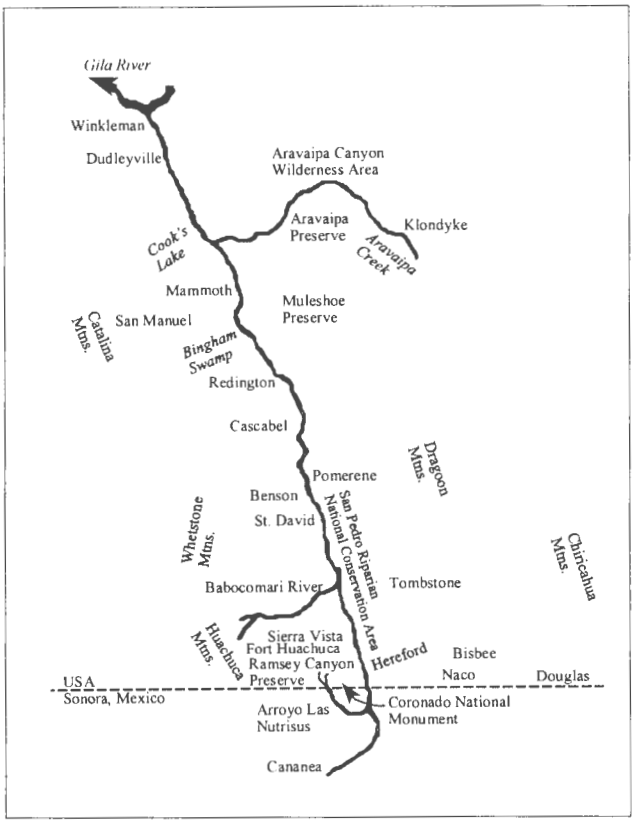
Philip St. George Cooke.

"My anxiety became very great and I pushed on at a fast gait to the guides, and after ascending a hill saw a valley indeed, but not other appearance of a stream than a few ash trees in the midst; but they, with the numerous cattle paths, gave every promise of water. On we pushed, and finally, when twenty paces off, saw a fine bold stream! There was the San Pedro we had so long and anxiously pursued." Philip St. George Cooke, 1847.

Bell noticed evidence of Indian wars and found two ranches in ruins. Cooke noted that it was from one of those ranches that "the wild cattle are derived, and they are the thickest at their old haunts. There are numerous traces of them, as of buffalo in their range; and the same, even to wallows. Their numbers are concealed by vast thickets of mesquite."

Construction of the first major road to cross Arizona, from El Paso to Ft. Yuma, began in 1858. The road followed the San Pedro River from the Dragoon Mountains to the mouth of Aravaipa Creek, where the road forded the river and headed towards the Gila River.

The flow of the river was unpredictable, with travelers placing bets on whether or not the stream would be flowing about 35 miles north of Tres Alamos. "Exceedingly to the surprise of every member of the expedition who had passed over this route in the months of March and April it was discovered after a march of a few miles that the waters of the San Pedro had entirely disappeared from the channel of the stream. ... So incredulous were many of those who were on the April Expedition that heavy bets were offered that Col M. was mistaken. A thorough examination proved his discovery correct much to the astonishment of many. Where the present reporter took quantities of fine trout in March and April 1858 not a drop of water was to be seen."



Twentieth century sites along the San Pedro River.

American Settlement

In the 1860s, the San Pedro Stagecoach Crossing near present-day Benson, was one of the first signs of the coming American settlement in the area. Grain for the station was grown at a small Mexican settlement on the river, nine miles below the station. Floods destroyed the stage station and a bridge at present-day Benson in 1883-1884.

Homesteading began in the upper San Pedro Valley in 1867, but early American settlement, like Spanish and Sobaipuri settlement, was marked by short periods of peace followed by abandonment due to Apache raids.

Military posts established after the Gadsden Purchase were quickly abandoned during the Civil War, leaving settlers unprotected. Fort Breckenridge (which became Fort Grant), at the confluence of Aravaipa Creek and the San Pedro River, was reestablished in 1862, as a base for fighting the Apaches. The Apaches were subdued after the Civil War and, in 1873, the Aravaipa Apache were relocated to the San Carlos Indian Reservation, and Camp Grant was moved to Bonita, leaving the lower San Pedro without a military presence. A traveler in 1875 in the lower San Pedro Valley reported that "there was not a single resident. Only the ruins of former homes greeted the eye." However, in 1877-78, a steady stream of homesteaders began to move into the area, using water for irrigation, ranching and mining. Between 1878 and 1880 Benson, Hereford, Redington and St. David were established.

The arrival of the railroad in 1881 brought major changes to the entire area, linking it with California and the East Coast. Tracks also linked Benson with Guaymas, Mexico. Other routes were built later, to meet the needs of mining and ranching.

On May 3, 1887 a major earthquake struck the area, wreaking havoc as far north as the Gila River. The aftereffects were felt for weeks. Patterns of water flow changed. In some places, water spurted from fissures in the earth, and in others, spring-fed streams stopped flowing.

Agriculture

American irrigation began in the lower basin primarily to support Fort Grant and Tucson settlers. Many homesteads were located along approaches to canyons, especially those with creeks and spring-fed streams such as Carr Canyon. For example at one ranch five springs that flowed year

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"The story of the farms was the saddest part of the history of the Lower San Pedro Valley. Once a hardy, ambitious, energetic class wrested many fertile acres from the mesquite and rocks. By 1904 the river had carved away the choice pieces of land. ... Ditches from the river were difficult to keep in place, and many an acre was allowed to grow into a mesquite thicket. Farmers found it easier to keep a few herd of cattle and forget about tilling the soil. . . . Along the San Pedro where once, more than fifty fine farms were to be seen, by 1930 only a few remained, and they were fast deteriorating. ... The banks became higher thus making it more difficult to take water out of the river by the use of ditches." B.W. Muffley, 1937.

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round provided water for a large swimming pond. Other homesteaders raised fresh fruits and vegetables, for their own use and for the growing Tucson market.

By 1899, 3,500 acres of land were under cultivation. Ten canals diverted irrigation water from the river. Ten years later there were four times as many canals, diverting more and more water. The first artesian well in Arizona was established in St. David in 1885, and irrigated agriculture soon expanded to 2,000 acres there. By 1903, there were more than 200 artesian wells between Benson and Fairbank.

Irrigated agriculture declined at in the lower basin around 1900. Much of this can be attributed to the problems in controlling the river. Today, alfalfa is grown on about 1,000 acres of land around St. David.

Agricultural activities in the upper basin also expanded during the end of the nineteenth century, with most of the irrigation and farming areas in the lower basin centered around Dudleyville. Until about 1890, Dudleyville was a prosperous town, with many of its residents engaged in cattle-raising and agricultural activities. By 1900, about 2,500 acres of land was being irrigated from Palominos to Winkleman, mostly from artesian water sources. Today alfalfa is still grown along the river from Benson to Winkleman.

Cattle were moved through Hereford for years. Huge herds were driven from Cananea to the railroad stockyards and shipped to California. The river from Charleston to Hereford was a haven for thieves who stole cattle and sold them across the border, stealing and selling Mexican herds on the way back.

Mules hauling ore near the San Pedro River.

"It was also during this time period that the Camp Grant Massacre occurred; Camp Grant was the site of a massacre of Apache Indian men, women and children in 1871 by a band of Anglos, Mexicans, and O'odham men, after livestock were stolen at San Xavier by Apaches. Over one hundred Aravaipai and Pinal Indians, over 90% of them women, were killed." Tom Sheridan, 1995.

Ranching

A drought in California in the late 1870s and the completion of the railroad, combined to bring an increase of sheep and cattle to the verdant grasslands of the San Pedro Valley. In 1879, one ranch just west of the Whetstone Mountains was reported to have 23,000 sheep. As ranching flourished during rainy years, overgrazing became a problem.

Small farms in the Redington area became consolidated into large ranch holdings. Droughts in Arizona in 1892-1893, 1895, and in later years, combined with overgrazing, resulted in the death of 50 to 75 percent of the livestock in Southern Arizona.

Overgrazing contributed to a cycle of erosion and channel-cutting. Droughts, followed by floods, also affected the river. Lands stripped of grasses and crisscrossed with cattle trails were subject to wind and water erosion. Grazing continues throughout the area today, but at much reduced levels.

Mining

Many "49ers" passed through the San Pedro Valley on their way to the California gold fields, with none known to stay. In 1863, silver was discovered at Copper Creek in the Galiuro Mountains. This started a boom period in the San Pedro Valley. Between 1887 and 1891 mines were established in Bisbee, Tombstone, Mammoth and San Manuel, across the border at Naco and Cananea, in Sonora at the headwaters of the San Pedro River and at six other places along the river.

Muster at Ft. Huachuca, 1887.

Tombstone was the most famous of these towns, both for its silver and for the many exciting stories it inspired. By the mid-1880s over 15,000 people moved into the community, hoping to get rich from the largest silver discovery ever made in Arizona. Nearly $30 million worth of silver was mined between 1879 and 1886. Mill operations sprung up around the valley to process the ore.

Wood was needed for mining activities, and for personal heating and cooking. So much wood was cut that the area was denuded of trees, from mesquite bosques along the river to upland trees. After residents cut all the available trees near Tombstone, they went further afield to the Huachucas, Whetstones, and other mountains. The impact on the vegetation was immense. Tombstone alone is estimated to have used 120,000 to 130,000 cords between 1879 and 1886. If this wood were stacked four feet high in four-foot lengths it would reach almost 200 miles.

Ironically, the town that had to import water for domestic uses from the Huachuca Mountains fairly quickly "drowned" when groundwater flooded the major mines. Groundwater began flooding the silver mines in 1881.

Powerful pumps ran 24 hours a day to keep the groundwater at bay until a huge fire in 1886 burned down the pumps and other structures at the Grand Central Mine. Soon the "town too tough to die" came close to becoming a ghost town.

A good example of an Arizona town that lived and died by the vagaries of the mining industry was Charleston, now in ruins. Established in 1879 to mill ore from the Tombstone mines, it prospered for eight years until water flooded the mines. At its height, over 1,000 residents lived in the area.

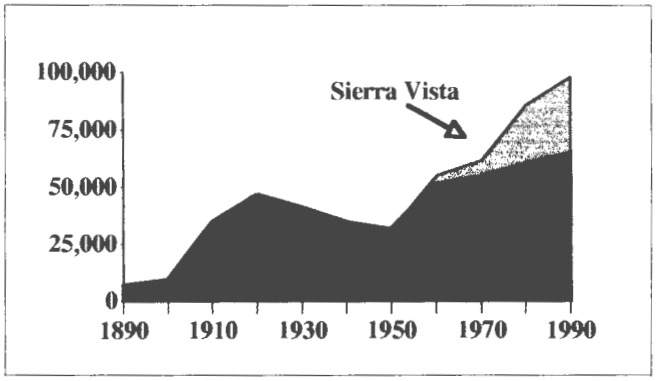
To supply water for the Charleston mill, a dam was constructed on the river. Water was led to the mill through a wooden flume. The surrounding area was virtually denuded of trees because of demand for construction and firewood. A 160 foot-long bridge was also constructed across the river in 1881 so that ore shipments would not be delayed by floods. The town, which lived by ore production, died when the Tombstone mines closed. Even the dam is now gone, although its site has been proposed several times during the twentieth century as a site for a dam.

Fort Huachuca

Fort Huachuca, one of the oldest active army bases in the Southwest, has a colorful history. It was established in 1877 to protect the settlers in southeastern Arizona. By 1920, it was the only remaining military outpost out of 70 cavalry posts established in the southwestern U.S.

The site for the fort was chosen largely because of the water supply, since natural springs in Huachuca Canyon could provide much of the water needed for the Fort. Selection of the mouth of the Huachuca Canyon for the camp site was based not only upon its elevation but upon the abundant supply of water, good grass and the presence of sheltering ridges overlooking the camp. Huge old cottonwoods and sycamores lined the creek, and the mountains were covered by dense forests of pine which supplied lumber for building.

During the twentieth century, Fort Huachuca gradually expanded its land base and water use. It was the nucleus around which Sierra Vista developed in the twentieth century.



Population in Cochise County.

In the lower basin, the Copper State Mining Company invested over one million dollars to develop mines along Copper Creek between 1908 and 1917. To supply water for the mine, a dam was constructed on Copper Creek. However, in 1917, a shortage of ore and "unsound business practices" closed the mine. In fact, most of the mining ceased during the early part of the century.

World War II caused a new demand for copper. Mining at Mammoth and Copper Creek again flourished. Since then, mines and a smelter have grown in San Manuel and Mammoth, as well as further north at Hayden and Winkleman along the Gila River. Huge tailings ponds mark the landscape near the San Pedro River at San Manuel.

Today, most of the mining in the basin is in the lower reach of the watershed, from north of Benson to Winkleman. The Magma Copper Company, which operates both an underground mine and an open pit mine, a smelter, and a refinery along the river in San Manuel, is the largest single water user in the San Pedro watershed. Its estimated annual usage is approximately 22,000 acre-feet.

Growth of Sierra Vista

Much of the upper basin settlement concentrated around Fort Huachuca, eventually giving birth first to a town named Fry and later known as Sierra Vista. Incorporated in 1956, Sierra Vista encompassed the communities known as Fry, White City, Hayes, Tanner Canyon, Overton, Buena, and Garden Canyon. The Sierra Vista area has become the largest user of municipal water supplies in the basin, with groundwater serving as the main water source, supplied by over a dozen small water companies. It is one of the fasting growing communities in the state because of its appeal as a military and retirement community. Sierra Vista is the largest town along the San Pedro River and has been growing rapidly since the 1970s, using increasing amounts of water. In 1994, a citizen group attempted to form a district

Riparian Vegetation Depends on Groundwater

In 1994, the Arizona Department of Water Resources examined what would happen to rivers like the San Pedro if groundwater levels declined as a result of pumping. Some species (such as willows) need to have their roots in the water most of the time, while others (such as mesquite) can send their roots deep to find water and can withstand some drought periods. The seeds of some species such as cottonwood, would have difficulty getting started if the water table dropped at all or if spring/summer floods did not occur.

Researchers looked at what would happen if the water table dropped three feet or six feet and found that a three-foot drop would eliminate the marshy species and a six-foot drop would prevent cottonwood and willow seedlings from sprouting. Mesquite and sacaton grass would occupy most of the floodplain, and most of the cottonwoods and willows would eventually die.

If pumping proceeds at the projected rate in the Sierra Vista area, they concluded that this would mean loss of 52 percent of the marsh vegetation, 42 percent of the cottonwood and willow seedlings, and 17 percent of the mature cottonwood-willow forest in ten to twenty years. Similar effects have already been experienced along the lower Santa Cruz River, the middle Gila River and other Arizona rivers, where even the deep-rooted mesquite died for lack of water.

to control groundwater pumping to protect river flow. This effort, however, was unsuccessful, and water use continues to increase.

Water Use

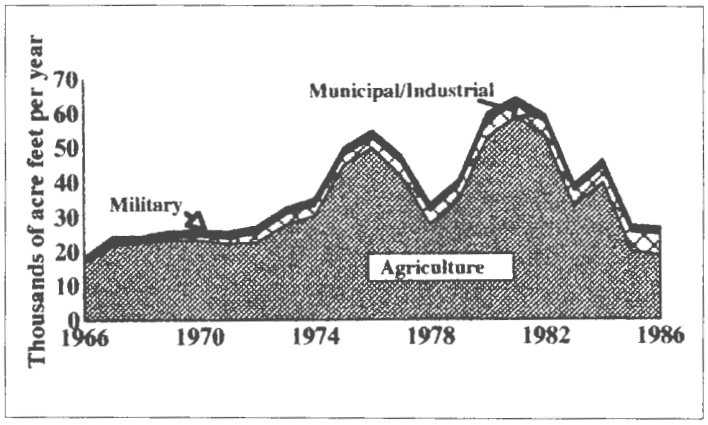
Historically, most of the water use in the basin was for agriculture and, during some periods, for mining. In the late twentieth century, however, much of the water used in the area is for Fort Huachuca and the rapidly growing Sierra Vista area. Most of the water used here is groundwater, but most of that groundwater is hydrologically connected to the river, so pumping affects river flows. Unlike Tucson where the water table has dropped so far that it is no longer connected to the river, the water table near Sierra Vista remains high enough to support riparian vegetation.

For a while, decreases in agricultural use made up for the increased urban use. Groundwater levels have been dropping at a rate of about 1.3 feet per year in recent years. This groundwater pumpage has created a "cone of depression" near the river, a low spot in the groundwater table. With such a cone, water that would naturally reach the river is intercepted so that the river receives less groundwater than in the past.

Wildlife

The San Pedro River supports growths of cottonwood forests, from its headwaters to St. David and also at various spots in the lower basin, especially beyond its confluence with Aravaipa Creek. A lush marsh near the confluence supports a wide range of wildlife, including many species of birds. The river has very little saltcedar compared with the Gila River. There may actually be more cottonwood trees along the river today than in the early 1800s, since cienegas which supported a different kind of wetland vegetation have disappeared. They have been replaced by cottonwood-willow forests and mesquite bosques. There are also more cottonwoods along the river today than at the heyday of woodcutting in the late nineteenth century.

The lower San Pedro River supports over 450 species of birds (two-thirds of all the bird species in North America), over 52 species of mammals, and 47 species of amphibians and reptiles. Fifty-five rare or endangered species live in the basin. The San Pedro River is one of the most important north-south bird migration routes in North America.



Water use in the upper San Pedro Basin.

Grizzly bears, wolves, antelope, and beaver are gone from the region, although antelope have been reintroduced in the nearby Empire-Cienega area. The loss of predator species has led to increased damage of riparian areas by deer in some areas, and to an increase in rodents and rabbits and the animals that eat them. Loss of beaver has had the most direct effect on the river because their dams created marshy areas throughout the basin.

Another big change is the loss of many fish species. Colorado squawfish as long as three to five feet once were seen, but none of any size survive there today. Historically, at least 13 native fish species lived in the San Pedro River. Only the longfin dace and the desert sucker remain.

Preservation and Restoration

Efforts to conserve range and forest resources in the San Pedro basin began at the turn of the century. Forest reserves were created in the Huachuca, Dragoon, and Whetstone mountains. In the lower basin, the Nature Conservancy bought the Muleshoe Ranch, which it oversees in cooperation with the U.S. Forest Service and the U.S. Bureau of Land Management (BLM). They are working to restore landscapes previously damaged by overgrazing of cattle. The Nature Conservancy also manages Ramsey Canyon, where

perennial flow supports a wide diversity of plant and animal life, including many species of hummingbirds and an endangered frog.

In 1988 Congress created the San Pedro Riparian National Conservation Area (SPRNCA), the first of its kind in the nation, on an old Spanish land grant. BLM administers this 47,668-acre refuge along a 36-mile section of the river from the international border to about eight miles south of Benson, for wildlife and recreational purposes. Cattle have been removed from once heavily grazed riparian areas and off-road vehicle use is limited. Most importantly, the SPRNCA has retired some prior water rights in the area. Since establishment of the SPRNCA, vegetation has increased greatly, which has improved habitat. Many more birds now are seen than in the recent past.

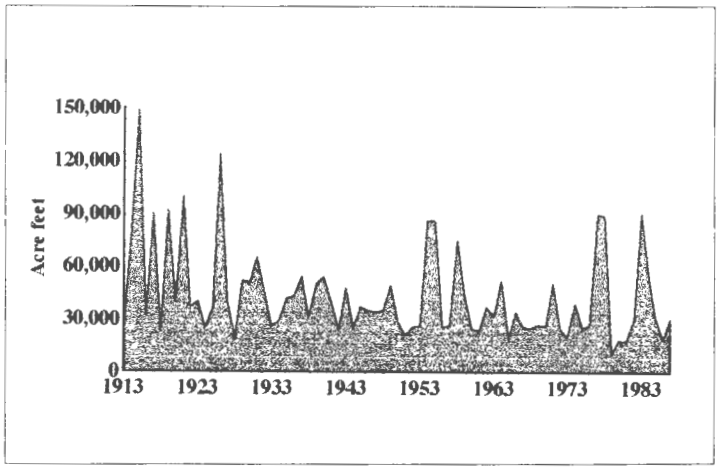
Pima County owns Bingham Swamp, near the San Pedro River about ten miles south of San Manuel. The Nature Conservancy operates this 300-acre preserve, which is open by appointment only, for Pima County.

Cook's Lake, a 270-acre wetland near the confluence of Aravaipa Creek and the San Pedro, is owned by the U.S. Bureau of Reclamation. One of only three wooded wetlands in Arizona, Cook's Lake has prime habitat for waterfowl and a variety of rare species. The Bureau purchased it from the ASARCO Mining Company in the 1990s as mitigation for damages to wetlands caused by modifications to Waddell and Camp Dyer dams on the Agua Fria River. As part of this project, ASARCO also is restoring 130 acres of abandoned farmland north of Cook's Lake to a mesquite bosque.

Changes in the River

In the 1800s the river was an irregularly flowing stream, marshy in places, free-flowing in others, and ephemeral in a number of stretches. The river and its tributaries wound sluggishly through grassy valleys dotted with cienegas and pools. One large cienega extended along the San Pedro from about modern-day Benson to the old site of Tres Alamos. Some areas were deeply entrenched.

Although the earthquake of 1887 affected the hydrology of the river, the most drastic changes followed American settlement. Human activities have changed the river from a free-flowing stream with marshes and rich riparian vegetation to a stream with perennial flows in only portions of the river.



Annual flow of the San Pedro River at Charleston.

Beginning in the 1880s, the river began to change in response to increasing Anglo-American use of the land. The loss of the beaver, mining, overgrazing and woodcutting contributed to severe erosion and arroyo cutting. By 1912, most of the river below Redington was entrenched.

Surface water diversions, entrenchment, and groundwater pumping led to the disappearance of cienegas and surface flows. By the 1920s, most of the cienegas had dried up and were replaced by mesquite. Cienegas can still be seen today about ten miles south of San Manuel and on some tributaries. Only the section of the river from Hereford to Charleston remains perennial.

"I am a Missourian living far from the San Pedro River, but I believe this emerald strand, still strung precariously with the iridescence of hummingbird bellies and scintillance of clear waters and the glow of cactus blossoms, is something that does not belong to me although I belong to it: its beauty, its history, and most of all, its significance."
William Least Heat Moon, 1988.

Malaria and other Water-borne Diseases

Malaria was a serious problem in many parts of Arizona until the 1940s, more so in the south than in the north. Malaria-bearing mosquitoes breed in stagnant water, carrying the disease from one person to another through bites. Spanish missionaries suffered from malaria as did later settlers. Military posts were established near reliable sources of water, which often turned out to be the same water bodies that harbored mosquitoes. The cause of malaria was not known in the 1880s but one theory was that it was caused by the exhalations arising from swamps.

At Camp Grant at the mouth of Aravaipa Creek, each of the 215 men was hospitalized an average of ten times, nine of which were for malaria. Near Benson the Arizona Daily Star reported in 1879 that "[the San Pedro Valley] might well be called the valley of the shadow of death. Malarial fevers of the most malignant type are prevalent eight months of the year." Other diseases spread by mosquitoes in Arizona were dengue and yellow fever, neither of which are problems in Arizona today. Numerous swamps were drained to reduce these exhalations—and the problem was sometimes thereby solved.

By the 1930s few swamps remained—either because of deliberate draining or because the water supply had been diverted or pumped away. By then, the main breeding grounds for mosquitoes were man-made—drainage ditches, stock ponds, sewage disposal areas and long-standing puddles, especially in agricultural areas. Recommended control techniques included eliminating standing water, using DDT and other chemicals, pouring oil on standing water, and stocking ponds with the non-native mosquito fish.

"Many Lagoons or slews were located along the Santa Cruz, two very large ones at Calabasas formed by the overflow of the Sonoita Creek and Santa Cruz, with others along the stream. The condition at Calabasas on account of this swampy land malaria was very bad and settlers suffered greatly with Chills and Fever and many were obliged to move away from that section." C.C. Wheeler, 1937, recalling earlier times.

By 1964 the fight accelerated. Big artillery was moved into the front line of the battle. Aircraft, tractors, bulldozers, trucks, and cars were used to carry the fight to the mosquito. Health authorities said that if the breeding areas were destroyed, half the battle would be won. The war on malaria eradicated the disease in Arizona. There are still mosquitoes that could carry malaria, but no infected humans to start the cycle.

Another mosquito-borne disease, encephalitis, became a problem in the 1960s. Aerial flights mapped breeding sites and intense campaigns were waged. Again, the battle was successful. Mosquitoes are not considered a major health problem today, although they are still a nuisance. Many of the man-made breeding areas are better controlled and few swamps remain.

The long-term impacts resulted from draining of cienegas, and introduction of mosquito fish which invaded many of the streams to the detriment of native fish.

The people here in Arizony
All look very pale and bony.
They shake and ache and burn and shiver
Up and Down the Gila River.
I'm freezing in the heat of day,
I feel like winter's here to stay.
I'm too cool for the month of June,
So bring me quinine and a spoon. ..."

Old song, sung to the tune of Old Dan Tucker.

ANGLO-AMERICANS ARRIVE

The first Anglo-Americans to reach what eventually became Arizona were "mountain men" who came to trap beaver in the 1820s. James Ohio Pattie's company traveled down the Gila in 1824, collecting some 250 pelts. His journals provide much information about the period, although they contain obvious exaggerations. He returned in 1827, concentrating on the San Pedro and Colorado rivers, with a goal of "trapping the rivers clear," or getting all they could. Other trappers who explored Arizona's rivers at this time included Ewing Young in 1830, who sold 1,500 pelts in Santa Fe; Pauline Weaver, who returned as a guide in later years; William Wolfskill; and George Yount. Hat fashions changed from beaver to silk, and by the 1860s beaver populations had recovered on many of the rivers. Their numbers later were reduced again by other human activities, including overgrazing, urbanization and loss of water supplies in the rivers.

Surveyors' party exploring a tributary of the Gila River in 1848.

After most of present-day Arizona became part of the United States in 1848, more and more American travelers arrived. Many were just passing through on their way to the California gold fields. The U.S.-Mexico boundary had to be surveyed, and wagon and later railroad routes had to be mapped. Whereas the Spanish routes tended to be north-south from Mexico, the new American routes most often were east-west, from the East Coast to California.

"The [Colorado at Yuma] river here is 170 yards in breadth, with a current of about 3 ½ miles an hour. It is crossed by means of a rope suspended from either bank—a mode of travel very disagreeable and somewhat dangerous. Capt. Thorn endeavoring to pass here ... on two log canoes lashed together, was upset, and together with three others, swept down on the current and drowned." Lorenzo Aldrich, 1849.

Travel Routes

Travel routes from the earliest historic times to the present tended to follow a few major routes, avoiding the very great barriers of the White Mountains, the Chiricahua Mountains, the Canyonlands of southern Utah and northern Arizona, and the Apaches. The Colorado River could be crossed in only a few places. Water was necessary, so travelers stayed within one or two days distance of drinking water. In Arizona, rivers

were important travel corridors, providing water and food for people and livestock. People ventured into rivers only to cross them, not to travel on them. Instead, they traveled along the river banks.

The Colorado River formed a barrier to exploration for most of its length in Arizona. Travel through the Grand Canyon by foot or mule was very difficult (although Indians had traveled there for centuries), and boat travel was risky. There were only two good crossing spots to the north—Lee's Ferry and another near what is now the Page area. There were about a dozen ferries and crossing locations around and south of the present Lake Mead down to Yuma. The Colorado River is the only Arizona river on which boats regularly traveled—and such travel ceased by the end of the nineteenth century, except for recreational boating. Even though travelers no longer are dependent on rivers for drinking water, many of today's major transportation routes, such as I-10, still follow the historic trails and roads.

To cross the state from the east in the nineteenth century, most travelers either followed the Gila River, entering Arizona about where I-10 is today, or they traveled south of the Chiricahua Mountains, crossing the San Pedro River and then traveling up the Santa Cruz River. The southern route was longer than the northern route, but had the advantage of avoiding much of the Apache danger. A northern route left the New Mexico pueblos and met the Zuni and Little Colorado rivers, then headed west by either of several routes. Another route skirted Arizona, going through Utah and down along theVirgin and Colorado rivers.

"I with Samuel & James & My wife commenced to cork an old flat boat & by noon we were ready to cross [the Colorado River at Lees Ferry]. When we launched the Boat, My 2 sons hesitated to venture in such a craft. My wife ... Said that She would go over with Me & steer. Then we reached the opposite side, the [Navajos] Met us with open arms of Friendship. ... After Much difficulty we Succeeded in getting them & their luggage over safe. Next was their horses which we failed to swim over after 2 trials & nearly upsetting the Boat. ... Night fall closed the scene. For the last 3 hours I worked through fever and ague & when I reached the fire on shore I was so near exhausted that I Staggered. ..." [sic] John Lee, 1872.

The Great Surveys

Surveys to determine the boundary and to establish wagon roads and railroad routes produced a great deal of useful information about the territory and its vegetation and wildlife, as many of the survey teams included biologists. Captain Sitgreaves sought a road from Zuni to California in 1851. John Bartlett surveyed from southeastern Arizona to California in 1851 and 1852. Lt. Amiel Whipple surveyed for a transcontinental railroad in northern Arizona in 1853-54. At the same time Andrew Gray surveyed a railroad route along the Gila River.

In 1854-55 Lt. John Parke resurveyed the area along the eastern part of that route. When the U.S. became a territory Lt. Emory's survey in 1855 delineated the boundary. Joseph Ives, who had traveled earlier with Whipple, returned in 1858 to survey the lower Colorado River. In 1869, John Wesley Powell made the first of several investigations of the upper Colorado River. The most unusual survey was made by Edward Beale, who traversed northern Arizona in 1858 using a caravan of camels, to establish a wagon route.

Travelers adversely affected rivers on the more common trails. Wheeled vehicles rutted the roads, causing gullying and erosion. Firewood near the stopping places was gathered and trees were cut. Livestock trampled the shores at water holes and river crossings, especially when many animals traveled together. Livestock also ate whatever vegetation was available. This left the river vulnerable to erosion and more devastating floods.

In some areas so little vegetation was left near the trails that cattle starved. By the time travelers reached areas with vegetation, their livestock were ready to eat less palatable kinds of plants. When travelers were few and far between, or parties were small in number, the long-term impacts to rivers were small. On the more-traveled trails, however, the impacts could be significant, especially at major crossing points.

Stagecoach Routes

Stagecoach stops were located where there was adequate water and at comfortable distances for travelers and horses. All the stops across Ari-

"There was a big 7 steel-span bridge across the Gila River six miles up from San Carlos, but travelers from the East could not get up onto it and those from the West could not get off, because the Gila River's trenching had been to dig away the river bank on the east end of the bridge and to flow around it instead of under it." Apache Dancer, May 11, 1979.

zona on the Butterfield route were located by rivers, near springs or near lakes, except one where water had to be hauled in. The most famous stage station was at a spring at Apache Pass, a favorite watering source for Cochise as well as the travelers. The continual use of watercourses by livestock and people had an impact on those watercourses but after the stops were closed, the areas recovered and the long-term impacts were generally minor.

River Crossings

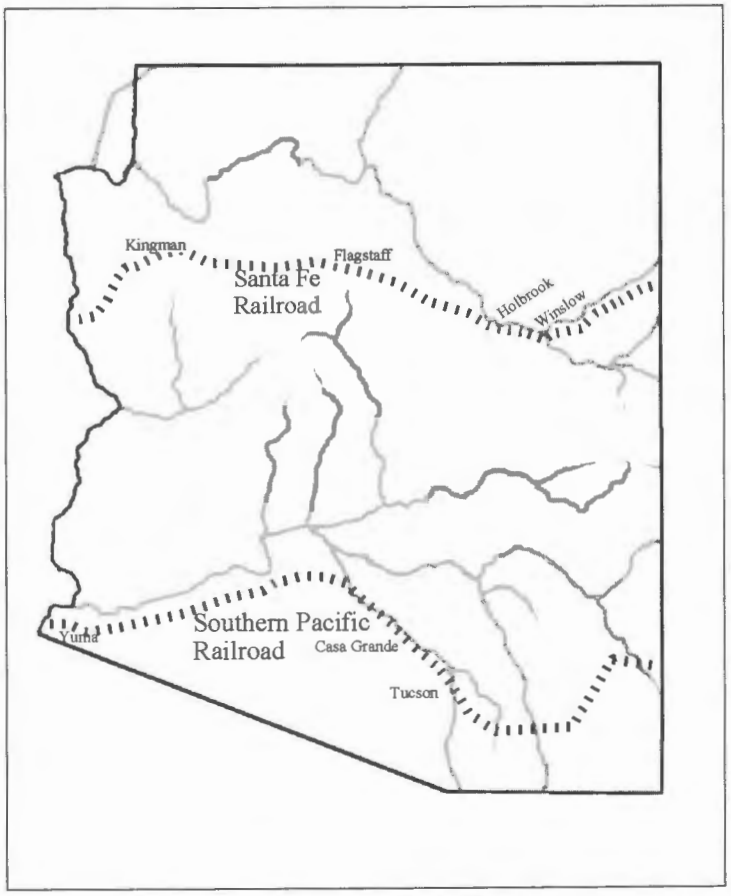
Most Arizona rivers were fordable during most of the year, but could become uncrossable raging torrents at other times. Only the Colorado River could seldom be forded and could be crossed at only a few spots. Enterprising pioneers set up ferry stations at the most desirable sites—Yuma, Lee's Ferry, and several others on the Colorado River, and Hayden's Ferry on the Salt River. Lee's Ferry in northern Arizona was the only feasible river crossing for hundreds of miles. The Yuma crossing was the most contested one, especially when travel to the California gold fields became popular. At least two pitched battles took place. Hayden's crossing over the Salt was principally needed only at flood time, but was essential then.

Railroads

Building of the railroads had a much greater impact on rivers than either trails or stagecoach routes. Lumber was needed for railroad ties and bridges. To provide an incentive for the investment needed, the federal government granted some major cross-country companies alternate sections of land for ten miles on both sides of the track. From these locations lumber and in the early days fuelwood could sometimes be gathered. Trains, however, soon converted to coal and later oil. Lumber for ties was usually brought in rather than harvested on site. Most railroad companies later sold their lands for ranching and other purposes.

In order to minimize costs of construction, bridges often were originally built as narrow as feasible, in some cases leaving the channel narrower than was necessary to carry flood flows. Washouts were a serious problem during infrequent floods. The Southern Pacific track along Cienega Creek, for example, had to be rebuilt several times, and finally was moved to higher ground.

The greatest impact of the railroads was in opening up lands that had formerly been inaccessible, such as areas on the Colorado Plateau. When the railroad reached towns such as Tucson or Phoenix, large numbers of people now were



Major cross-country railroads.

able to reach the area in relative comfort, and all kinds of materials could be imported and exported. Ranching was initially profitable largely because the beef could be sold in the East. Some communities, such as Casa Grande, developed originally as railroad towns.

Highways

Many modern highways approximately follow the old trails. I-10 follows the old trails (north of Apache Pass) along the Gila River west to Casa Grande, with a curve south to Tucson. I-8 resumes that trail all the way to Yuma. I-19 parallels old trails from Tucson to Nogales. In the north, I-40 follows the routes of travelers from Santa Fe west. The old trail around the Guadalupe Mountains east of Douglas has been abandoned, but parts of it have become highways 80 and 82. Old trails from Prescott west and south and through Wickenburg are now highways. Most of the roads going through Phoenix are recent since the city was not on most older routes. North-south travel from Flagstaff is also relatively recent, as is the Salt River route through Globe.

Impacts on the Rivers

The opening of the West through increasingly mechanized transportation had major impacts on Arizona's rivers. From the earliest times travelers and their animals left their marks on the rivers they crossed or traveled along. Beaver trapping radically affected the rivers by eliminating the many pools behind the dams. These pools created wildlife habitat and slowed river flow so that downstream floods were usually minimal. When the dams were eliminated, erosion damage to rivers increased and wildlife habitat was lost. Large numbers of livestock drastically reduced vegetation in some areas, leading to erosion and more devastating floods. Probably the greatest impact of improved transportation was to open up the West to large numbers of people who then impacted the rivers in many ways described throughout this book.

"After a wearisome ride I saw the wagons and the tall cottonwoods of the Gila, and when within half a mile of it, my tired mule smelt the running water. She pricked up her ears, gave one long bray, and made a beeline for the Gila directly through the thick chaparral. I hung on to her back like death to a deceased African and away we went like the wind to the banks of the Gila, into which she plunged her head and never raised it till her sides were distended like a hogshead. ... There was no checking their impetuosity; some of their riders were left hanging in the branches of the trees, some were thrown, and some were pitched headlong into the water. ..." John Durivage, 1849.

The Mormon Battalion

The first "official" American exploration of southern Arizona was led by Philip St. George Cooke, who took an ad hoc U.S. Army battalion of five companies of Mormon volunteers in 1846 from New Mexico to California to create a wagon trail to San Diego. They were also supposed to help consolidate U.S. victories over the Mexicans. Some of our best early descriptions of southeastern Arizona are from that trip. Traveling with the batallion were 36 wives and 54 children.

Cooke and his men made their way through the unknown terrain with the help of local Indians and experienced guides, including Pauline Weaver, who had trapped beaver in Arizona in the 1820s. They traveled the length of the San Pedro River from near the border with Mexico. It was not uncommon for soldiers, Mormons, and early explorers to battle wild cattle as well as Apaches in the San Pedro Valley. After a major battle with a herd of wild bulls (the only real battle of the journey) Cooke declared that he feared bulls more than Apaches.

The battalion went on to the Santa Cruz River to ensure that Mexican troops vacated the Presidio of Tucson. When they got there, the Mexicans had prudently left for San Xavier and the encounter was peaceful.

After many hardships and adventures, the battalion finally crossed the Colorado River at Yuma, having blazed an important route used by later travelers. Once they reached California the battalion dispersed and many of the soldiers joined the Gold Rush, while others settled in Arizona and elsewhere.

VERDE RIVER

The Verde River is one of Arizona's few perennial rivers, still greatly valued for its wildlife, scenic, and recreational features. It has been important to Indian tribes for hundreds of years, and in the past century has served mining, agriculture and ranching needs. More recently tourism and second-home development are occurring along the river. The river also is a water source for the Phoenix urban area.

The River

The Verde River begins at Del Rio Springs in the Chino Valley, high in the mountains of west-central Arizona, and flows south through 150 miles of grasslands, steep canyons and deserts to join the Salt River. Water enters the Verde River from many tributaries, the major ones being Sycamore Canyon, Oak Creek, Beaver Creek, Fossil Creek, the East Verde River, West Verde River and Clear Creek. The river can be conveniently divided into three sections: the Upper Verde and tributaries in sparsely populated areas; the Verde Valley; and the Lower Verde where two major dams exist. The entire watershed covers 6,650 square miles and has 464 miles of perennial streams; 8,280 miles of non-perennial streams; and 8,320 acres of lakes.

The Early Inhabitants

The first known people to enter the Verde Valley between 2,000 - 10,000 years ago were nomadic.

"... the head of one of the branches of the San Francisco [Verde] River, where beaver dams form a succession of ponds that are literally filled with fish. On the maps this valley is called Val de Chine (Chino Valley]; here it is called Cienaga." Joseph P. Allyn, 1866. Val de Chine was named by Whipple for its lush gramma grass, which the Mexicans called "de china."

Later the Sinagua people inhabited the upper and middle regions of the Verde River, from about 700 A.D. to about 1425 A.D. Some experts think the Hohokam either moved in or influenced development of agriculture in the area. The Sinagua also traded with the Anasazi to the north. By 800 they were farming the tops of mesas using dry farming techniques with masonry field houses, rock borders and check dams. They grew corn in the floodplain.

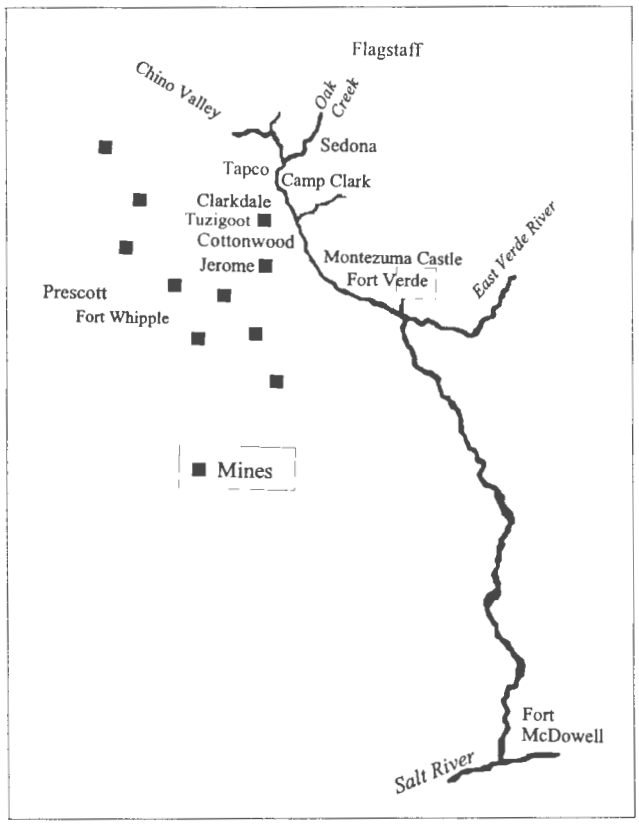
The Palat- kwapi Trail was a 150-mile long major trade route from Sinagua territory to the Colorado Plateau. The Northern Sinagua moved into the Verde Valley from drought-stricken areas in the 14th century. This was the high point of Sinagua civilization. They built Tuzigoot near present-day Clarkdale in the 14th century and other pueblos located about two miles apart on Beaver Creek and Oak Creek, including Montezuma's Castle farther east.

During this time people congregated in fewer large areas and irrigated the floodplains to grow such crops as corn, squash, cotton and tepary beans. They also dry-farmed crops such as agave.

Something happened within a century of these achievements, and by 1425 the Verde Valley was abandoned. The people moved to the northwest—to Anderson Mesa (40 miles southeast of Flagstaff) and maybe to Hopi areas to the north-

east. Why they left is uncertain. Possible reasons include drought (although climate records don't indicate a major change), waterlogging of the soil, warfare, disease, overpopulation, depletion of resources, and loss of trade networks. The amount of irrigated agriculture along the river must have greatly altered the river vegetation and removed quite a bit of water from the river. By the time the first Americans appeared the river had lush riparian vegetation.

Sometime after the Sinagua abandoned the area, nomadic Yavapai and Tonto Apaches moved in and were well established by the time American miners entered the territory in the 1860s. Many of these native people practiced simple ditch irrigation and farmed part of the upper Verde floodplain. The rest of the Upper Verde is said to have been too marshy for agriculture. The Yavapai and Apaches developed rancherias where a few extended families lived, mainly through hunting, gathering and some agriculture.



Historic sites along the Verde River.

"In those days malaria was common. Everyone had it in the summer. There were few if any floods, and the Verde River spread out wide, and so shallow you could cross it on clumps of grass. Willows and undergrowth were so heavy all over the river bed that the water was forced into standing pools which bred mosquitoes." Leonora Bristow Lee, 1954.

Spaniards Pass Through

The Spaniards had little impact on the Verde River. Most of the descriptions of their routes are vague, and it is difficult to know just where they went. In 1582, Espejo described the people of the Verde Valley as having mines, parrots, grapevines, flax and maize. In 1598, the Oñate expedition came through, and the journalist, Farfan, mentioned that the Indians were mining, with shafts 16.5 feet deep, obtaining powdered ores used for coloring. They used beaver pelts for clothing, made mescal and grew maize. More than a century passed before the next Spaniard, Valvarde, mentioned Indians who were probably the Yavapai, although he seems not to have gone up the Verde River. Sixty years later Garcés left the Colorado River south of Needles and traveled east through "Yabapais" rancherias on his way south and west. Between 1605 and 1850 no foreign expedition entered the Middle Verde Valley. Probably the most lasting impact of the Spanish was the introduction of horses, which changed the lifestyle of the Apaches. Horses made them more mobile and allowed them to roam farther.

American Expeditions

Several parties of American trappers hunted beaver along the Verde River in the 1820s, but while other parts of Arizona were being explored at that time, the Verde Valley was mostly ignored. Sitgreaves came through in 1851 on a survey trip, but may have only reached a tributary. In 1854 Whipple reached the headwaters, while surveying for a railroad. His guide, Leroux returned to the area on his way back east, exploring a little more of the upper Verde. There was little

"[Clarkdale] was laid out then ... on three levels: the top of the hill where the business section, the school and the best houses stood; the second level where the blue-collar workers lived; and the lowest plane, where the Mexican laborers lived. .. Mexican town .. was on the banks of the Verde on that level lower than ours. It was the most human and enchanting place of all, everything helter skelter, geraniums blooming everywhere. In a way, the residents were the most favorably situated of us all, sheltered by the native cottonwoods that grew slightly above the willow thickets. ... After a while, a number of strong-minded Gringos decided they would rather live there too, and in the end there was quite a mix down by the river."
Patricia Paylore, 1980.

long-lasting impact from these exploring and trapping parties. The beaver apparently recovered to their former population levels by the time American settlement got underway in the 1860s.

Early American Occupation

Americans again entered the Verde Valley—this time to mine gold, silver, and later copper. From the beginning there were major conflicts between the Yavapai and Apaches accustomed to hunting over a very large region and American settlers who claimed many of the best areas (always near water) for their own. After the Civil War, the military arrived to protect miners and settlers. In 1865 Fort Whipple was established to protect the gold-seekers. The fort became the territorial capital until Prescott was designated the capital.

After much conflict between Americans and Apaches, the military prevailed, and in 1871 the Camp Verde Reservation was established, 40 miles up from Camp Verde, extending for 10 miles on both sides of the river. The Indians were expected to become agriculturalists but once irrigation became successful in this rich land, American settlers coveted it, and the Yavapai and Apaches were again resettled—this time mostly to the San Carlos Reservation. By the 1880s, war was over and most of the local Indians either had been killed, died of disease or moved to reservations. Farther downstream, Fort McDowell was established in 1865 to protect settlers in the Salt River Valley. After the fort was abandoned in 1890, the area became a Yavapai reservation.

Mining

Spanish explorer Espejo reported that the Indians were mining for colorful minerals in the soil, but he had little interest in those minerals—he was seeking gold or silver. After the California Gold Rush, Americans traveled throughout the West hoping to make another rich strike. After the Verde Valley was conquered, thousands of prospectors moved in. Many surface finds were made, but it was not until 1876 that Morris and Sally Ruffner filed claims on the old Yavapai mines. Although the mines contained gold, silver and copper, the Ruffners did

United Verde mine and smelter at Jerome. (Note that the hill has been denuded of trees.)

"In another locality where the flood washed away several acres of a cultivated farm exposing to view a former channel of the river with a stone dam across it, which when first exposed was 4 feet higher than the old channel, built in a straight line across the river, the outer walls of which were laid with immense stones with smaller ones between. Growing over the dam and ditch were great trees over 5 feet in diameter." Undated letter from John Davis to Sharlot Hall, probably written in 1895.

not have adequate transportation to make mining profitable. James Douglas (who developed the Phelps Dodge copper mines) examined the claim and decided not to buy it. It was not until the late 1880s that industrial giant William Clark decided to buy the mine. The railroad had come to Ash Fork, and Clark saw great possibilities in property at what is now the town of Jerome. To develop these possibilities Clark eventually oversaw the construction not only of huge mining and smelting facilities, but also a railroad and power plants in Fossil Creek.

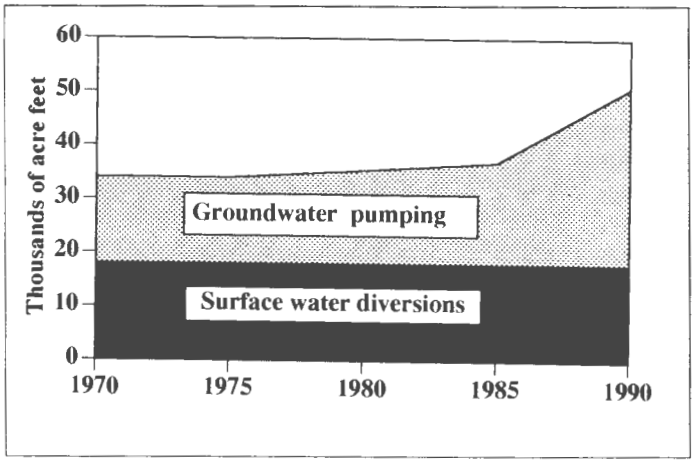
When it became clear that a new town was needed, Clark bought some ranches along the banks of the Verde River and their water rights and designed Clarkdale as a model planned community. The town was considered an ideal place to live, except for the severe air pollution. Little could grow in the path of the smoke - and much of the vegetation along the hillsides was either killed or stunted. Even though the mine and smelter were closed in 1953, vegetation on the hillsides is still stunted. After the mine and smelter closed, the population decreased, although Jerome and Clarkdale have remained popular tourist destinations.

Long-term mining impacts at the "richest copper mine in North America" were direct changes to the land from the underground and open pit mines and the smelter; elimination of vegetation from fuelwood cutting and air pollution; use of water for the smelting process; changes to Fossil Creek from the power plant; and the impacts of the mining communities themselves on the river. Tailings at Peck's Lake and spots close to the Verde River nearby have destroyed the riverbanks.

Agriculture and Grazing

American settlers moved to the Verde Valley in the 1860s and soon were making a living selling food to the miners and soldiers. The first large agricultural ditch was dug by hand with crude tools in 1874 by the Yavapai who by then had a reservation along the river. After one good crop year, the Yavapai again were relocated, and American farmers took over the successful ditch. In 1878 the Cottonwood Ditch was completed and is still the mainstay of the largest irrigation project in the Verde Valley. Between 1865 and 1880, 11 significant irrigation ditches were built to divert water from the Verde River. When it became clear that some regulation was needed to assure that water would be fairly divided among the settlers, a filing system was developed. To this day the river has generally been able to supply enough water for each user. Today, approximately, 19,000 acre-feet of water are diverted per year for agriculture and domestic use.

By 1913, erosion had deepened the river channel so much that one farmer could not get water to his farms by gravity flow, so he dug a tunnel to turn the river into Peck's Lake, from which he drew his water. Wastewater from the farms gradually filled the lake, turning it once again into a swamp. This lake later became part of a country club and a major recreational and wildlife facility.



Water use in the Verde Valley.

Below the middle Verde Valley, there is virtually no agriculture until the confluence of the river with the Salt River at the Fort McDowell Indian Reservation. Even here, little agriculture occurs.

Grazing also was an important business in the area since the late 1880s and had the greatest impact on the area in the late 19th century. In some areas overgrazing continues to be a problem, and the spring which forms the headwaters of the Verde River has been impounded as a stock pond.

Water Use

The Salt River Project (SRP) holds major water rights along the Verde River for use in the Phoenix area. This has to some extent assured that large amounts of water are not diverted by upstream users, thereby maintaining river flow. This has, however, also led to conflicts between SRP and the upstream communities. Because there are no unappropriated surface water rights in the Verde Valley, groundwater pumping has become important. Some studies have shown a clear relationship between the groundwater and the surface water in the area, but groundwater pumping does not legally affect surface water rights. Pumping has not severely affected the river, but concerns have been raised about whether flow of water in the river will be reduced as the population expands in the Verde Valley, increasing water use.

Between Cottonwood and the confluence with Oak Creek there is little water left in the river. Ditch companies remove water upstream then return it downstream, often laden with silt, drastically changing the natural characteristics of the river.

Saltcedar.

Water Salvage

In 1965, private land owners began a cooperative program to eradicate phreatophytes (water-loving plants such as cottonwood and saltcedar). The objective was to eradicate saltcedar and willow and thin the cottonwoods in approximately 1,000 acres of riparian habitat to increase water supplies for humans. Large driftwood dams were eliminated. These dams formed after major floods and were important for retaining water in the vicinity. While some water was probably salvaged, tree removal also resulted in hastening the flow of the river and much of the "saved" water moved

Sand and Gravel Mining

Mining for sand and gravel is an important industry in the Verde Valley, from Tapco to Camp Verde. Demand in Arizona for these construction materials has grown faster than the rate of population increase. Growth in Flagstaff and the Verde Valley depend largely on Verde Valley sand and gravel. One study showed that for every 1,000 new Arizonans, 7,000 additional tons of sand and gravel are required. They are used for highway construction, plaster, concrete block and other purposes. The Verde River is one of the few rivers in the United States where sand and gravel is mined from a live stream.

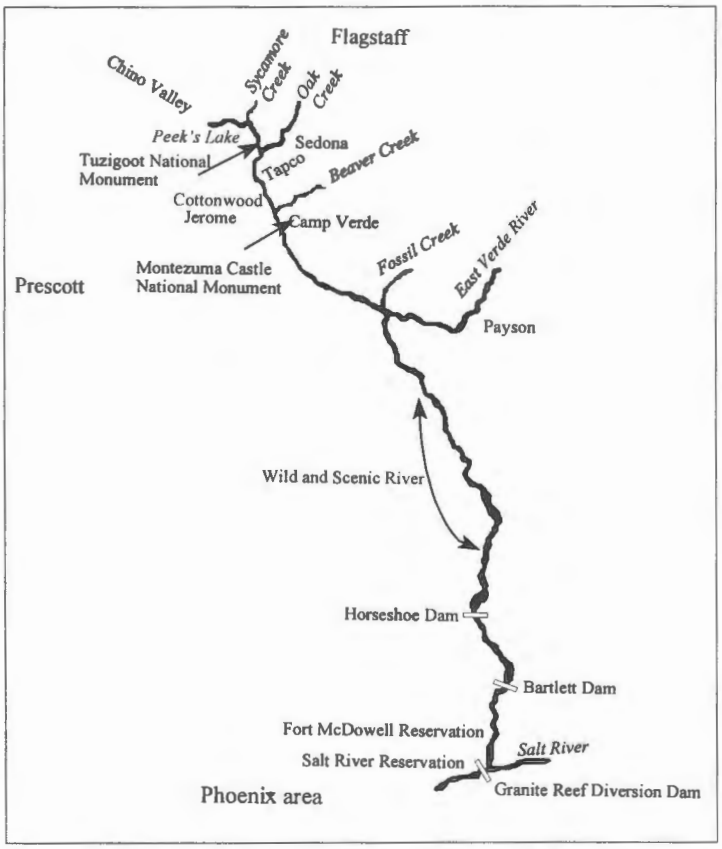
Mining requires land clearing, mining and processing the materials and reclaiming the site. Use of the location is temporary and operations are moved to a new site when materials have been mined. The impacts on the river include channel erosion and instability, migration of the stream channel, temporary lowering of water tables, loss of sand and gravel to the river and beaches, loss of habitat (especially mature trees), and lower water quality. In the Verde Valley, reclamation is required.

downstream. Salvage also caused siltation of the river gravels and spawning beds.

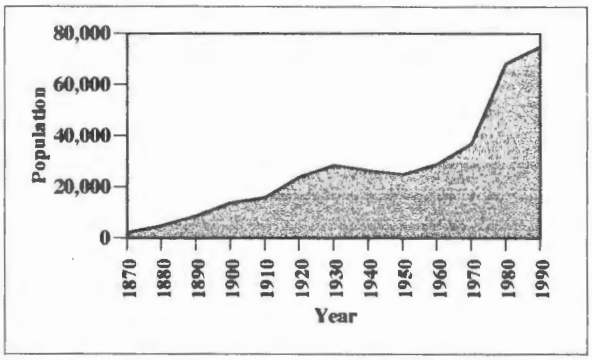
Also in the 1960s the U.S. Forest Service implemented a major watershed clearance project on the Beaver Creek watershed. The plan was to rid the area of trees by mechanical removal as well as the use of herbicides. Some of the herbicides used were highly toxic, but the U.S. Forest Service did no monitoring, so long-term impacts on other vegetation, wildlife and humans are unknown. The project was found to have little long-term impact on water supplies downstream, so it was discontinued after more than a decade of effort. No long-term studies of the impacts were conducted.

Dams

Small dams have been part of the Verde River for centuries. Dr. Edgar Mearns described the Verde River in the 1880s. It was "deep, flowed slowly, and was impeded by many beaver dams." Similarly, Mrs.



Twentieth century sites along the Verde River.



Population in Yavapai County.

Nick Perkins stated that in the 1890s "the river flowed slowly, impeded by many beaver dams and extensive marshes occupied the floodplains." Prehistoric agricultural practices included check dams in the upper watershed as well as dams in the Verde River itself.

There are few of these smaller dams today, except for beaver dams on some tributaries. Fossil Creek was dammed in 1907 to provide water for power generation, with its entire flow diverted through a flume. Diversion has led to destruction of an unusual travertine formation in the stream. This power plant has since been upgraded and continues to provide power for the area. The impacts of the facility were significant for wildlife and mitigation measures are currently underway, as part of relicensing the facility.

As population and agriculture in the Phoenix area increased, and occasional floods inundated the Salt River Valley, demand arose for water storage and flood protection. Bartlett Dam was finished in 1939 and can impound 178,477 a.f. of water in its 12-mile long lake. Horseshoe Dam, farther upstream, was finished in 1946 and can impound 139,238 a.f. in its five-mile long lake. Both dams are operated by the Salt River Project for water storage, and the lakes are popular recreation sites. The dams are managed to supply downstream water demands, except at flood time. Through a complex arrangement in which Phelps Dodge Corporation helped build Horseshoe Dam, exchanges water with the Salt River watershed, resulting in about 9,000 a.f. of water added to the Lower Verde River.

Cottonwood Ford of the Verde River at Camp Verde about 1890.

The Granite Reef Diversion Dam is just downstream from the confluence of the Salt and Verde rivers, 32 miles from Phoenix. It was completed in 1908 to provide water for the growing Phoenix area, especially for agriculture. The dam diverts almost a million acre-feet a year into Salt River Project canals. This is virtually all the flow in the river, except at flood time.

Growth of Towns

The rapid growth of Prescott and towns in the Verde Valley (along the upper Verde) has placed strains on water supplies for the Verde River. After slow growth through most of the twentieth century, the Prescott area is one of the fastest growing parts of Arizona. Granite Creek no longer flows through Prescott most of the time. Even the wastewater flow from the Prescott treatment plant no longer flows along the creek to recharge water supplies for agriculture in the valley below. Instead the wastewater now is used on golf courses and is directly recharged. Granite Creek through Prescott now is a park and hiking trail.

Developments in upstream areas, such as in Chino Valley, use groundwater, which appears to be affecting surface water supplies downstream. Demands for water throughout the Verde Valley have grown rapidly and increased use of water in the Prescott area may affect del Rio Springs, an important tributary.

Recreation

The Verde River and some of its tributaries offer important recreational opportunities for Arizona residents. Oak Creek is one of the most popular outdoor areas in the state, both for Arizonans and out-of-state visitors. Parts of the area, especially in and near Sedona, are popular second-home areas for people from the Phoenix area. The lower Verde also is a popular river for rafting and canoeing, especially in the section designated "Wild and Scenic." In the more popular recreation areas, the river has been severely impacted by trampling, litter, paving for parking lots and facilities, and water quality problems. Areas with many second homes and tourist facilities are putting strains on the water supplies.

The Verde River flowing perennially through the Fort McDowell Reservation is another popular recreation area for people from the Phoenix area, for tubing and other water-based activities.

Wildlife

Few people have studied wildlife along the Verde River, and few early travelers wrote about wildlife. Since the Verde River still flows freely for much of its length, changes in wildlife have been less dramatic than on many other Arizona rivers. In areas where cottonwood or sycamore forests prevail, bird life is probably fairly similar to what it was in the past. Bird diversity has been greatly reduced in those areas where saltcedar is the dominant tree or where rivers have lost their cottonwood forest by other means.

Beaver were plentiful when trappers Ewing Young and Kit Carson came through in 1829. There are no beaver on the river today. Otters were reintroduced around 1980 and can be occasionally seen today.

Restoration and Preservation

The river today includes a few largely unchanged tributary areas. The best example is Sycamore Creek, now a wilderness area. The Fort McDowell Indian Reservation occupies 24,680 acres along the Verde and Salt rivers. After many years of controversy, the Yavapai and others succeeded in blocking construction of the Orme Dam (a proposed part of the Central Arizona Project) which would have inundated many acres of the reservation and displaced most of the Indians and their agriculture, as well as protected bald eagles. Much of the watershed is managed by the U.S. Forest Service.

A middle portion of the river has been designated as "Wild and Scenic," a federal designation giving it some protection from development. Two large state parks on Oak Creek and two on the Verde River near Cottonwood and Camp Verde offer both protection and extensive recreational opportunities. A restoration project is currently underway at Tavasci Marsh near Clarkdale to restore some valuable wildlife habitat. In the early 1990s, Arizona State Parks facilitated a "Corridor Planning Process" in an attempt to get agreement among residents on managing the river in the Verde Valley. This process was partially successful, and resulted in formation of the Verde Watershed Association, a group of residents and agency representatives working to preserve the river as well as human uses of it.

Changes to the River

The visitor to Tuzigoot National Monument today can witness a vivid contrast in human-made change. Looking in one direction from the hilltop ruins, the visitor sees a healthy river with lush riparian vegetation. There is probably considerably more of this vegetation than in the heyday of Tuzigoot when much of the land would have been cleared for farming. Turning around, the visitor sees a quite different scene. The valley floor is lined with waste left from twentieth century copper mining. Little or no vegetation grows here.

The river in the upstream areas and some of the tributaries are generally little changed, with the exception of Oak Creek and Fossil Creek. Oak Creek has been facing pressures from tourism and urban development, while Fossil Creek has been changed by stream diversions for the power plant. Historic overgrazing contributed to downcutting of the stream in some of the these areas, making it flow faster and narrower.

Early settlers reported that the Verde Valley had numerous marshes and that the stream was wide and slow-moving and impeded by many beaver dams. Malaria was a serious problem. Today the stream in that area has downcut and flows strongly in the high-water season. Only one marsh remains. Mesquite trees are now common where the marshes once were. The land is intensively used for agriculture and towns. These changes occurred because of loss of beaver, historic overgrazing, urban development, agriculture, water diversion, groundwater pumping and loss of native vegetation.

The 17 miles of river which have become lakes behind dams have completely different vegetation and characteristics from the former unregulated river. Saltcedar has replaced native vegetation. Downstream of the dams, the river at low-water times has only enough water flows to satisfy downstream water demands. This has altered wildlife habitat.

"In February 1957, 82 years to the day from the departure of the Indians, I visited the Camp Verde area to try to locate some of the old sites, but little remains to suggest the hardships encountered in the early days. Ha-ka-roo-ya creek has disappeared, and nothing remains but a 'hot spring.' Grief Hill has lost its 'grief.' ... The bend in the river, which was the original site of the agency at Cottonwood, has washed its banks beyond recognition, and the Verde Valley has 'flattened out.'" J. Corbusier, 1968.

MINERS, FARMERS AND RANCHERS SETTLE ARIZONA

The three C's, cotton, copper and cattle, were considered the mainstay of Arizona's economy for more than 75 years. All three have long histories in Arizona, played a major role in settlement of the state, and have had important impacts on Arizona rivers. All three proved to be subject to booms and busts. In recent times, other sources of wealth have overcome the big three. By 1991, all agriculture and ranching made up only about one percent of Arizona personal income, and all mining another one percent.

In the nineteenth century, mining, farming and ranching developed simultaneously. Cattle drives across Arizona brought meat to the California gold fields. Ranching within Arizona provided meat for miners and farmers. Farmers sold crops to the miners. The three ways of life were closely related. And for some 20 years following the U.S. Civil War, the military, which protected the settlers, provided a steady market for their products.

Water was the key to success in mining, farming and ranching. Those who controlled the water supplies were the most likely to succeed. When the windmill became readily available in the late nineteenth century, many ranchers and farmers became less dependent on surface water. When pumping technology improved, people could take advantage of deeper water supplies. Some people thus were less dependent on streams and springs. Where groundwater was connected to surface water, however, streams were affected when pumping lowered water tables.

The Czar Mine in Cochise County about 1890.

Early Mining

Early inhabitants mined on a small scale for salt, coal, turquoise, pigments and other minerals. They did not, however, have the rich gold mines the Spaniards sought when they arrived seeking the fabled cities of gold. The Spaniards mined successfully for silver and gold in Mexico, and on a much lesser scale, primarily for silver, in southern Arizona. Espejo discovered a rich vein of silver south of the San Francisco Peaks of northern Arizona in 1582, but realized that mining would not be economically feasible in such a remote area.

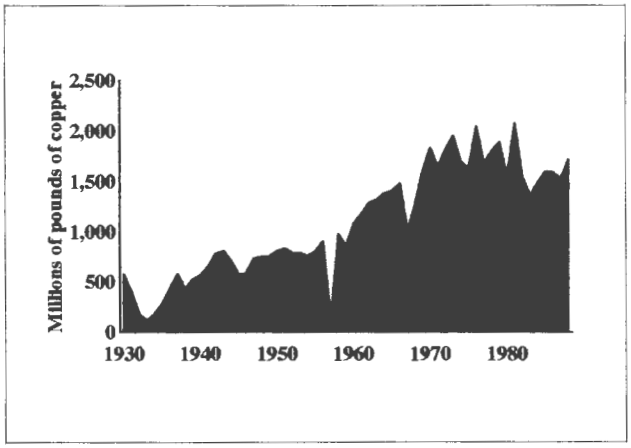
Gold and Silver Mining

It was not until after the California Gold Rush ended that the Anglo search for gold and silver in Arizona began in earnest. Reports went out that gold had been found

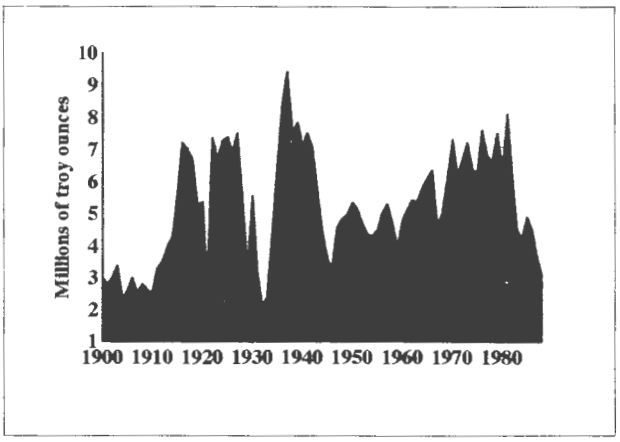
at spots along the Colorado River. Steamboats had reached the river about the same time, and boats transported prospectors up the river. More than 50 towns sprang up, but they usually disappeared after a few years. Only a few mines were successful. The difficulty of mining in a water-scarce region, coupled with problems of transporting supplies to the mines and moving the ore out to market defeated many. Most rich veins played out quickly, leaving the prospector not much wealthier than before. Often the people supplying the miners ended up richer than the miners.

In 1857, gold was discovered along the Gila River, 20 miles upstream from the Colorado River. Within a year more than 1,000 people were panning for gold, and the thriving town of Gila City sprang up. While a few got rich, most left with nothing. Even well-financed companies did not always make a profit. It was not until the railroad arrived, making transport easy, that mining really became profitable.

In 1856, enterprising businessman Charles Poston organized the Sonora Exploring and Mining Company and settled along the Santa Cruz River with about 80 mining claims. For a short time he was the "alcalde" (mayor) of Tubac. Gardeners soon produced all the vegetables and fruits the community could eat, using a canal from the Santa Cruz River to irrigate the crops. The high cost of transporting supplies in and ore out meant that only the richest veins were profitable, and soon these were exhausted. Poston went on to play a major role in the development of the Arizona territory and was known as "the Father of Arizona."



Copper production in Arizona.



Silver production in Arizona.

In 1862, gold was found along the Hassayampa River, with the Vulture Mine the most productive of the early gold mines. The gold rush that followed alarmed the Apaches who, fearing loss of their lands and hunting grounds, attacked pack trains and isolated miners.

Copper Mining

It was not until after the Civil War and military "pacification" of the Indians that mining proved profitable. The arrival of the cross-county railroads in the 1880s and many local lines also increased the profitability of mining.

The great silver boom along the San Pedro River in the late nineteenth century made Cochise County the leading county in production of gold and silver. In Cochise County and other areas, gold and silver were soon replaced by copper as the most profitable metal, although occasional rich gold or silver finds were still made in the twentieth century. Nearly all of Arizona's great copper mines—Clifton-Morenci, Globe, Ray, Bisbee, Ajo, Mammoth, and United Verde—were discovered in the late 1800s, and some continue to produce today.

Over the years, copper production has risen and fallen, depending on economic conditions. Since 1858, Arizona has led all other states in copper production, and Cochise County historically produced more copper than any other part of the state, but Pima County leads in copper production today. Development of new technology

in the 1970s made it possible to extract copper from ore with very low percentages of copper, using a water-based leaching process.

Other Kinds of Mining

Uranium mining was important in northeastern Arizona in the 1950s and 60s The mines resulted in short-term pollution problems from radioactive materials, especially along the Rio Puerco. Health problems now plague Navajos who worked those mines.

Coal mining began in prehistoric mines on the Colorado Plateau. Coal mining is now a major industry in northeastern Arizona, largely to provide coal for power plants throughout the state. Exportation of coal slurry from the area to Nevada has reduced water sources for the Hopi and Navajos. Some ancient springs are drying up.

Sand and gravel mining to provide construction materials occurs in all counties, but primarily in river beds of the Verde, Salt and Santa Cruz rivers. Lead, zinc and molybdenum also are mined in significant amounts in several Arizona watersheds.

Burro bringing water to miners about 1880.

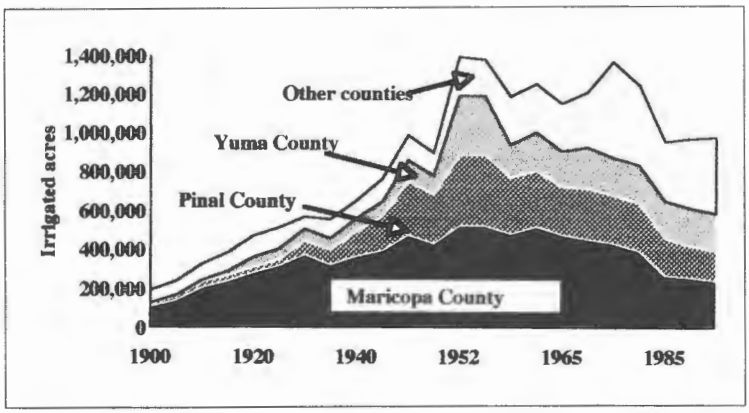
Morenci mine and smelter 1985.

Impacts of Mining

Virtually all hard rock mining requires water at some stage of the process of extracting minerals. Placer mining of gold involves the use of water to separate tiny gold particles from other materials in the water. One of the most important impacts of mining is reduction of water supplies for rivers because of groundwater pumping or surface water use. These impacts can be seen most dramatically on the Gila and Santa Cruz rivers.

Chemicals used to process ores may pollute water if improperly released. Radioactive pollution from a uranium spill was a problem for years along the Rio Puerco. The Arizona Department of Environmental Quality considers continued pollution from long-abandoned mines a significant water quality problem. Modern operations must meet strict standards for releases to surface or groundwater (with some exceptions on tribal lands). Spills, however, have continued to be problems as recently as 1993 in Pinto Creek and the Gila River.

Mines, especially surface mines, can totally change the landscape, replacing forested watersheds with mined-out land and removing entire hills. Since tailings ponds are difficult to vegetate, mining companies have tried innovative methods to get plants to grow and stabilize the soil, including the use of cattle to spread and fertilize seed on tailings near Globe. Some old min-



Agriculture in Arizona.

ing ghost towns such as Ruby have become prime wildlife habitat. Ruby's ponds which developed in old mining excavations provide habitat for many kinds of wildlife, including endangered bats.

Farming

Cotton was domesticated in North America by 2500 B.C. and is found in archaeological sites throughout Arizona. Corn was domesticated in North America by 1500 B.C. and was a staple crop in Arizona by 500 B.C. The early farmers grew many other crops, including agave, squashes, amaranths and tobacco.

The Spaniards brought new farming techniques and crops. Probably the most important crop change was the introduction of wheat, the first winter crop in Arizona. Before this time crops were planted only in the spring and summer. The Spaniards introduced fruit trees, barley, grapes, and other crops. Alarçon, in 1540, found over 150 introduced crops in Sonoran mission gardens.

Pima Indians along the Gila River.grew enough surplus food to sell to thousands of people joining the California Gold Rush starting in 1849. Once Arizona had become a territory, the pace of agriculture again quickened. Settlers moved in to all the major river valleys with good farming land, from the Little Colorado in the northeast to the Colorado in the southwest. After the Civil War, expansion of farming was rapid.

Mormons settled the Little Colorado River basin, then moved on to parts of the Salt, Gila and San Pedro rivers, as well as northern Sonora. They built communal irrigation systems, with dams when necessary. Other farmers claimed sections of all arable river valleys in Arizona by the early 20th century.

Cotton became the most important crop in Arizona during the early 1900s. Utilizing a long staple variety from Egypt, farmers rushed to convert their fields to cotton. Cotton fields increased in Yuma County from 2,500 acres in 1917 to 27,000 acres in 1919. In 1920 the worldwide cotton supply was so great that prices plummeted and many farmers lost their investments. Farmers diversified into citrus, alfalfa and vegetables. In 1990 cotton was Arizona's most valuable crop, followed by fruits, vegetables and hay.

The Great Depression brought about new farm policies, with help for farmers in times of disaster. Rural electrification combined with new farming technology made it possible to use much more water for farming. These new factors encouraged the development of larger farms. While the amount of crop land doubled, the number of farms increased only 30 percent. Millions of acre-feet of groundwater and surface water were

Cotton farm along the Santa Cruz River about 1920.

"On the haciendas where there were no ponds or streams the cattle obtained water from the 'pasos or simple wells, and the 'norias or draw wells where the water was drawn up by a wheel worked by mules. I met with many of these wells far away from any stream. In the northern part of Chihuahua or Arizona the cattle herds have long since disappeared, owing to the incursions of the Apaches and Comanche.... The great herds have disappeared and the haciendas are everywhere in ruin." John Bartlett, 1854.

used throughout Arizona for agriculture. In areas such as the Santa Cruz Valley, the combination of urban and agricultural water use dealt the final blow to the river, which finally ceased to flow regularly sometime in the 1940s.

Impacts of Farming

At the peak of agriculture, most of the water used in Arizona was for agriculture. Currently about 76 percent of all water used in Arizona is for crops. Most of the arable floodplains in the state have been cleared for crops. The Salt and Gila rivers have been affected the most, with water loss great enough to dry up the rivers. Diversions and pumping have both played a role in dewatering the rivers for farming. Water quality problems also have developed from use of pesticides and herbicides as well as high salinity in wastewater from farms. Abandoned farmland causes problems because of erosion, duststorms, and prevalence of weeds.

Ranching

Ranching was unknown in North America before the Spaniards introduced cattle, sheep and horses in the late 16th century. Although turkeys, dogs, and tropical birds were domesticated in America before Columbus, grazing animals were not. Columbus brought domesticated animals and crops new to North America with him on his second voyage. In his journey to Arizona, Coronado brought cattle, horses and sheep. Livestock significantly slowed down the expedition, but provided valuable food for the explorers. Missionaries used livestock as a way of "civilizing" Indians. Ranching spread from Mexico north into Arizona and New Mexico.

Spanish ranching went through periods when thousands of cattle roamed the range and other times when Apache depredations made ranching impossible, and the ranches were abandoned. Wild cattle roamed the area when the first American explorers reached the San Pedro and Santa Cruz valleys. Bartlett saw thousands of head of wild cattle when he surveyed the boundary. In 1854, more than 4,000 sheep grazed along the Santa Cruz River at Calabasas.

Felix Aubrey drove a band of 350 sheep from Santa Fe to California in 1854. He was followed by many others driving cattle or sheep over the years. Cattle and sheep became a valuable commodity, and many were herded along the Santa Cruz and Gila rivers through Arizona from Texas to California to feed the 49ers. Because of the severe conditions and lack of water between Tucson and the Gila River and again west of the Colorado River, thousands of animals died along the way of thirst, hunger or Apache attacks.

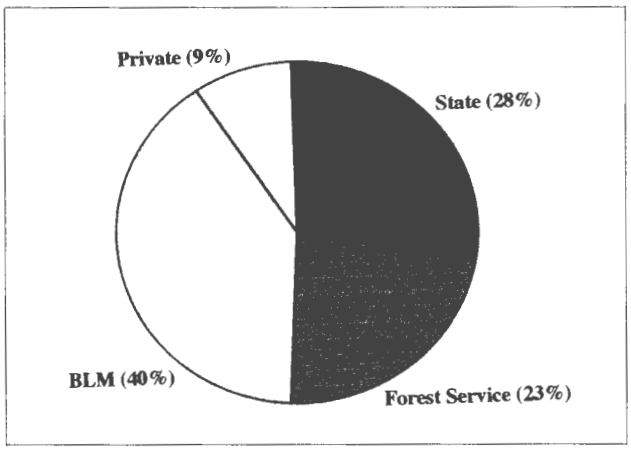
Effects of the 1903 drought. Thousands of cattle died.

Once the Apaches were defeated, ranching replaced the semi-nomadic way of life in much of Arizona. Mormons were pioneers in introducing stock, but were soon eclipsed by huge ranching operations. Droughts in Texas and California led ranchers to export their herds to Arizona in an effort to save them. The 1870s and 1880s were times of average or above average rainfall and the lush grasslands invited introduction of hundreds of thousands of cattle in most of the watersheds of the territory. Arrival of the railroad in the 1880s made import and export even easier and made the business profitable.

For a while the ranges seemed inexhaustible, but in the 1890s drought came to most of the state's watersheds. Cattle died by the thousands. When people tried to sell their herds, prices fell dramatically and many ranchers were forced out of business.

The disasters of depleted ranges brought about intense controversy. Downstream farmers urged that cattle be removed from the watersheds because they saw severe problems when the eroded soils ended up on their farmlands along with increased flooding.

Cattlemen and sheep men were often at odds because of the different requirements of cattle and sheep. Sheep would be driven to mountain pastures in the spring and back to lower pastures in the winter. The driveways were denuded during the annual trips and became eroded ruts. Sheep using watering spots owned by cattlegrowers did a lot of damage in a short time, and the cattlegrowers wanted them banned from the region. Whatever the merits of cattle vs. sheep, both were grazed more intensively than the range could handle.



Land base of Arizona ranches in 1990.

The famous Pleasant Valley War between cattlemen and the sheep men which resulted in numerous casualties was the most extreme example of the feuding. In 1897, the cattlemen tried to get the Legislature to prohibit movement of sheep from one county to another without a permit from the commissioners in the county in which the sheep were to be moved. The cattlemen felt they could control the commissioners. The sheep men counterlobbied, and no law passed.

Establishment of the National Forest system in the late 1890s brought some order to this chaotic situation, but not until many years had passed. In 1902, the U.S. Secretary of Interior ordered that cattle be taken off the federal rangeland, but President Roosevelt rescinded the order.

In 1910, J.J. Thornber, University of Arizona botanist, was alarmed by the continuing degradation of the ranges and argued for a permit system. He was opposed with all the same arguments heard in the 1990s—ranchers knew best how to run ranches; there weren't too many cattle; fees would drive them out of business, etc. In 1918, E.C. La Rue argued (in a USGS paper) for a leasing system stating that the State Land Board seemed favor big companies and that smaller ranchers should have a better chance to compete.

Cattlemen and sheep men felt they were best able to determine how the ranges should be grazed and resented any federal control over their activities. After fees were set for grazing on National Forest land federal agents were attacked by ranchers who resented any increase in those fees.

Finally during the 1930s agreement was reached on policies and the Taylor Grazing Act was passed, which regulated grazing on public lands. This act set up a system favoring the bigger ranches and was not based on determining carrying capacity of the ranges or protection of watersheds.

Since then, management of the ranges on federal lands has varied from virtually unlimited use of the ranges to projects which encourage fencing

Footbridge over the Salt River Canyon at the site of modern Highway 60 in the 1930s.

off riparian areas and rotating grazing to protect those areas.

Management of state lands paralleled federal grazing policies. Approximately 90 percent of all State Trust Land is leased for grazing. Today, as in the past, most of Arizona, except the lowest deserts, is grazed.

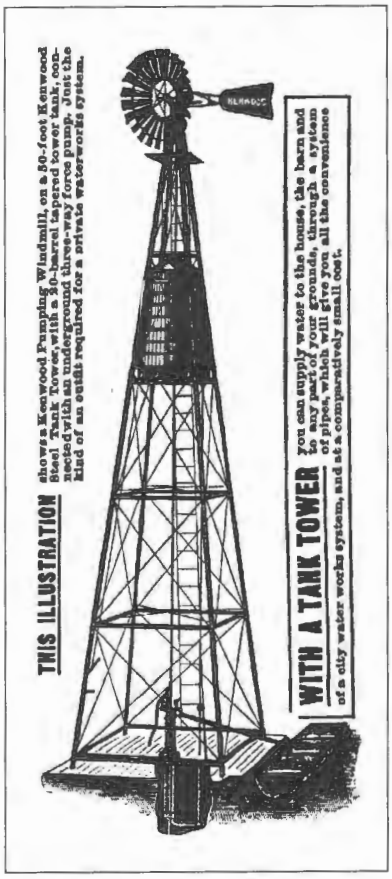
The numbers of cattle never again came close to the numbers grazed in the 1880s because of this control and because the ranges have not recovered from past degradation. Many Arizona ranchers practice new methods to protect watersheds while ranching. The Arizona Department of Environmental Quality has worked with ranchers to develop "Best Management Practices" for grazing to control these sources of water pollution. Some of the most healthy watersheds today are grazed successfully, such as the headwaters of the Santa Cruz River. Others, such as parts of the Tonto Basin, are overused and in poor condition.

Impacts of Ranching

Settlers moved first to surface water sources—the streams and springs. Cattlemen didn't need to own thousands of acres of land if they owned the water sources, since their cattle could roam without much competition. Neither the desert nor the mountains evolved along with large grazing animals. Native creatures such as antelope, deer and bighorn sheep were adapted to live with alternating drought-plenty cycles. Cattle and sheep, however, need water daily—as much as 30 gallons per animal per day—and have great impacts on riparian areas.

Overgrazing had extreme impacts at the end of the nineteenth century, leading to erosion, gullying, entrenchment of streams and loss of vegetation. With better grazing practices, many areas of the state have healthier riparian areas than they did one hundred years ago, but few areas have recovered to their pre-grazing state. Some riparian areas have been fenced off, with alternate water supplies provided for cattle. This has helped restore some rivers, but many riparian areas are still overgrazed.

One unintended impact of both mining and ranching has been the proliferation of feral horses and burros, especially in the northern and western parts of the state. These animals have caused damage in the Grand Canyon and other places, leading to denudation of vegetation and erosion.

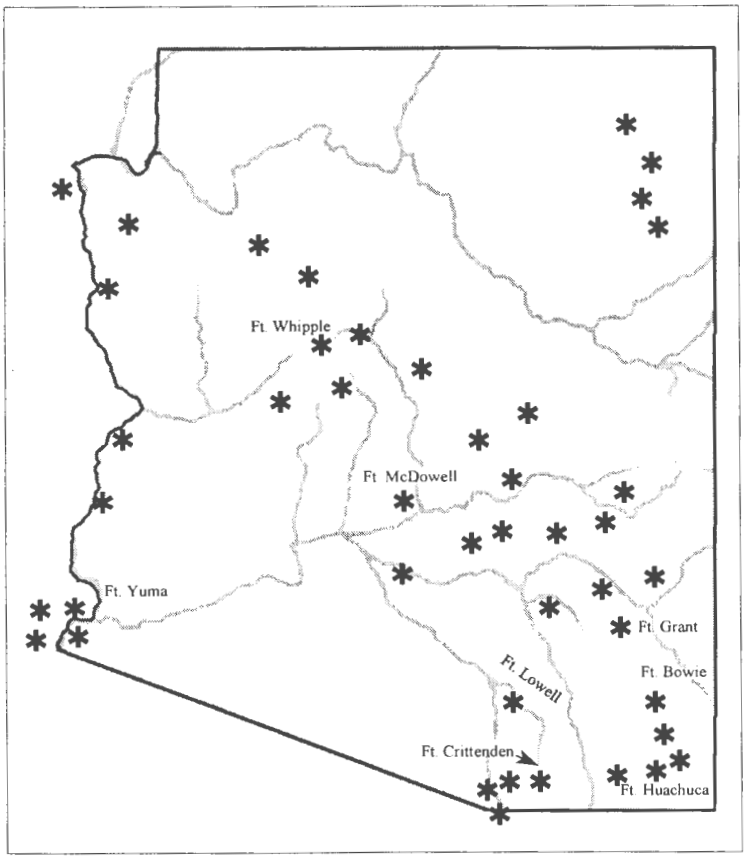


The Military in 19th Century Arizona

In 1846, Mexico fought the United States for control of border areas. With the Treaty of Guadalupe Hidalgo in 1848, the war ended and the U.S. became the owner of all of Arizona north of the Gila River. The Gadsden Purchase in 1854 added the remainder of the land south of the Gila to the U.S.

The Indian Wars

During the Civil War, the military was mostly withdrawn to fight elsewhere and many Apaches became bolder. Areas unprotected by soldiers (especially in southern Arizona) were largely depopulated by Americans. After the War was over, forts were established at strategic locations to protect miners and other settlers. In a period of about 20 years, the military moved into strategic parts of Arizona and subdued the Indians. In most cases, the military took advantage of long-standing hostilities between tribal groups and employed rival Indians as scouts and soldiers. The military were not successful at protecting settlers until the arrival of General Crook in 1872. He organized systematic eradication of Apaches from the Verde Valley to the San Pedro. In about one year he had subdued most of them and destroyed not only their weapons, but even their homes and food supplies. The survivors had little choice but surrender and submit to deportation from their tribal lands. Some of the conquered peoples were sent to Oklahoma, Florida, and places within Arizona outside of their ancestral homelands. By 1885, tribal lands had shrunk from almost 100 percent of Arizona to less than 15 percent. Later reservations brought this up to about 27 percent of Arizona's total land.



Military posts in Arizona from 1850-1920.

Impacts of the Military

Of the more than 110 military installations established after the Gadsden Purchase, only three lasted more than 40 years; Six lasted from 25-40 years and six lasted from 10-25 years. Most of the others lasted only a few years in the 1870s. The most important impact of the short-lived military period was to completely change the population distribution in Arizona. The semi-nomadic Apache lifestyle was eliminated with survivors crowded in unfamiliar, territories where they could not make their living by traditional means. No longer did the Apaches dominate southeastern and central Arizona and the land was quickly appropriated by American settlers and miners. Forts were of necessity located near permanent water. Soldiers at forts as widely separated as Camp Verde and Fort Buchanan suffered from water-borne diseases, especially malaria. Swamps were drained for health reasons and some remain dry today.

SALT RIVER

The Salt River is the major river in east-central Arizona, with tributaries throughout the White Mountains. The most sophisticated prehistoric irrigation system in North America was in the Salt River Valley. Its more modern history includes farming, ranching, a series of dams and the largest metropolitan area in the state.

The River

The Salt River begins high in the White Mountains where the Black and White rivers converge and meets the Gila River about 80 miles further downstream below the Phoenix area. The major tributaries are the Verde, White and Black rivers and Tonto Creek. The entire watershed (including the Verde) covers about 6,600 square miles. Steep canyons mark much of the upstream area, while the Salt River Valley below is a broad floodplain. There are 1,262 perennial stream miles, 7,469 nonperennial stream miles and 27,544 acres of manmade lakes in the watershed, including the Verde River.

The Early Residents

The Hohokam inhabited the Salt River Valley for more than 1,000 years using sophisticated irrigation systems.

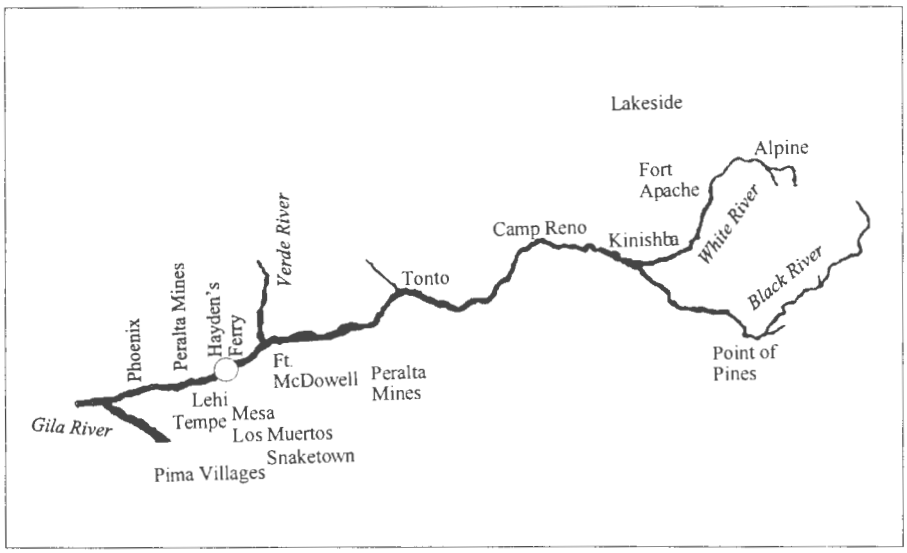
The Salado people occupied the upper Salt River Valley at about the same time that the Hohokam lived downstream. They, too, lived in agricultural communities and farmed areas such as the confluence of the Salt River and Tonto Creek, an area now inundated by Roosevelt Lake. The Tonto National Monument and Besh-Ba-Gowah Pueblo in Globe are preserved examples of Salado dwellings. At its height in the 15th century, the population of the Tonto Basin was probably about 5,000. The Salado abandoned their homes and fields by 1450 for unknown reasons and moved north and east to join existing Hopi and Zuni pueblos. Hohokam civilization declined in the fifteenth century. Little use was made of the Salt River Valley for two hundred years after the disappearance of the Hohokam.

The Yavapai and Apache people moved in and were utilizing much of the upstream area by 1700 or earlier. While they were largely nomadic, agriculture was an important seasonal source of food for them. Using horses introduced by the Spaniards they were able to range over a large territory, including the Salt River watershed.

The Spanish Period

The Spaniards were barely aware of the Salt River, although Coronado probably crossed it in 1540. Even Father Kino on his travels did

"We are now between the Salt and Gila Rivers, on a very extensive rich plain, covered with trees and small brush, watered in some places by means of canals from the two rivers named. The river dams and canals are very easy made, on account of the solid bottoms of the rivers and pure farming clay of the plain. In fact, the people who are now living here find it very easy to get good farms in one or two years without much hard labor. They unite as we do in making canals. The climate is one of the most delightful in the world and until a few years ago, one of the most healthy too, but lately the people have been troubled with fevers, which nobody seems to know the cause. The water is good and the sky is clear, there being no stagnant pools; the ground is dry and the winds blow freely in every direction." Deseret News, Jan. 1878.



Historic Sites Along the Salt River.

not go north of the Gila, although he did mention the confluence of the Gila and Salt rivers. The most lasting influence of the Spanish in this area was the introduction of horses.

Trappers and Anglo-American Explorers

James Pattie explored most of the Salt River in the 1820s. Young, Wolfskill, Yount and Weaver also explored the Salt to its confluence with the Verde River at that time. They trapped hundreds of beavers in the early 1820s.

The river was again mostly ignored by outsiders until after the Civil War when several forts and camps were established and were active for about twenty years. The largest were Fort McDowell at the confluence with the Verde River and Fort Apache far upstream on the White River. Indian occupation was severely reduced and ranching expanded into the upland areas from the Little Colorado River basin and from areas to the south.

The Walker Trail from the Pima Villages on the Gila River to Prescott was pioneered in 1864. It crossed the Salt River in the Phoenix area. This trail later became a stagecoach route.

Few Indians were living in the Salt River Valley when pioneer settlement began in the 1880s. Pioneers encouraged Pima Indians to move from the Gila River to an area north of the Salt River to help serve as a buffer against the Apaches. When the Gila River began to dry up because up-stream farmers were using so much water, other Pima Indians migrated to the Salt River Valley which still had water for farming. Later, when competition for farm land and water increased, settlers harassed the Pimas and tried to remove them from the area.

Anglo-American Settlement

In 1868 Prescott entrepreneur Jack Swilling saw great agricultural possibilities in the Salt River Valley and successfully reused an old Hohokam ditch. From then on, settlers built earthen dams and planted fruit trees, such as fig, plum, peach and citrus and were growing crops such as peanuts, alfalfa, tobacco, barley and corn. By 1889 more than 35,000 acres were under cultivation in the Valley. Ten years later almost four times this much land was cultivated. Settlers found that mesquite land supported more thriving crops than bursage land, but cutting down mesquite trees and preparing land for the plow cost them $3-$7 per acre, while bursage land clearing was only $1-$2 per acre. Ultimately, both mesquite and sage brush lands were converted to farming.

Mormon settlers who found the area appealing in the late 1800s, settled in the eastern part of the

"Much difficulty has been experienced by the flood waters of our rivers going to waste at a time when they were not much needed, and when needed there was not enough to supply the demand. This difficulty will soon be overcome by impounding the flood waters by means of great dams and reservoirs. ... Happy homes will spring forth and millions of people will live and prosper where once there was nothing of value to mankind." Phoenix Chamber of Commerce, 1908.

Dam	River	Year	Lake
Granite Reef	Salt	1908	no lake
Roosevelt	Salt	1911	Roosevelt Lake 1,381,600 a.f. 23 river miles
Horse Mesa	Salt	1925	Apache Lake 245,100 a.f. 17 river miles
Mormon Flat	Salt	1925	Canyon Lake 57,852 a.f. 10 river miles
Stewart Mt.	Salt	1930	Saguaro Lake 69,765 a.f. 10 river miles
Bartlett	Verde	1939	Bartlett Lake 178,477 a.f. 12 river miles

Dams on the Salt River and its Tributaries.

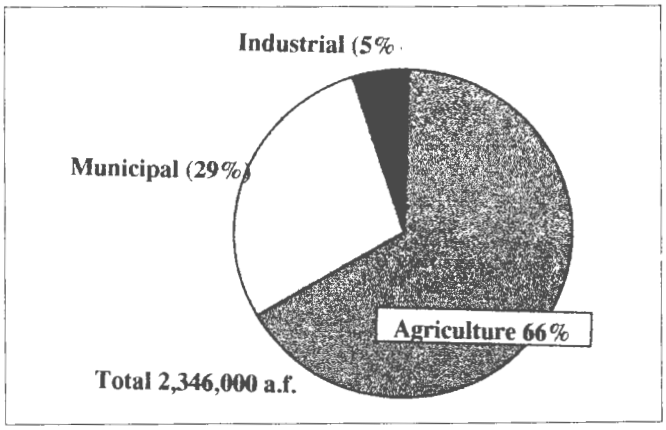
Valley, establishing Lehi, Mesa and Tempe on the south side of the river. Charles Trumbull Hayden was one of those who recognized the possibilities of the area on a trip to Whipple barracks. He arrived at flood time and had to wait two days to cross the Salt River. This gave him time to dream not only of finding ways to help people cross the river, but also of growing wheat. A year later he returned and established an important river crossing with a ferry—the only way to cross the river for miles in either direction when river flows were high. Hayden also built a store and water-powered flour mill at that location, which became Tempe. From 1887 to 1889 severe drought hit the valley, limiting the amount of land that could be irrigated. This was followed by extensive flooding.

In February 1891 rain began to fall and it continued to fall for days. By February 18th, most of the town of Lehi was under water. The Steele family on West Lehi Road saw their adobe house melt into a large pile of mud. At one point, the river measured eight miles wide near present-day 24th Street in Phoenix. Rain continued to fall even after the first crest of the river. A week later, 225 men were working to protect the Arizona Dam with gunny sacks and other supplies. The river was rising at a rate of one foot per hour. All of Lehi was flooded except for about two acres of rocky ground where large numbers of rabbits gathered with the people.

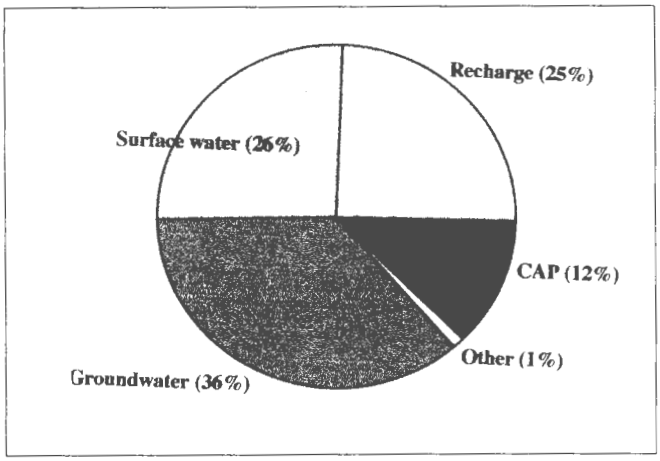
This time of flood was followed by a decade of severe drought. Only a trickle of water flowed in the canals, if it flowed at all. No water flowed in the river through Phoenix. In the year 1900, violence broke out over water when there was not enough for all who claimed water rights. The Mesa Free Pres reported "Lehi has had quite a good deal of trouble during the past week over the water question. A scrap occurred Wednesday evening in which guns, revolvers, and other weapons figured conspicuously. ... if it continues to get much worse, it has been suggested that the sheriff call out the National Guard. The shortage of water increased fire danger so much that on June 22 the Free Press expressed the hope that 'owing to the scarcity of water ... the small boy with firecrackers will be rigorously suppressed'." The long drought brought about a spirit of cooperation among water users who united to support building storage dams.

Dams

Historically, beaver dams throughout the river system held back water in pools, promoting water recharge. Although beavers were heavily trapped in the 1820s and 1830s, they had pretty much re-



Phoenix Area Water Uses in 1990.



Phoenix area water supplies.

covered by the time American settlers arrived. By the 1920s, however, settlers had eliminated beaver from all except the high elevation tributaries.

Diversion dams have been necessary for irrigated agriculture since Hohokam days. Before the twentieth century, dams were small, usually built of trees, brush and earth and were easily washed out by floods. The twentieth century brought a whole new type of dam—very large dams intended to last for many years. The purpose of the dams was to distribute water supplies throughout the year, through times of summer low flow and control floods.

Roosevelt Dam was the first dam ever built by the newly created U.S. Reclamation Service. It is located 80 miles from Phoenix, at the confluence of the Salt River and Tonto Creek. It took six years to build and was completed in 1911. The dam was modified and raised 77 feet in the 1990s, increasing the flood storage capacity. In the 1920s and 1930s three more large dams were built on the Salt River and two on the Verde River, largely to serve the Salt River Valley. A dam once planned on the Fort McDowell Indian Reservation was never built because of opposition from Indians and others. This dam would have flooded most of the useable land and damaged bald eagle nesting areas.

The cumulative effect of the dams has been to completely change the character of the river.

The Salt River Project

In 1889 the Maricopa County Board of Supervisors wanted to build a dam site 80 miles east of Phoenix on the Salt River. The expanding population of the Phoenix area, coupled with uncertain river flow, had prompted local irrigators to look for new ways to supply water. In territorial times there were federal restrictions that kept the territory, county, or individuals from proceeding with water reclamation projects, so, in 1903, the Salt River Valley Water User's Association was formed.

Under the National Irrigation Act of 1902, the federal government provided the funds for water reclamation projects. Using these funds, the association welcomed the start of construction, in 1903, of its first water storage facility—Roosevelt Dam. The Federal Reclamation Service controlled the operations of the dam and related irrigation system until 1917, when the Association took over control of all water and power activities. About a decade later it began drilling wells to pump groundwater.

In 1937 the Association created a new municipality, the Salt River Project Agricultural Improvement and Power District. This was a semi-public, tax-exempt organization responsible for power generation. The two organizations tried to operate distinctly, but in 1967 increasing overlap in their duties led to the combination of the Association (water) and the District (power) into the Salt River Project.

When the dual Salt River Project (SRP) was formed, it had six dams on the Salt and Verde rivers with a capacity of over 2 million acre feet. From the main distribution point, Granite Reef Dam, 131 miles of main canals delivered 1,050,000 acre feet of water to 238,252 acres of land. Hydroelectric generators and steam electric plants had a capacity of 598,162 kilowatts.

The SRP today has about as many storage facilities, miles of canals, and serves the same number of acres as it did in 1967. However, to serve the growing population, it has expanded by drilling wells. SRP serves over one million power and water customers in the Phoenix area, and has 250 wells. SRP has also initiated a groundwater recharge project to capture surplus water from years of high precipitation and store it underground.

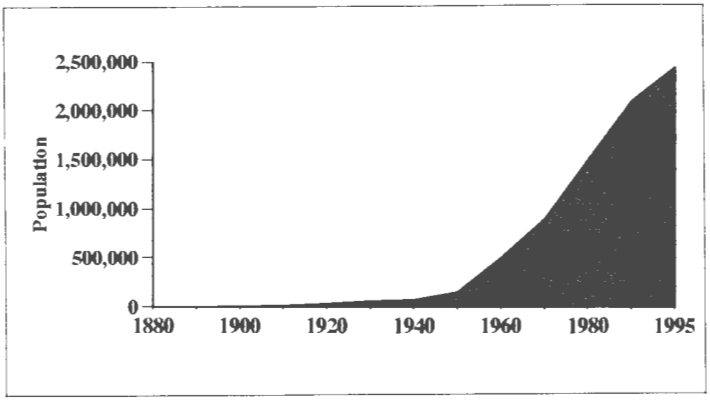
Before 1900, the river's flow was heaviest in the spring and early summer when snow melted in the mountains. Heavy summer storms also could bring about high water. Flows were generally low in fall and in drought years.

The dams transformed some 70 miles of flowing river into a chain of lakes and changed the way water flowed downstream. No longer did high spring flows ensure cottonwood regeneration. Instead, saltcedar (a non-native tree), which has much less demanding germination and growth requirements and disperses seed throughout the summer, took hold. Native fish were unsuited to lakes and could not compete with the sport fish introduced into those lakes.

Diversions from Granite Reef Dam, a dam which diverts most of the water in the Salt River to the Phoenix area, effectively dewatered the river, turning it into a sandy expanse experiencing high flows only during unusually rainy years when flood waters had to be released from the dams upstream.

Agriculture

Settlement in the valley depended on agriculture, and agriculture depended on a reliable water supply. When the dams were completed, agriculture began to expand and flourish. Dams not only provided water, but also power, allowing more groundwater pumping. Cotton and citrus became the most important crops. By 1930, about 375,000 acres were under cultivation, using over 2 million acre-feet of water. In recent times much of the former agricultural land has been converted to urban land, except on the Salt River Reservation and the west side of the valley.



Population in Maricopa County.

Urbanization

As more and more people moved into the Phoenix area, agriculture began to decline. Urbanization had new impacts on the river, which was already drastically changed from its pre-Arizona Territory status by dams and diversions. While total water use did not change much, land use did. Instead of porous soil surfaces where crops were grown, much of the area became either paved with streets and parking lots or covered with homes. During intense storms water now runs off quickly into the river and goes downstream, often as flood water. Local regulations have mitigated the problem somewhat by requiring that certain new construction include provisions for detention or recharge of flood water.

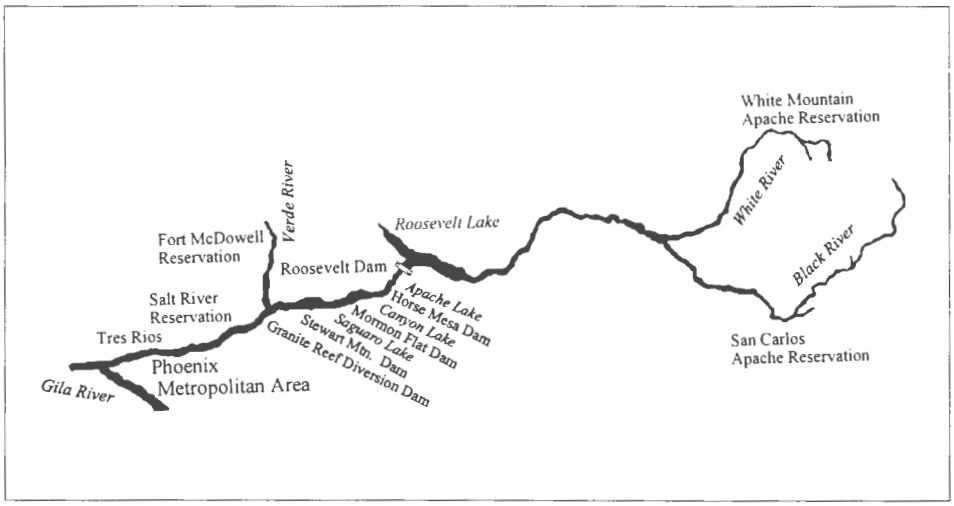
The dry floodplain attracted developers. Many commercial and residential buildings are located in the former floodplain of the river. This means that flood control projects are needed to protect those structures. The dry river bed is also an economical place to mine for sand and gravel for construction purposes.

The dry river bed also was a convenient place to dispose of trash, especially where holes were already dug to excavate sand and gravel. A large metropolitan landfill operated by the Salt River Indian Tribe on the north bank of the Salt River across from Mesa was damaged in the 1993 flood and large amounts of trash fell into the river. A volunteer effort was able to remove some of the larger materials after the flood had subsided, but some contamination occurred. Contamination from old landfills is a continuing problem during high flows.

Water Use

Water diversions have taken their toll on the amount of water in the Salt River. Below Granite Reef Dam, all its water is diverted. The river is normally dry and no longer supports riparian vegetation until it reaches the first wastewater plants downstream of the Phoenix area. Groundwater pumping has further depleted the amount of

water available to the river. Only on the west side of the valley are water tables still high, due to wastewater. In 1990 2,725,447 acre-feet of water were used in the Phoenix Active Management Area, while only 2,397,152 acre-feet of renewable supplies were available. Even with Central Arizona Project (CAP) water from the Colorado River, over 300,000 acre-feet of groundwater were used beyond the natural recharge level. C.A.P. is helping to eliminate the overdraft problem.



Twentieth Century Sites along the Salt River.

Much of the Phoenix metropolitan area is served by the Salt River Project (SRP). SRP delivers water from both surface water and groundwater sources and holds water rights for a large portion of the Salt and Verde rivers. These water rights, requiring that water be delivered downstream for use in the Phoenix area, have limited surface water use in the upper reaches of the river, keeping the river flowing to Granite Reef Dam.

Wastewater Flows

Treated wastewater enters the Salt River downstream of the metropolitan treatment plant at 91st Avenue west of Phoenix, creating a riparian area—dominated, however, by saltcedar—and wildlife habitat all the way to the Salt River's confluence with the Gila River. Even the endangered Yuma Clapper Rail has settled in this riparian area. Much of this water is used downstream by agriculture and the Palo Verde Power Plant. This effluent flow is gradually being replaced by recharge projects and a constructed wetland, the Tres Rios Project, near the confluence of the Agua Fria, Salt and Gila rivers.

"For the past five or six days about half our living has been fish. Our only trouble is that we have not got lines strong enough for the large fish which weigh from 10 lbs. to 40 lbs., neither can we catch many of them in our willow drag." F.A. Cook, 1864

Vegetation and Woodcutting

Cottonwood, willow and mesquite were once common in the Salt River Valley. As recently as 1921, a photo of the Central Avenue bridge in Phoenix revealed extensive cottonwood stands. From the days of earliest settlement, the demand for fuelwood was enormous. As in most other early communities, woodcutting had a major impact on the river and nearby lands. In towns, trees were planted for shade, but the surrounding areas were largely deforested to provide wood for heating, cooking, powering steam engines, and many other purposes. Once the local supply was exhausted, lumber was brought from as far away as Prescott and the White Mountains.

As competition for water increased, irrigation districts, businessmen and homeowners were determined to eradicate cottonwoods, which they considered water guzzlers. According to the newspaper editor, "They pollute the air and the ground about them with their masses of white, fluffy seeds, and they are subject to disease, and their brittle limbs, easily broken, constitute a hazard during our violent windstorms." Native trees were replaced with exotics such as umbrella, eucalyptus and citrus trees in yards. Today cottonwoods are rare along the Salt River. Only a few isolated stands are found in the urban area, though there are extensive stands at the Salt-

Verde confluence. Near the dams, saltcedar thickets predominate in many places.

Mining

Mining has greatly impacted tributaries in the Globe-Miami region, especially Pinto Creek. Some of the most dramatic changes in land use can be seen near Globe, Miami, and Superior where large open pit mines and tailings ponds dominate the landscape. Small watercourses have been filled in or diverted. Pumping and water diversions have taken water from the rivers. Water quality problems from metals, low pH and other contaminants are attributed to mining activity, especially occasional tailings ponds spills during flood times. Mitigation measures are underway to improve water quality.

Hayden's Flour Mill about 1895.

Fishing

Fishing was an important food source for the early inhabitants. Hohokam trash mounds contain bones of several kinds of large edible fish. Pima Indians ate bony-tail, sucker, humpbacked sucker, squawfish and several species of smaller chubs and dace.

In 1877 Lehi pioneers found edible fish abundant in the Salt River, which was an important food source for them, especially before they established successful farms. Dan Jones bragged that he had caught "a five-foot long salmon [squawfish] weighing 40 pounds." In 1888, a fishing party near the site of the present Granite Reef Dam reported catching 64 fish, with many of them being "that prince of Arizona waters, the Colorado salmon [squawfish]." In 1879, the Phoenix Herald called indiscriminate killing of large numbers of fish with gunpowder a serious problem.

Fishing is popular today in the upper stretches of the river although it no longer provides a major food source. Introduced fish have mostly replaced the native fish, except for a few native species in the mountain streams. Official warnings have been issued for fishing downstream of Phoenix, because of water pollution.

Farming in the Salt River Valley about 1885.

Recreation

The Salt River has many popular recreation areas. Rafting trips starting at the Highway 60 crossing are popular during the late spring and early summer. The Apaches limit the number of rafters and canoers on their section of the river to minimize negative impacts on the river. The four reservoirs provide manmade lakes that are popular boating, fishing and camping areas.

Restoration and Preservation

Where the Salt River flows through Tempe, a major restoration project is underway: the Rio Salado Project. In the planning stage for more than 20 years, the project is under construction.

Near the confluence of the Salt River with the Gila River and the Agua Fria a large constructed wetland, the Tres Rios Project, is being built using wastewater that has been flowing into the river from the wastewater treatment plant.

Apaches helping build Salt River Project canals, 1906.

Changes in the River

Far upstream, the Salt River continues to flow freely through National Forest and Indian Reservation lands. Here some remote creeks have changed little through history, except for several modern impacts. In some areas, however, changes have occurred. For example, beaver dams are few, and in some areas overgrazing has seriously impacted some of the tributaries. Logging in the White Mountains also has impacted the rivers. Downstream water rights serving Phoenix area water demands ensure that most of the water remains in the river until the big SRP diversions, thus protecting the upstream areas.

While Hohokam agriculture and settlement certainly had an impact on the river, the river by 1850 probably looked much like it did before Hohokam times. It flowed all the way to the Gila River except during drought. Cottonwood trees and other vegetation lined the banks. There had been virtually no direct impact during the Spanish period, except the introduction of horses and new crops and diseases.

Beaver trapping changed the river dramatically in the 1820s and 1830s. American settlement brought major changes to the Salt River Valley, by eliminating many small dams (beaver and man-made) that kept water in the upstream areas. At first the biggest changes resulted from woodcutting, water diversion and land clearing for agriculture. By the early 1900s alternate flood damage and water shortages led to construction of dams which completely changed the river. By the time the upstream dams were completed, water no longer flowed beyond Granite Reef Dam except at flood time. Lakes that replaced the flowing river support a quite different type of vegetation and wildlife.

Groundwater pumping lowered the water table in most parts of the Salt River Valley further depleting surface flow. The Salt River is a dry, sandy channel through the metropolitan area except when water is released from the dams. Downstream of the metropolitan area, wastewater supports a riparian forest, made up largely of saltcedar much of the way to the Gila River.

Urbanization has had other impacts on the river from increasing the intensity of flood flows from creation of impervious surfaces to creating an environment inhospitable to most kinds of wildlife.

Mining has impacted the tributaries of the river near Globe-Miami, where there are several huge copper mines. Upstream from Roosevelt Lake the river is less impacted by human activities. Most of the upstream portion within either National Forest or Indian lands is relatively unchanged by most human impacts, except grazing and some timber cutting in the higher elevations.

Arizona's Public and Indian Lands

All of Arizona's rivers pass through public lands, especially in the upper watersheds. These public lands originated in several ways. When the United States acquired what is now Arizona, lands not privately held were considered lands of the United States. Some were kept as federally reserved lands, while others were given away or sold. Some were maintained as reservations held in trust for Indian tribes. At statehood, a portion of the federal land was given to the state, in discrete sections, as a trust to be used primarily for the benefit of public education. Later, the federal government purchased lands for uses such as National Parks.

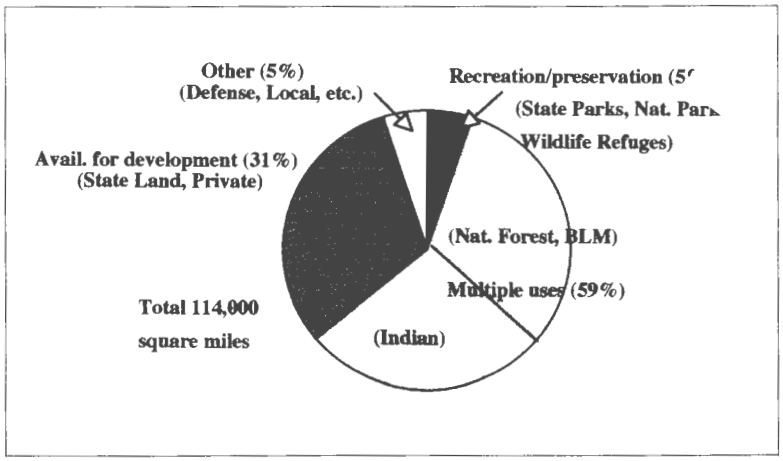
The map on page 167 shows major public lands in Arizona. In addition to the lands shown on the map, the State Land Department and Bureau of Land Management administer small pieces of land checkerboarded among private or Indian lands that are too small to show at this scale. Almost all of these lands are available to the public for various uses, usually with little or no user fee. Not shown on the map are city and county public lands and parcels of land such as State Parks, too small to show up at this scale. Also see the recreational map in the chapter on preservation and recreation.

Different categories of public lands are managed differently. Some may be sold or exchanged easily, some are managed for multiple uses and some have restricted uses. Management styles affect the rivers which pass through them. There are difficult problems in managing rivers which pass through different kinds of public land as well as private land.

State Land

The Arizona State Land Department manages almost 9,600,000 acres of land in trust for Arizona's education system, of which 90 percent are leased primarily for grazing. At the time of statehood, the federal government gave Arizona land throughout the state (often alternate sections interspersed with private land) to provide a basis for funding the public schools. The lands are operated to provide revenue in the short and long term. Lands may be sold at auction or leased for a variety of uses. Voters have three times failed to approve allowing the State Land Department to trade state land. Thus, the State Land Department is quite limited in what it may do to benefit riparian areas without obvious economic value. The Department, however, owns few prime riparian areas because the best riparian lands were settled by private landowners long before 1912.

Arizona State Parks Department manages some 44,842 acres of land as historic, natural or public recreational areas in 27 parks. Several parks include important riparian areas such as Sonoita Creek and lakes such as Alamo Lake on the Bill Williams River. Lands are generally managed in a way that promotes recreation while protecting wildlife values.



Management of land in Arizona in 1990.

Federal Lands

U.S. Forest Service (USFS) manages 11,232,000 acres in Arizona, mostly at higher elevations, as multiple use land. Some federal forest preserves were established in 1891 in response to concerns that uncontrolled grazing and logging were causing irreparable harm to watersheds that provided water for thousands of people. In 1911, the Forest Service was created and given responsibility for protecting headwaters and preventing fires.

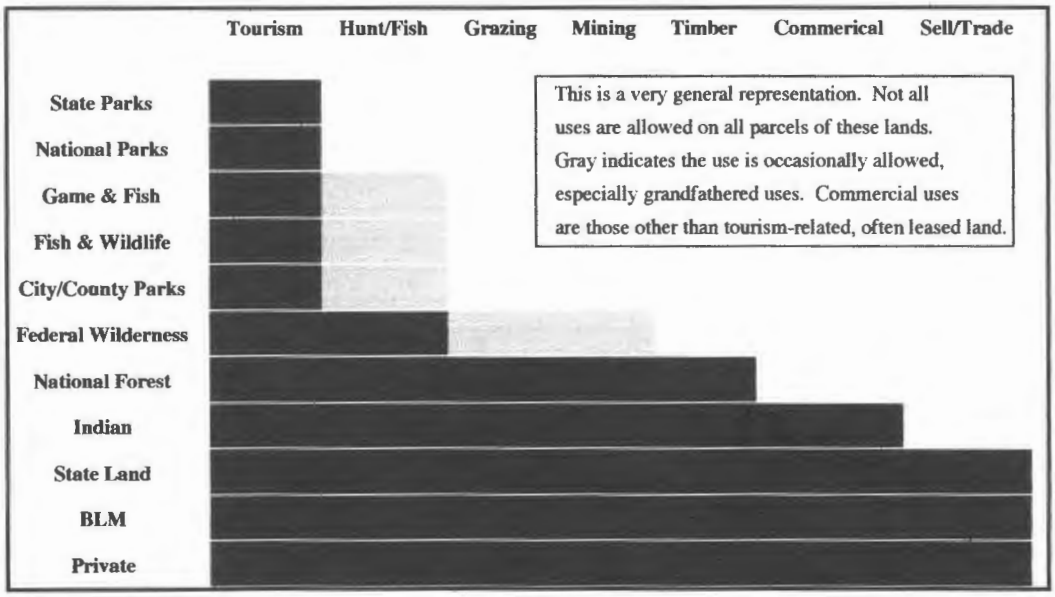
Permitted uses include grazing, mining, timber cutting, recreation, hunting, fishing, wood collecting and similar uses. Grazing is under a long-term permit system in which the number of cattle is regulated. Grazing plans may be required and the Forest Service may set conditions for use. Most of these uses require some type of permit or contract arrangement. Specific areas may be managed to benefit just a few uses.

Bureau of Land Management (BLM) manages over 12,000,000 acres of lower elevation lands in Arizona, reserved by the federal government at the time of statehood or acquired since for multiple uses. BLM manages four conservation areas in Arizona to preserve riparian values, of which two are riparian - the Gila Box and San Pedro Riparian National Conservation Area. Both the USFS and BLM have inventoried streams on their lands for Wild and Scenic River designation, although only one stream (a portion of the Verde River) has attained this status.

The 1872 Mining Law allows anyone to stake a mining claim on National Forest, BLM, and some other federal lands and maintain that claim under certain conditions with virtually no compensation to the public. Lands claimed for mining may later be transferred to other uses (e.g., resorts).

National Park Service (NPS) operates 21 areas of special natural or historic significance in Arizona, on a total of 2,500,000 acres. The primary goal is to protect the stated values while providing appropriate recreational opportunities. The Grand Canyon, for example, is managed by the Park Service.

U.S. Fish and Wildlife Service (USFWS) manages 8 refuges in Arizona to protect or reestablish wildlife and/or habitat, on a total of 1,700,000 acres. Most of these refuges also are open to rec-



Permitted uses on various categories of land.

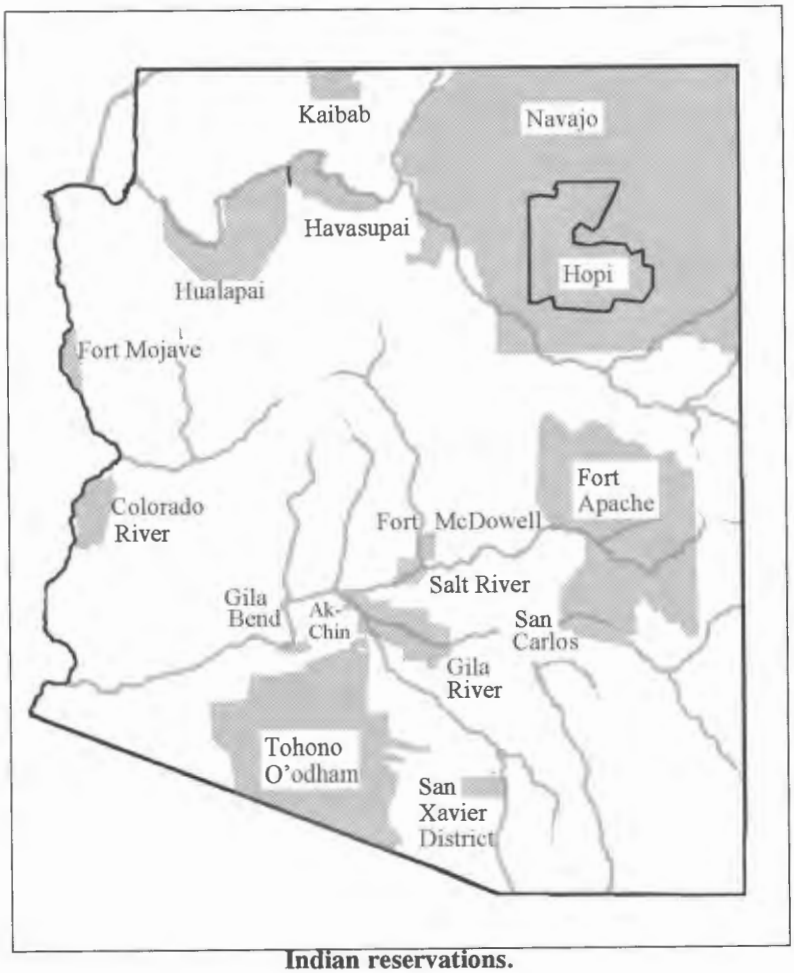
reation. The USFWS has responsibility for implementing the Endangered Species Act. Decisions made by them may affect management of most of Arizona's rivers, including the Colorado, Verde, Salt, Gila, and San Pedro.

Wilderness Areas

BLM and USFS manage four million acres of land as wilderness areas. Existing grazing uses are grandfathered in and may continue, although some restrictions may be placed on them.

Indian Lands

Most of Arizona's rivers originate or pass through Indian lands. These lands are neither public nor private, but are lands held in trust by the federal government for a specific tribe. They are generally not subject to state and federal land or environmental laws, but have their own systems for such activities as grazing or timber permits, recreational uses, water use or pollution control. Most tribes claim water rights based on historic land use and the purposes for which the reservation was established. Tribal lands are often leased to non-tribal entities for farming, mining or other purposes, but are not subject to trade or sale.



Indian reservations.

The following are just a few of the specific programs implemented by various tribes. The Navajos have a Department of Water Resources and a river restoration program (e.g. in Canyon de Chelly). The Gila Tribe has a master plan for the Gila River and the Colorado River Indian Tribes participate in habitat conservation. The Havasupai were an important element in the Glen Canyon Environmental Study and are involved in Grand Canyon management decisions affecting endangered species. The White Mountain Apache tribe is actively involved in management of grazing by installing fences to protect perennial streams.

City and County Lands

Local governments may own land for many purposes, including parks and flood control. The Phoenix area has several large natural public parks, as does the Tucson area. Pima County owns about 9,000 acres of floodplain land in an effort to control downstream flooding by keeping construction off sensitive floodplain areas. Prescott manages Granite Creek as an urban hiking trail. Sedona has developed a wastewater program to protect Oak Creek.

Regulatory Agencies

Several state and federal agencies have responsibility for public lands and rivers although they are not listed as land managers above. The U.S. Bureau of Reclamation determines operation of dams and other activities on the Colorado River and provides funds for some types of mitigation projects and constructed wetlands. The U.S. Army Corps of

Engineers operates dams such as Painted Rock Dam on the Gila River and Alamo Dam on the Bill Williams River. It also must approve permits for activities within the floodplains of watercourses.

The U.S. Environmental Protection Agency (EPA) and the Arizona Department of Environmental Quality (ADEQ) regulate activities that may affect water quality. A "unique waters" designation from ADEQ helps to protect streams of unique value. Cienega Creek, Peeples Creek and a few others have been so designated. The Arizona Department of Water Resources has responsibility for surface and groundwater laws (including instream flow permits) and dam safety.

Rivers and Public Lands

Government agencies may claim water rights to protect rivers on their lands. Because rivers flow through more than one jurisdiction, joint management of rivers can be a challenge. Activities allowed upstream will affect the condition of the river downstream. One example is the Gila River. The Forest Service manages the headwaters as grazing lands, while the BLM manages a section below as a Riparian Conservation Area. Overgrazing the headwaters has damaged the river so that downstream restoration in the BLM National Riparian Conservation Area is difficult. Cooperation among agencies and landowners and lessees continues to be vital to the fates of rivers.

'View on the Gila' from Emory's 1855 survey.

WOODCUTTING AND TIMBER HARVESTING

Nineteenth century woodcutter.

Before the days of electricity, oil, and gas, wood was the primary fuel for Arizonans. It was used for cooking, heating, smelting copper, making bricks, and powering steam engines for various uses—trains, steamboats, ice makers, ditch diggers, flour mills and many others. Wood also was cut for fence posts, houses, bridges, railroad ties and a multitude of other uses. Some of it was made into charcoal, which was used for many purposes, from blasting furnaces to laundry irons. Early photos show denuded hillsides around mines and near towns—due to extensive wood cutting.

Mesquite and oak were favored for charcoal, while juniper, mesquite and desert willow were favored for fenceposts. Conifers were cut for mine timbers throughout southern Arizona. Willow and cottonwood were used for corrals and fire brick. Livestock were fed willow leaves and cottonwood bark. For domestic use, mesquite and juniper were common, but virtually anything that would burn was used, even the malodorous palo verde if necessary. By 1882 cordwood had become so scarce that the mines were buying coal from New Mexico. Wood collecting became a major occupation, especially for Indians in the Tucson and Phoenix areas. Walnut stumps were harvested for fine furniture as recently as the 1930s along Aravaipa Creek and elsewhere.

Wood for Cooking and Heating

One scholar calculated that in the Tombstone region alone during its heyday from 1879 - 1886, 31,000 cords of wood were consumed for domestic use (assuming 4 cords per family per year, a conservative estimate). This is almost four million cubic feet of wood. An additional six million cubic feet were used for processing ore at the mines. These figures don't include wood that was used to build homes, businesses or mining facilities. In seven years at least ten million cubic feet of wood were used in this one small area.

Similar impacts on local wood supplies occurred near all mining towns and other settlements. When electricity arrived in those areas starting in the 1920s, the use of wood gradually diminished, but as recently as 1940, 30 percent of families in some areas were still cooking and heating with wood. In areas such as Pinetop-Lakeside today, most people still heat with wood, which is much cheaper than electricity or propane. In 1988, at least 264,750 cords of fuelwood were used in Arizona, mostly gathered from National Forests.

"Every tree over 7 inches in diameter had been cut and used for fuel within a 7-mile radius of Tucson." A.E. Harrison, 1972, describing Tucson in 1905.

Woodcutting for Commercial Uses

Every mining community had much the same woodcutting history as did Tombstone. Smelters using wood were built throughout the state. Until

Woodcutting camp in the 1880s.

the use of coal became feasible, woodcutting played a bigger and bigger role. In many areas entire hillsides were harvested.

During the period that steamboats plied the Colorado River, large amounts of wood were used to fuel the boilers. The boats made regular stops along the river to take on more wood. Once the easy-to-get wood had been stripped from near the river, Indians went farther and farther up the hillsides to get mesquite and juniper to fuel the steamboats. Railroads were another major user of wood. The wood supply was so important for the early railroads that the federal government granted alternate sections of land to railroad companies for the purpose of supplying wood for the ties as well as for fueling the boilers. Until coal and oil replaced wood as fuel in the late 19th century, the impact on nearby forests was great, especially near the railroads.

Long-Term Impacts

The long-term effects of nineteenth century woodcutting varied throughout the state and depended on the harvesting method used. In cases where branches were lopped off and the tree allowed to recover, the long-term impact was probably small. Many old oak trees in the Tombstone area show marks of having been repeatedly cut over a period of many years, having old ax and saw marks. Most species will survive repeated cutting of branches. Another harvesting practice—cutting the tree back to the stump—often led to resprouting, except for junipers which do not resprout as readily from the stump. In situations where the stump also was harvested, the long-term impacts were much more severe. In southern Arizona, a large percentage of the current forest is new growth. In some areas the hillsides never recovered, as the cutting was so massive that soil was lost to erosion.

The long-term impacts from harvesting of cottonwood and willow trees along rivers is less well known because other human activities also impacted those areas. For example, cottonwood and willow seedlings are tasty to cattle, and, as a result, forests often do not readily regrow because of grazing. The impacts from harvesting therefore are difficult to separate from the impacts of grazing.

"Timber depredations in southern Arizona are becoming so extensive that there is just cause for alarm. Even the palo verde trees are being stripped from the mesa lands."
Arizona Daily Star, March 7, 1884.

Around Tucson the cottonwood-willow forest and mesquite bosques had been harvested before 1900. While Tucsonans embarked on a beautification effort and planted hundreds of trees within the city, they destroyed the riparian forests. When the Santa Cruz River cut a deep channel through Tucson in the 1890s seedlings no longer had ideal places to grow. Finally, the loss of water supply through diversions and pumping made it impossible for cottonwoods and willows to germinate and grow except in isolated areas.

"Firewood has disappeared from above ground on the hills around the town, but the resourceful Mexican was still supplying his individual needs by digging for it."
F.R. Barr, 1940, describing Morenci in 1890.

"We came to a glorious forest of lofty pines, through which we have traveled ten miles. The country was beautifully undulating, and although we usually associate the idea of barrenness with the pine regions, it was not so in this instance; every foot being covered with the finest grass, and beautiful broad grassy vales extending in every direction. The forest was perfectly open and unencumbered with brush wood, so that the traveling was excellent." Edward Beale, 1858.

The same pattern can be seen in the Salt River Valley. The cottonwood forests along the Colorado River might have recovered if dams had not been built, and the river channelized, changing the conditions radically. With the establishment of the National Forests in the early 1900s, wood harvesting began to be regulated. One of the primary reasons for setting aside these lands was to protect the watersheds from excessive woodcutting, which had led to erosion and subsequent flooding and water quality problems downstream. In many areas more trees now are present than 100 years ago because of lowered demand for fuelwood as well as regulation.

Because of grazing and fire suppression more mesquite grows in grasslands in some areas than grew before 1850. Cutting of fuelwood did not have major long-term effects in such areas. In areas where cutting caused soil loss without recovery, the long-term impacts were severe, but no thorough study has yet been made of the extent of the impacts. It also is difficult to determine how much soil loss from harvested hillsides caused changes in the streams through increased sedimentation and soil erosion. In some areas this effect was undoubtedly important but difficult to separate from other impacts such as overgrazing. We will never know whether the floods that changed the Santa Cruz River in the 1890s would have caused less damage if the riparian vegetation had been intact to slow down the flow and hold the soil with extensive root systems.

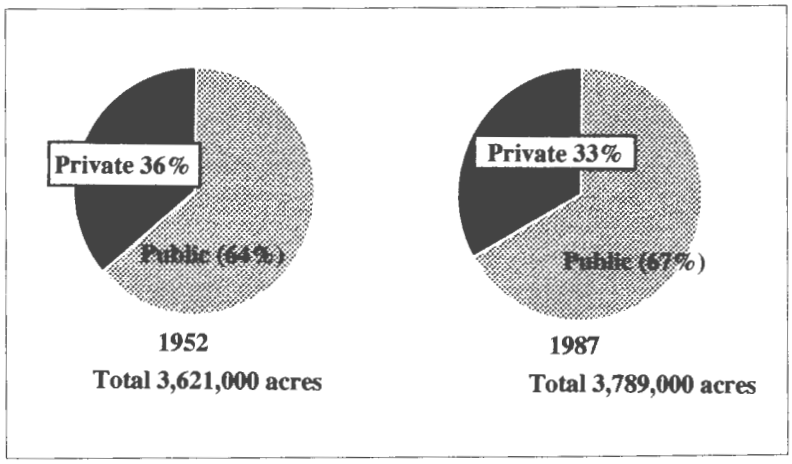
Growth of the Timber Industry

Though the wood resources of river valleys were already being exhausted by the early 1900s, the huge mountain forests had just begun to be harvested. In 1880 the area north of Prescott was still considered an unexplored wilderness. The Atlantic and Pacific Railroad (later the Atchison Topeka and the Santa Fe), still was many miles away.

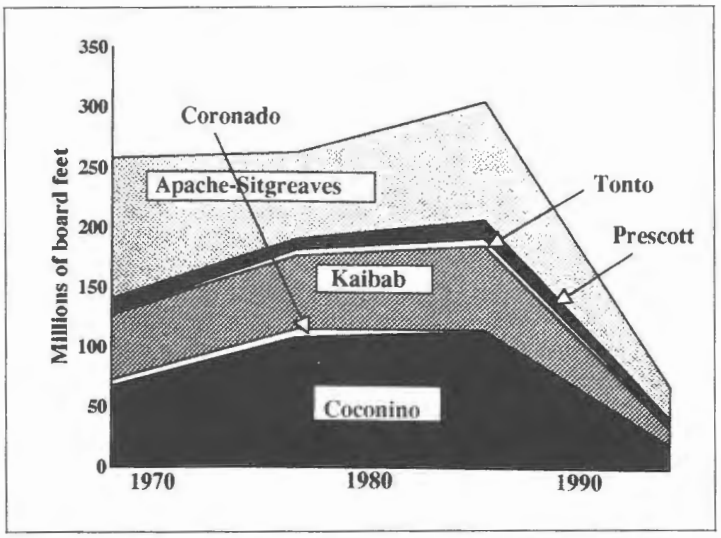
Edward Ayer, a businessman from Chicago, came into this wilderness hoping to build the first sawmill in the Arizona Territory. It was a reasonable dream—the forest of northern Arizona was described repeatedly as "the largest tract of virgin pine in the world." The only obstacle for Ayer was to bring in the machinery, still 45 miles to the east in Winslow where railroad construction had been temporarily stalled.

Ayer was determined to make the sawmill work. He invested $150,000 in the project, and despite the lack of transportation the task was completed in 1882. Later that year, when the railroad finally made it to Flagstaff (the town that sprang up around the sawmill) the tracks were being laid on railroad ties cut at the mill.

The Ayer Lumber Company, later the Arizona Lumber and Timber Company, was the most important industry in Flagstaff, and all of northern Arizona, for decades. In 1899, the mill



Arizona timber-producing land.



Timber harvest in Arizona national forests.

employed about 350 men and cut more than 35 million feet of lumber.

Despite its output, the demand for lumber in Arizona was still much greater than the Arizona Lumber and Timber Company could supply. Even with other sawmills opening, Arizona had to import most of its lumber in the nineteenth century. The sawmills of northern Arizona, however, grew to meet the demand. In 1907, the National Forests in Arizona were ranked fourth in the country for timber production. Most of it came from the Coconino National Forest, southeast of Flagstaff. In 1927 Arizona reported a record harvest for those days—169 million feet of lumber, more than 90 percent of it being processed by three lumber companies in northern Arizona.

Since that time, the timber industry in Arizona has diversified to include wood product manufacturing and paper mills. The industry's main effect on Arizona's rivers has been to change its vegetation. Other impacts include water quality issues (mainly from erosion of soils and sedimentation) and high water use. The wood products industry, especially paper mills, use a significant amount of water in processing.

Southwest Lumber became one of the largest corporations in the United States in the mid-1900s. It was listed as a Fortune 500 company, partly because of an exclusive contract to cut pulp trees on five national forests in Arizona and New Mexico. In the 1970s, a Southwest Lumber paper mill in Snowflake was using about 15,000 acre-feet of water annually.

For a good portion of the twentieth century, Arizona has been one of the leading timber producers in the nation. Between 1908 and 1983, the rate of timber cutting on national forests in Arizona was more than twice that of any other state. Even other forested western states that are known for producing a huge amount of timber, like Montana, were out-produced by Arizona until about 1950. Arizona was the most productive timber state in 1925 and 1933. Timber production declined rapidly starting in the 1980s.

Impacts

Nineteenth century travelers described the ponderosa pine forests of northern Arizona as open and park-like, with large trees widely spaced. Lush grasses provided good grazing for wildlife and later cattle. The same forests today tend to

Logging train in Northern Arizona about 1885.

be dominated by many small trees closely spaced. In one area, for example, where the number of trees in pre-settlement times was under 60 per acre, the present density is over 275 per acre. In another area the presettlement density was less than 25 trees per acre, while the current density is over 850 per acre. In such areas the number and variety of other plants is much less, leaving less browse and grass for wildlife.

The vegetation changes now favor species that feed in dense forests (such as the Abert squirrel) over those that feed in grasslands (pronghorn antelope and turkeys). Closely packed trees use more water, leaving less for streams. The reasons for these changes are complex, including overgrazing, fire suppression, logging, and road construction. The combination of all these factors has resulted in forests much different than those of 150 years ago.

Some methods of timber harvesting have more impacts on the rivers than others. Where strips of forest are left near rivers, the river will be less impacted. When trees are selectively harvested rather than "clear cut" less erosion is likely to occur. When replanting occurs immediately after harvest soil erosion is less. Most modern timber harvesting involves more careful methods than in the past.

The major impacts of timber harvest are mainly erosion from roads and clearcut areas, and loss of shade and habitat along rivers and streams.

"The 169,000,000 feet of lumber produced in Arizona last year, if laid end to end, would be sufficient to encircle the earth with enough left over to lay a two-plank board walk from Los Angeles to Boston, it is estimated." Arizona Republic 1928.

Big Scudder Camp, Northern Arizona 1912.

"The Patagonia Mountains are on fire and the country between the Patagonia and the Huachucas, a distance of twenty miles, is covered with smoke. The tall grass and the pine timber is burning furiously, the noise being like a rushing storm. The heat is so great that one cannot approach within a distance of it. ..." [sic] Arizona Daily Star, June 14, 1887.

Changing Attitudes Toward Fire

Some native peoples used fire to clear land for farming and to chase animals in the hunt. Mesquite was intentionally kept back by the use of fire, so that grasslands prevailed in parts of southern Arizona. These practices ended with conquest by the Americans, but natural fires were allowed to burn because the technology to stop them was not available until the 20th century. Many fires were set by lightning during the monsoon season and were eventually put out by rains. These fires served the purpose of clearing out fuels so that fires were seldom really devastating. Studies of tree rings have shown that fire is part of the natural cycle for most of the upper elevations in Arizona, and for some of the lower elevations. Big fires in some areas tended to occur about every 200 years, replacing stands of trees and opening up the forests for browsing animals. Fires were generally limited to an average of 3,000 acres in presettlement times, so forests were periodically renewed in relatively small patches.

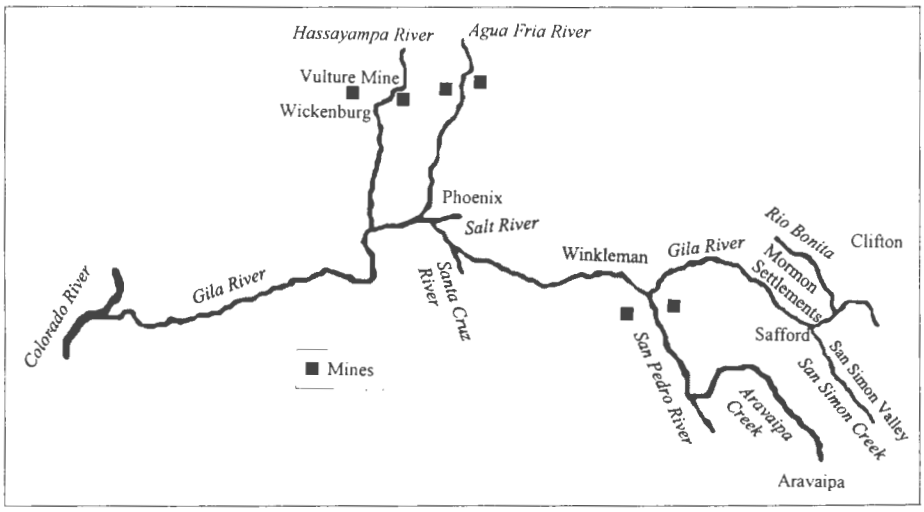
After the establishment of the National Forest system and the spread of homes and businesses into fire-prone areas, fires were felt to be harmful and were suppressed where possible, especially where property was threatened. After some 75 years of fire suppression, attitudes have again begun to change. In ponderosa pine forests where fire suppression has been practiced, the amount of fuel that has built up on the forest floor results in much more devastating fires when the fires finally come. Fires now reach 10,000 - 20,000 acres, a three to six-fold increase over presettlement times. Many fire experts fear that catastrophic fires are inevitable throughout much of Arizona s mountains unless preventive measures are taken to reduce the fuel load through clearing and prescribed burning.

The impacts of fire exclusion in the timber regions include the growth of too many small trees crowded so close together that large trees never develop; increased disease and insect problems; increased severity and potential of wildfire; decreased water availability, streamflow and recharge; and decreased quality of wildlife habitat and diversity. Where fires are very hot, the soil may be sterilized, making it very difficult for plants to grow.

Fire is not part of the natural cycle in the Sonoran Desert and cacti are not adapted to fire. The introduction of exotic grasses has increased fires in the desert with some devastating fires in the Tucson and Phoenix areas. When a dry summer follows a wet winter, the effects have been devastating, since the winter rains encourage a lush growth of grass to fuel the summer fires. Such fires have become common where discarded matches and cigarettes may easily ignite grasses growing along the roads.

FIVE TRIBUTARIES

Arizona's rivers have many tributaries, all with histories of their own. This chapter briefly describes five tributaries of the Gila River with very different histories. Ranching took place on all these rivers with varied impacts. In one, major erosion problems developed and in two ranching had little impact. Two have dams—one a successful dam and one resulting in Arizona's greatest dam disaster. Three have preserves and one has a successful restoration program.



Historic Sites along the Agua Fria River, the Hassayampa River, Aravaipa Creek, Rio Bonito and the San Simon Valley.

AGUA FRIA RIVER

Hohokam Settlement

The Agua Fria starts near Prescott and flows south to the Gila River, joining it west of the Phoenix area. Hohokam people lived along the Agua Fria, living much as the Hohokam did elsewhere in Arizona, farming with irrigated agriculture along floodplain terraces. Here the people used both rainfall collection methods and irrigation. With irrigation, two crops a year could usually be grown. Year-round occupation of the area ended earlier than it did farther south.

Archaeologists have looked at one village to see what impact the people had on their surroundings. Wood was one of their most important resources—for building homes, cooking, heating and cremating the dead. During the first few centuries a small number of people lived along the floodplain of the river and probably had little impact on the resources. In the eleventh century, the rainfall was above normal. Population increased and the irrigation systems were expanded. A travel distance of six to twelve miles would have been required to obtain food, game and wood. As long as the rainfall was plentiful, people were able to survive, but when drought came in the 13th century, there probably was not enough food and fuel for the expanded population and some people would have had to move or starve. If there were only one community, people could have traveled the long distances for wood, but other communities were also exploiting the same region and competed for available wood and other resources. The archaeologists conjectured that wood shortage was a severe problem for these people because wood gradually disappeared from housing, remains of burned material in fireplaces contained more small twigs than logs, and because burial gradually replaced cremation. We will probably never know how much climate change contributed to the demise of this early farming community, but resource depletion was an important factor.

Hydraulic mining along the Colorado River in 1877.

Hydraulic Mining

Five hundred years after the Hohokam left the Agua Fria, prospectors found gold on Humbug Creek, a tributary of the Agua Fria. They built a 35-foot high masonry dam, canals, tunnels and a siphon in 1890-91. In one of the few examples of hydraulic mining in Arizona, the company sprayed a stream of pressurized water at the creek's high gravel embankments, hoping to expose valuable gold. After initial success, the operation failed because of lack of water. They had not found much gold.

Waddell Dam and Lake Pleasant

When mineral resources were about exhausted, promoters expanded Salt River Valley agriculture into the area. Dams were considered important for storage. Four possible dam sites were located and canal lines were surveyed by 1892. Settlers and developers joined to form the Agua Fria Water and Land Company and plans for construction moved quickly. With no government assistance, the Company sought funds for private construction of the first dam, in spite of a severe national depression. By 1895 a diversion dam had been completed, but funding was lagging. After years of litigation and bankruptcy, funding was again found, land exchanges were made, and construction finally began in earnest in 1919. When the Waddell Dam was finished in 1927, it was the largest privately funded dam in Arizona and had an innovative but controversial design. Actress Gloria Swanson christened the dam with a bottle of Arizona grapefruit juice.

During and after construction, the state questioned the safety of the dams. Alterations were ordered by the State Engineer before the dam was even finished, but troubles were not over. Litigation over water rights proceeded for years as more than the normal flow of the river was allocated. In normal rainfall years no water was left for the river itself. Sixty years after completion of the dam, a major renovation was done. Lake Pleasant is now an important recreational lake for people from the Phoenix area and provides storage space for CAP water.

Impacts on the River

Hohokam settlement left little if any impact on the river the miners found in the 1800s. Mining on Humbug Creek also had little long term effect on the river, although the short-terms effects on Humbug Creek were great. Construction of the dam and water use for agriculture, however, have impacted today's river. Downstream of the dam, the Agua Fria River, which used to flow much of the time, is dry except in occasional heavy flood seasons. Upstream, the lake forms a very different environment from the historic ephemeral stream. Where the river traverses the Phoenix area, the river is totally changed.

Construction of Waddell Dam.

HASSAYAMPA RIVER

The Hassayampa River arises in the Bradshaw Mountains, nine miles south of Prescott, and extends south for approximately 100 miles toward its confluence with the Gila River. Along most of its route, the Hassayampa River is a dry streambed, but water comes to the surface a few miles north of Wickenburg in Box Canyon and again downstream at the Hassayampa Preserve. South of Wickenburg, the largest town on the Hassayampa River throughout history, the river spreads out into a large riparian area and at times a cienega. Below this, it is again a usually dry river all the way to the Gila River.

Walnut Grove Reservoir in 1887.

The Vulture Mine

The first significant Anglo-American contact with the Hassayampa River was in 1863. Three prospectors, including Henry Wickenburg, the town's namesake, arrived. Wickenburg and his two companions were prospecting several miles from the Hassayampa River when they hit a vein of gold-bearing quartz. The others didn't think it worthwhile, but Wickenburg decided to work the mine. According to legend, Wickenburg was walking around picking up nuggets of pure gold when the shadow of a vulture passed over him. The bird perched on a rock not far away from where the prospector would start his work. Thus the town of Wickenburg and the Vulture Mine were born.

Wickenburg was alone at the mine. He found water at the river to process the ore, which was crushed by an *arrastre*, a Spanish mill with heavy rollers turned on a beam to crush rock. Passing miners saw the extent of Wickenburg's discovery, and it was not long before others were building their own *arrastres* along the banks of the Hassayampa River, all buying ore from Wickenburg for $15 per ton.

The town of Wickenburg sprouted rapidly like many other Western boom towns. In early 1864, there were no homes in Wickenburg, and the population was seven. Within a year, more than forty mills had been built. By 1866, the town was one of the largest in the Territory, and lost out on being Arizona's capital by only two votes.

The banks of the Hassayampa River were crowded with homesteads, with farms irrigated from the river's water wherever an irrigation ditch could be dug. The large swamp that had existed below Wickenburg was a breeding ground for mosquitoes, and so malaria was a problem for early pioneers. The swamp was gradually replaced by Ramboz Ranch, with thousands of fruit

How the Hassayampa Got its Name. Four Explanations.

The name of the river which flows by the town [Wickenburg] was derived from an Indian name, variously spelled Aziamp, Hessiampa, Haviamp, and Ah-ha-Seyampa, in early accounts, and meaning gliding or smooth-running water.

One origin is that it is the Apache word for "The river that sees itself," from its characteristic of disappearing into the ground and coming to the surface at a point far below. Others say that the word is Apache for "the beautiful river."

"...the [Walker] party met a Pima Indian. They asked the Indian about gold and about the mountains at the head of the Creek. The Indian in his way of telling would say Hassayampa, Hassayampa, and would make motions with his hands as if to say 'Higher up! Higher up! So the party named the creek Hassayampa."

The most enduring explanation is "the river that flows upside-down."

and other trees. Farms up and down the river were, by the 1870s, producing peaches, strawberries, quince, pears, apples, potatoes, grapes, various vegetables, barley, corn, sorghum, wheat and beans. In 1888, the Buckeye Canal was built to further capture waters from the river. It was a simple sand dam raised in the riverbed, and could be reconstructed in a day, after a washout.

Farming and mining led to an increase in the demand for water around Wickenburg. The importance of water to the mines along the Hassayampa River prompted Wells Bates, in 1883, to ride to the Yavapai County Courthouse in Prescott and record a location notice claiming all of the water in the Hassayampa River for mining purposes. This led to founding of the Walnut Grove Water Storage Company, and the building of the Walnut Grove Dam.

The Walnut Grove Dam Disaster

Construction of the Walnut Grove Dam began in 1886 and continued until the fall of 1887. Problems with construction began immediately. Supervisors were fired frequently for various reasons, mainly because many had no engineering education. Work on the dam was hurried and focused on economy rather than sound construction. Before the dam was half completed, observers noted a bulge in the back wall and a foundation that may not have been sound. It was made of loose rock, lined with packed clay and supported on the downstream side by boards, with little cement.

"The fact is this disaster demonstrates, although with fearful results in the attendant loss of life, that Arizona has a sufficient rainfall to furnish an abundance of water for storage purposes. Future companies, if they are wise, will profit by the experience of the Walnut Grove Water Storage company and the faulty and defective construction of their dam, which caused its loss, can easily be remedied. Not only will another water storage enterprise be inaugurated in this section this season, but it is now pretty definitely stated that the Walnut Grove dam will be rebuilt." Arizona Journal Miner, March 3 1890.

Walnut Grove Dam after the collapse in 1890.

The dam soon filled up with water. The reservoir was 2.5 miles long and three-quarters of a mile wide and averaged 60 feet deep. Although the dam was leaky, the reservoir was a success for the miners and the community nearby. Sailboats drifted across the glassy water.

Because of the poor construction of the dam, though, the serenity of the Walnut Grove reservoir did not last. On Friday, February 21, 1890, heavy rains came. The *Arizona Journal-Miner* ran the headline "The Storm: An Unprecedented Downpour of Rain." Two prospectors reported having seen the water at the dam rising at eighteen inches an hour, even with both discharge pipes running full. Workers used dynamite to widen the spillway, but the rush of the water was so great that the channel next to the spillway began to wash out. Still, this did not relieve the pressure of the flood waters behind the dam. Thomas Brown, the dam superintendent who ordered the spillway to be widened watched helplessly as a solid wall of water three feet deep poured over the dam. He sent messengers out to warn people below the dam that he was certain of its breech. Unfortunately, one of the messengers was a notorious drunkard who stopped to warn a group of people at a tavern, but stayed to have a few drinks. The other messenger was too late.

Shortly after midnight on February 22, 1890, the dam collapsed. Billions of gallons of water that had been precariously held behind the

"Modern Wickenburg is proud of its healthful climate but early Wickenburg had quite another reputation. What some called 'Panama Fever' [malaria] in 1867 was very fatal and was said to have retarded the town s progress to some extent. For years afterwards it was called a sickly locality." Hawkins, 1971.

unstable structure swept down the Hassayampa River valley at twenty miles per hour. Witnesses described the front as a wave fifty feet high, seeming to glow in the darkness. The valley was swept clean of vegetation and most of the other life that had been there. One construction worker reported that before the flood there was a boulder weighing hundreds of tons in front of his tent. After the water receded, he went down the stream for four or five miles and found no trace of it. All the huge cottonwood trees that once lined the banks of the Hassayampa River were swept away, and farms were destroyed all the way to the Gila River. From there, the waters washed away ranches and many of the man-made diversion structures on the Gila River all the way to the Colorado River. Hundreds of fish, cattle, sheep and other animals were drowned.

Estimates of deaths range from 50 to over 130. Many bodies were found, but still many more were never accounted for. The Walnut Grove Dam collapse stands as Arizona's worst "natural" disaster.

The Vulture Mine's legacy was years of litigation, as many different interests tried to claim the rights to its gold. After all, it was worth fighting for—it produced over $15,000,000 in gold during its century of on-again, off-again production. It wasn't worth it to Henry Wickenburg, though. Wearied by the litigation and the loss of much of his property to the Walnut Grove Dam collapse, he trudged on to his eighty-eighth birthday in 1905. And at sunset on his eighty-eighth birthday, at the same spot on which he had first camped when he came to the banks of the Hassayampa, Henry Wickenburg was found dead, a pistol in his hand and a bullet in his brain.

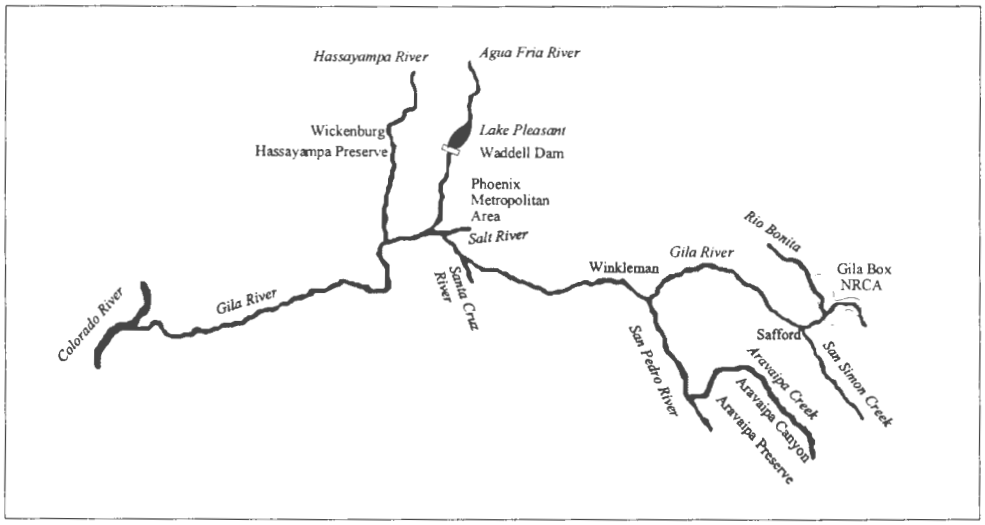
Hassayampa Preserve

The Nature Conservancy purchased the perennial section of the Hassayampa River near Wickenburg in 1986, and established the Hassayampa River Preserve. The preserve is dedicated to managing the riparian habitat, including cottonwood-willow forests, and its accompanying wildlife. Included in the preserve is a spring-fed oasis, Palm Lake, in which several endangered fish species survive.

Impacts on the River

The dam disaster had a lasting impact on the Hassayampa River by washing out the cottonwoods and other vegetation, and scouring the channel down to bedrock. The town of Seymour was flattened by the flood, and most of Wickenburg destroyed. Although many lives were lost, both communities were re-established.

Today, the Hassayampa River is much like it was when Henry Wickenburg first arrived. The channel is dry for most of its length, and is perennial in the short reach near Wickenburg. The water table has not declined significantly.



Twentieth Century Sites along the five tributaries.

ARAVAIPA CREEK

Aravaipa Creek is the San Pedro River's major tributary, flowing northwest to join the San Pedro River near Winkleman. The central portion of Aravaipa Creek runs through a beautiful canyon and is a popular hiking and birding area in central Arizona. Perennial flow in this part of the creek comes from a spring in the main channel. The river then goes underground before reemerging. A very large groundwater basin in volcanic rock supplies a steady flow of water to the river, and other springs add to the flow. A wide range of vegetation is found in the watershed. Aravaipa Creek has changed less than other southern Arizona watercourses.

Human Use of the Creek

Use of the creek goes back many thousands of years. In 1540 the Spaniards explored the area, but did not settle there. In the late 1700s Sobaipuris abandoned the San Pedro River to settle along the Santa Cruz. This left much of the basin open to unopposed Apache settlement and by the 1770s Apache farming had begun. Through most of the 19th century there was sporadic warfare between the Aravaipa Apaches and the Spanish and Mexican military.

After the Gadsden Purchase, American travelers explored the creek. Prospectors came in 1863 to mine silver and lead on a small scale. After the Aravaipa Apaches were sent to the San Carlos Reservation, homesteading and ranching began in earnest. A wagon road and telegraph line were finished by 1875. Settlers in the area ran cattle and angora goats and grew hay, fruit trees, vegetables, and other crops.

Clearing of land in the early days was an arduous chore, involving cutting the trees, pulling out the stumps, and leveling the land with a horse-drawn fresno. In some cases huge old mesquite stumps were left in the fields and crops were planted around them. Most of the early farms were fairly small by Arizona standards—from five to 40 acres.

After 1920 farm production increased, the size of farms grew, and well water often was used for irrigation. Aravaipa growers often won the prizes at the county fair. After 1960, however, many farmers moved out as a result of floods, and the number of

Aravaipa Canyon in 1996.

acres farmed were less than in 1880. Even at its peak, less than 500 total acres were farmed.

Most of the huge old walnut trees were harvested during the early twentieth century for fine lumber. Even the stumps were pulled out because they contained the best furniture wood. Local residents were angered that outsiders were damaging their area and finally succeeded in getting the activity regulated.

Floods on the Creek

The first settlers contended with floods as did all who followed. In the great flood of 1915, the creek jumped its banks and washed away several pieces of land. In 1923 a hurricane-like storm caused the biggest flood in 20 years, damaging orchards and carrying away cattle. None of the early floods, however, compared with the floods of 1963, 1977, and 1983.

In 1960, the perennial stretch of the creek remained pretty much as it had always been, with deep holes, sandy bottoms, and minimal downcut-

"When we first arrived at the ranch in 1920, Mother told us boys right off: 'Now whatever you do, when Dad and I go, this ranch should be preserved.' ... My brother and I spent six years trying to find someone who would buy and preserve our ranch, which is right next to what is now the Wilderness Area. ... In 1969, the Aravaipa Canyon was designated a Primitive Area, but I think when any piece of land becomes a Wilderness it becomes a little more secure. I worked to have it designated a Wilderness because I wanted to be positive before I leave this Earth that it would be preserved." Fred Wood, Aravaipa rancher, 1986.

ting in the channel. The floods of 1963 and 1977 were damaging, but the 1983 flood was devastating to farms and vegetation. Residents believed the changes were partly due to altered weather patterns and partly human-caused. The bulldozer allowed people to radically alter the creek, starting a chain of events. Removal of trees and channel straightening caused the water to move faster and create more damage downstream. Dikes were built for flood control and confined the creek to a narrower channel, cutting the channel deeper and increasing flood flows.

Aravaipa canyon has more than 50 non-native plant species, but has not been plagued with the most troublesome—saltcedar. This probably is because the undammed creek has not had its flow changed to favor saltcedar over native plants.

Preservation and Restoration

In 1971 the Arizona Nature Conservancy and others recognized the unique values of the creek and worked with local residents and the U.S. Bureau of Land Management to establish a preserve in the scenic perennial section of the creek. Part of the area is managed as a BLM Wilderness Area.

Aravaipa currently has seven native fish species, more than any other stream in Arizona, and virtually no exotic fish. This is largely because its conditions have not been altered to the detriment of the natives.

Only 50 permits per day are granted for visits to the perennial section to avoid damage to vegetation and the stream banks, and no commercial uses are allowed. Upstream and downstream of the preserve, most land owners continue to use the land carefully as in the past and some are working to restore the vegetation.

To restore the stream to its 1870 conditions, much more needs to be done than planting a few trees. Restoration would be multifaceted and include removal of exotic plants, introduction of beaver (sterilized at first until it is determined that beaver will not excessively damage the vegetation), and introduction of more native fish species.

Changes in the River

Use of the canyon by the Sobaipuris and later the Apaches probably had little lasting impact on the canyon. Even after the arrival of livestock, there was little change because of the small numbers. The most significant impact probably was the practice of using fire drives to clear land for agriculture and for hunting. The Indians also probably used water harvesting for their farms, with the use of small check dams. The creek normally flowed all the way to the San Pedro River.

Much greater impacts on the creek came during the mining and ranching period. People introduced angora goats, and about 100 species of exotic plants. They cleared land for farming and logged and cut walnut stumps for making fine furniture.

There was much less human impact in Aravaipa Creek than on most Arizona streams. The canyon is narrow and not suitable for paved roads or a railroad. Much of the canyon contains little arable land, so there was no impetus for groundwater pumping or surface water diversion. Storage dams were neither needed nor feasible. The ranchers of the area were committed to protecting Aravaipa. The major changes to the river appear to have come at a fairly late date and were related to attempts to control flooding.

SAN SIMON RIVER

The San Simon River flows from the Chiricahua Mountains north to the Gila River just east of Safford. Eighteenth century travelers and settlers described the area as a rich grassland, with numerous springs and marshes and often referred to the area as "Valle del Sauz" meaning "Willow Valley."

The valley was considered pretty much unoccupied in 1878, but some 750,000 acres of grazing land beckoned. The stream was intermittent, with "great water holes" that held water at all times. The stream had practically no banks and meandered through the valley from the upstream cienega.

Change Comes to the San Simon

Some cattlemen, driven out of Texas by severe drought, brought large herds of cattle to the San Simon Valley in the 1880s. After the 1889 roundup, the San Simon Cattle and Canal Company, one of many local cattle companies, shipped out 8,000 head of cattle. By 1895, even after three years of severe drought, about 50,000 head of cattle grazed in the San Simon Valley. Within a few years forage was so depleted that nearly all the ranchers had to reduce their herds, but much damage already had been done. Without vegetative cover, soil-laden waters rushed rapidly towards the Gila River.

"...we reached 'El Sauce' or the Willow Marsh, which seemed to be the basin where the waters collected from the adjoining mountains and slopes. Here was a great abundance of water, which, from the rushes that grew on its margin, I suppose to be permanent. Grass was also plenty here." John Bartlett, 1853.

In the mid-1880s some settlers near Solomonville became annoyed that after heavy rains the San Simon River washed down much sand and detritus. As a result, they excavated a small channel about four feet deep and 20 feet wide to discharge the flooding San Simon and its concentrated flow into the Gila. They also built funneling levees to direct the flow. They were cursed with success. By 1919 the small channel was 600 to 800 feet wide and 10 to 30 feet deep for about 60 miles. "Oh Liberty, how many crimes are committed in thy name!" said Frank Olmstead in his 1919 report to Congress on flood control on the Gila River. The channel continued to cut deeply into the formerly shallow river bed.

Dam on the San Simon.

Artesian basins were discovered in the late 1800s, assuring a plentiful supply of water. Many farmers settled in the area at that time. Many, however, were disappointed since little of the area was suitable for farming. Most left the area to become absentee ranchers.

In 1934 the U.S. Soil Conservation Service evaluated the condition of the area and found extreme erosion and almost total loss of the once-rich grasslands.

Reclamation of the Valley

Local residents and BLM agreed that something needed to be done to restore at least part of the valley's former lush grassland. During the 1930s the Civilian Conservation Corps and the Soil Conservation Service worked out projects. They built an

Will Barnes first came to the San Simon Valley in 1882 looking for a place to raise cattle. He found the area *"... a well watered, well grassed area. ... On its lower course were many beautiful grassy meadows spangled with flowers of every hue. Great cottonwood trees, the pioneer's best friend, and willow thickets lined its banks. In the widespread branches yellow and orange blackbirds, goldfinches and other birds of brilliant plumage made colorful pictures..."* He returned 15 years later *"...great herds of cattle were devastating the San Simon Valley. It was a mad race to get the grass first. ... No one sounded a word of warning; none could foresee the rapidity with which these glorious ranges would pass out of the picture, victims of man's carelessness and lack of understanding."* He returned again in 1934. *"Many of the old valuable grasses and forage plants were gone. The green meadows were replaced by wide expanses of drifting sand. Of running water, except during the summer rains when floods occurred, there was almost none. ..."* Will Barnes, 1956.

extensive system of earthen dikes, wing dams and rock-walled barriers throughout the valley.

When the first small dam showed signs of success, more were proposed. In 1953 the first major dam was built to retard the flow of the San Simon River and allow sediment to settle in the channel, to recreate the broad shallow floodplain of the past. About 50 years and additional erosion control structures were expected to be needed for full rehabilitation.

In 1980 BLM built the largest of the structures on the main channel. Eighteen other control structures have been built on the main channel and side channels. With volunteer help, BLM built wildlife enhancement projects near the newly reclaimed lands and water holes. Antelope were reintroduced in 1986—the first to be seen in the area for 100 years. Bighorn sheep also were transplanted. In 1988 the Arizona Republic reported success from the series of projects. Some arroyos had filled in as far as 12 miles upstream. In the 1960s efforts to reseed with grasses, mostly the non-native Lehmann's lovegrass, were partly successful.

The only opposition to the erosion control structures came from farmers along the Gila River, who believed the dams would capture too much of their water supply and reduce flows to Coolidge Dam, downstream on the Gila River. They went along with the projects, however, when BLM demonstrated that while some water might be held back, the benefits of sediment control would far outweigh the water loss. BLM estimated that 30 percent of the San Carlos Reservoir had been filled up with silt from the San Simon, even though only three percent of the reservoir's water came from the river. By halting further erosion in the San Simon Valley, the expected lifespan of Coolidge Dam could be extended, with little water loss.

Impacts on the River

Even today, after millions of dollars spent on highly successful restoration, the San Simon is very different than it was in 1850. Restoration efforts have restored some areas, making them attractive for wildlife. Non-native grass species predominate, however.

"We have quail at nearly every restored dam area, and the water catchments provide shelter to ducks and shorebirds. ... We have perhaps one of the biggest concentrations of raptors in the state here during the winter months. Mule deer come down from the mountains now and we've even seen a mountain lion run out when we set one of our brush-burning fires. .. .It's kind of neat seeing the land come back again. It really isn't a great deal of land restoration because it is confined to the bottom and backed up by the dams. But it is growing, and with the addition of the last of our planned dams, we should have at last a good handle on controlling the San Simon floods once more." Larry Humphrey of the Safford office of BLM, Arizona Republic, January 1988.

Arroyo Formation

In the final decades of the 19th century, arroyos suddenly appeared throughout the Southwest. Some of these arroyos were in rural areas such as along the Little Colorado and the Verde rivers, while others were in more urban areas such as Tucson. Arroyos also appeared in many areas within the neighboring states of New Mexico and Utah. They appeared over a period of about 20 years, with most forming from 1885 to 1900. Many arroyos formed suddenly during a single severe storm.

Overgrazing

To many people at the time, the causes were obvious. Overgrazing was blamed in most cases. During the 1880s rains throughout the state were above average, and the ranges could support large numbers of cattle. The arrival of the railroad provided easy transport of cattle from drought-stricken areas in Texas. Following the rainy years were several years of drought. Cattle starved by the thousands after eating what little vegetation was left, leaving the ranges bare and susceptible to erosion when rainy years returned. Farmers along the Little Colorado River in northern Arizona had no doubt that excessive numbers of cattle overgrazing the range caused arroyo cutting. Some writers in central Arizona also believed strongly that cattle were to blame.

Arizona Agricultural Extension Botanist Robert Forbes wrote about southern Arizona in 1905: "... excessive numbers of animals are put upon this free pasture, the profits are run up as quickly as possible while yet range remains free; and then, when the grass is gone, when the plains and hillsides are converted into gullied barrens, and oftentimes, when the profits of the first years are canceled by the losses of later ones, the nation's ruined estate is abandoned to the tender mercies of the next and more ruthless occupant who may still find something convertible thereon. The effect of this unregulated and destructive tenure varies greatly with those conditions of soil, topography, rainfall, heat and frost which affect the endurance of a grazing country."

"Arroyo"—a gully with steep or vertical sides, through a valley floor that has cohesive fine sediments.

"'The next morning ... I began to ascend the bank of the stream to explore ... the first day we were fatigued with the difficulty of getting through the high grass which covered the heavily timbered bottom.' [quoting Pattie, 1825] If Pattie could only see it now! The same West Fork ... is now within a brief one hundred years a boulder-strewn stream, where countless cattle have lived and wandered and died since the white man first brought his herds of domestic cattle, in the early eighties. There is now scarcely a vestige of grass for miles ... and even the cottonwoods and willows have been eaten off or trampled under foot by the constantly moving cattle. The innumerable canyons and arroyos which are tributary to the west Fork of the Gila are deeply scoured by flood waters due to the grazing off of the adjacent hillsides." Fred Winn, 1926.

Other Human Activities

In the Tucson area, a very different cause of the arroyos was obvious to contemporary observers. In the Great Tucson Flood of 1890, the Santa Cruz River changed within a few days from a shallow narrow stream to a roaring river with deeply cut banks. The Hughes ditch, built to divert water to fields, played a major role in starting the downcutting, as people at the time recognized.

Two scholars who looked at the Santa Cruz River in great detail in the 1980s, came to the conclusion that a combination of human activities resulted in arroyo formation in the Santa Cruz River. Irrigation ditches, in their opinion, played

a major role in starting the downcutting after a period of dry years had set the stage for devastating floods in 1890.

They concluded: "In summary, catastrophic erosion failed to occur for at least 200 years prior to 1890, even though the floodplain in the area of San Xavier and Tucson had been heavily cultivated and grazed. On the Santa Cruz River, poorly-engineered dams and ditches concentrated floodflows, which were apparently of large magnitude and certainly of long duration, to initiate arroyos."

There were other explanations. Wagon roads became well-worn ruts which were lower than the surrounding lands and became easy channels for movement of water, developing into arroyos during major storms. Railroad embankments directed water to low spots which then turned into arroyos during storms. Woodcutting removed vegetation holding the soil in place, and the banks of streams suddenly collapsed during heavy flows. All of these explanations involve human activities and interpret arroyo cutting as an unusual phenomenon.

Climate Change

More recently, scholars have questioned those simple explanations. They pointed to earlier instances of arroyo cutting long before cattle arrived in the Southwest. Cycles of downcutting and filling up of streams have occurred many times in the past, as can be seen when new downcutting reveals the evidence of past human occupation. In some places several different episodes of filling and cutting can be traced. While scholars cannot explain why there are such cycles,

"When I was a boy, there were no river banks. I remember the time the banks were washed out. It isn't very long that the present channel has been here. Mr. Hughes used to own a small piece of land where the Deaf and Blind School is now and he dug a channel about 5 or 6 feet wide and when the floods came along the waterfall began to cut away the land greatly, clear back to San Xavier. This lowered the water level all over the whole valley. Much of the land that is now dry had water before this." Leon Betancourt talking about the Santa Cruz River in Tucson in 1891.

"Sinkhole" at San Xavier.

they believe that climate change must have played a role in these earlier instances. They consider that stages of arroyo cutting and filling are natural geological processes occurring through the millennia and that the recent arroyo cutting should be viewed in this context.

Kirk Bryan was an advocate of this viewpoint back in the 1920s. "So far as the cause of the arroyo cutting which began after the year 1800 is concerned, the dates set forth in the table are conclusive that arroyos similar to and even larger than the recent arroyos were cut in past time. As these ancient episodes of erosion antedate the introduction of grazing animals, they must be independent of that cause. Each interval of erosion apparently occurred synchronously over the Southwest. ... They must be due to a general cause, such as successive fluctuations in climate by which the streams cut down and formed arroyos in dry periods and built up their channels and filled their valleys in wet ones. ..."

Summary

Later scholars questioned this viewpoint. While they agreed that there were arroyos in former times, they pointed out that there is no evidence of climate change in the late 19th century and that alternate periods of drought and heavy rain are normal fluctuations in the Southwest. That arroyos cut in dry periods and fill in wet ones also was questioned, as the most recent cycle occurred in a short time when a wet period immediately followed a dry one. They also point out that arroyo cutting did not happen everywhere at exactly the same time, but tended to occur in areas where human activity was heavy. Some scholars believe that some former cycles of arroyo cutting could easily have been related to human activity, such as Anasazi occupation.

The debate continues to this day, in an attempt to explain the many different cases of arroyo cutting. The preponderance of opinion at this time is in favor of attributing the 19th century arroyo cutting largely to human activities combined with weather conditions. Conrad Bahre in 1991 listed fourteen writers who believe human activities were largely responsible, four who support a combination of human activities and climate change, and two who favor climate change alone.

"The great flood 4 years ago caused the [Verde] river to leave its channel in many places cutting a new one, washing off the surface soil to the depth of from 10 to 20 feet exposing to the astonished beholder former Irrigating canals in perfect state of preservation. In one place in particular the surface Soil was washed away to the depth of 10 feet. ..." Verde Valley Pioneer, 1954.

Common to most of these explanations is the loss of vegetative cover due to grazing, wagon roads, woodcutting, railroad construction, irrigation ditches and other human activities—or prolonged drought. Prolonged drought puts heavy stress on vegetation and animals which depend on the vegetation. Where several of these factors prevailed, arroyo cutting became almost inevitable when heavy rains arrived, as they were sure to in the Southwest.

ON THE PUERCO RIVER, ARIZONA

AS BEALE SAW IT IN 1857:

"On arriving at the banks of this river, we found no difficulty in getting down without locking a wheel."

80 YEARS LATER—THE PLACE BEALE DESCRIBED:

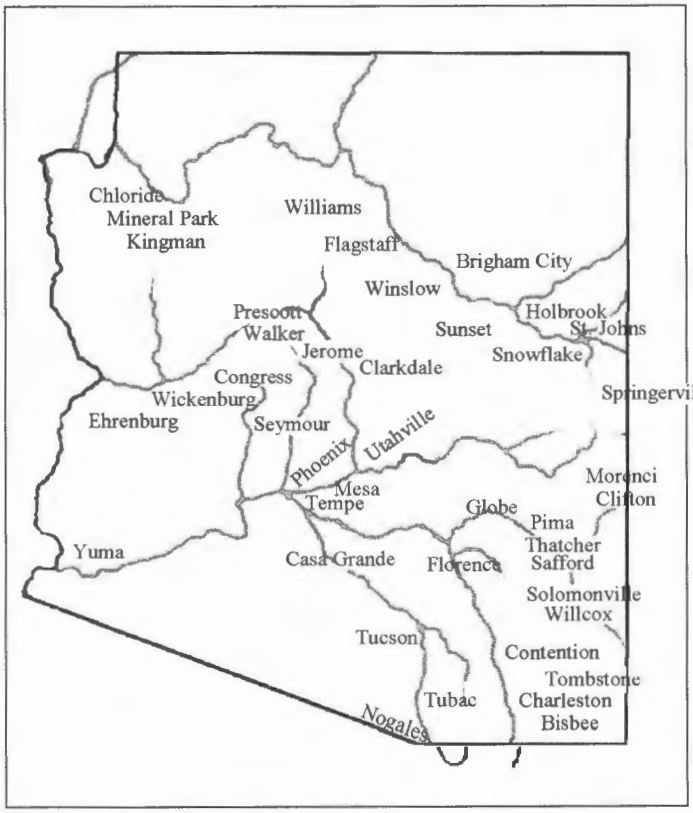
"Thundering walls of soil are dumped into the Rio Puerco with each flood of water. Once a small stream that could easily be crossed, the Rio Puerco has become a barrier cutting the country like a knife. When the grass was gone, the water carried away the soil. Each year more soil is lost. (Note the figure, upper left.)"

GROWTH OF TOWNS

The Earliest Towns

Before the twentieth century, almost all towns were established near rivers or springs which provided dependable sources of water for drinking and agriculture. The earliest towns were Hohokam, Sinagua and Anasazi settlements that had disappeared by the time the Spaniards arrived. Short-lived Spanish settlements were established along the Colorado River and in northern Arizona, but the ones that grew into modern towns were along the Santa Cruz River. Tubac is Arizona's oldest town, but Arizona's oldest existing large town is Tucson. The Spanish founded Tucson in 1775, and it has been continually inhabited since that time (and long before by the Hohokam). Tucson remained a very small outpost of Pimeria Alta until after the Civil War.

Water wagon serving Globe residents about 1904.



Towns of more than 100 people in 1890.

Defeat of the Indians after the Civil War opened up the territory to rapid development of towns. Mining often was the initial impetus, and towns sprang up almost overnight when ore was discovered. Most of these town were short-lived, lasting until the ores were mined out. Towns such as Bisbee, San Manuel, Morenci and Globe, however, became modern mining towns. Others such as Tombstone became resort or tourist towns. At least 200 once flourishing Arizona towns servicing mines, railroads or steamboats are now ghost towns or submerged under lakes. These towns were near water sources: major rivers, streams or springs. They all had short-term impacts on watercourses, as short-lived as the towns themselves.

In the Salt River Valley agriculture was the impetus for towns to develop, as it had been for the Hohokam. Yuma developed because of a major Colorado River crossing. Its importance as an agricultural center grew, once dams provided

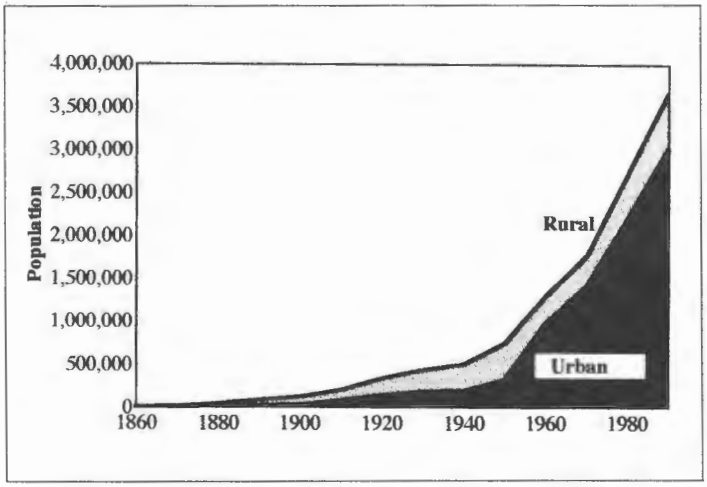
a dependable agricultural water supply. Flagstaff and Casa Grande were two of the few Arizona towns that developed because of the railroad or lumber production, despite limited surface water supplies.

Twentieth Century Cities

Towns generally grew slowly but steadily in Arizona until World War II. The evaporative cooler, invented in the 1930s, made life in the desert more appealing. Military training and aircraft construction brought many people to the Phoenix and Tucson areas. Many stayed or returned after the war, triggering a boom in construction. Urban populations grew much faster than rural populations. An increased demand for water resulted. During the last half of the twentieth century new water uses developed, hardly known before that time. Swimming pools, golf courses, lawns and other uses put heavy demands on the water supplies. The Salt River Project supplied much of the demand in the Phoenix area with surface water supplies, but groundwater pumping also was necessary. In the Tucson area, groundwater pumping dried up the flow of the Santa Cruz River. Where subdivisions replaced farmland in the Salt River Valley water use remained the same since farms and suburbs use roughly the same amount water. When suburbs replaced desert, however, water demand often increased.

Arizona counties in 1990.

Urban areas in outlying counties also grew during this period, but to a lesser degree. Some communities such as Show Low and Sedona flourished as vacation spots for urban dwellers.



Urban and rural population.

Impacts of Urbanization

Early towns had a somewhat different impact on rivers than those of the twentieth century. Gathering of wood in the nineteenth century for heating, cooking and many other uses often led to deforested surroundings. Water for household use and farming was taken directly from the rivers and springs. In some cases, digging of ditches resulted in major changes to the river, such as occurred in Tucson's Santa Cruz River.

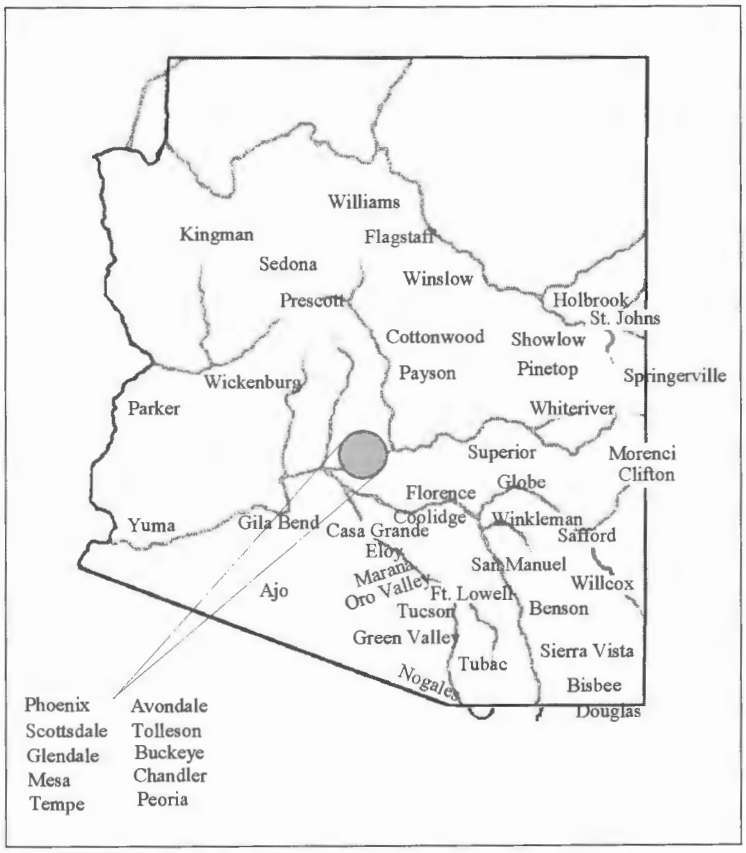
After groundwater pumping became economical in the twentieth century, lowering of the water table further impacted the rivers. The

burgeoning towns began to demand regulation of water supplies along the Salt, Gila and Colorado rivers for flood control and water supply.

How specific cities impacted certain rivers is discussed in more detail in the chapters devoted to individual rivers. Some impacts common to all Arizona cities are:

- Sand and gravel mining, often in river beds, to provide construction materials.
- Disposal of trash in riverbeds.
- Disposal of wastewater in the rivers.
- Depletion of water supplies, with effects on rivers.
- Increased amount of land under impervious surfaces—streets, parking lots, buildings—causing sudden large flows to rivers.
- Building of flood control structures that change the structure of rivers.
- Increased demand for recreational facilities, often along rivers in rural areas.
- Increased use of the floodplain for homes and businesses.
- Loss of wildlife habitat and corridors.

Rural towns experience many of the same impacts but on a lesser scale. The seasonal influx of tourists often brings important income to those areas, but also strains the resources.



Towns of more than 2,000 people in 1990.

The 1983 flood Tucson eroded the banks of the Rillito River.

Floods and Flood Control

Short-term and long-term weather changes cause river levels to fluctuate between high-water and low-water stages. Fast flowing water deposits sediment in locations where water is slow moving, forming new beaches. Rivers also tend to meander and change courses. Some banks erode away while others form.

Native plants and wildlife adapt to such changes, and in many cases even depend on them. The first farmers took advantage of the spring floods to grow crops along the Colorado River and elsewhere. Sometimes they could not get a crop because of too much or too little water, but in most years farming was good because floods enriched the soil.

In the late nineteenth century, attitudes towards flooding changed and new technologies were developed. Arizonans sought ways to control floods to stabilize water supply and protect land. Erosion control became important when homes were built on erosion-prone land. The major techniques are:

Ditches - to divert water from a particular place.

Dams - to hold water back for later release.

Channelization - to straighten a river, usually with cement, and solidify the channel, so water will quickly flow downstream and not flood or erode a particular area. Soil cement, used in channelization, made of cement mixed with soil from the river and is more natural looking than cement.

Rip-rap and gabions - to channelize rivers, but with a more natural appearance.

Bridge protection - to protect a bridge around its supports to prevent erosion, especially if the bridge is built partly in the floodplain. Protection starting at a bridge structure often extends along the channel.

Retention structures - to slow water flow for gradual release to reduce flood peaks.

Floodplain ordinances - to discourage people from building in the floodplains, so that artificial methods to protect floodplains will not be needed.

"What you have here in Tempe is a river that is changing its regime. It's going from a wide braided river to a narrow meandering river, banging around on its way. It's a river in transition, and transitions in nature are always messy ... you can't force a river to do anything, you try to find out what the river wants to do." George Cotton, engineer. Tribune Newspapers, April 26, 1993.

Land purchase - to set aside portions of a river as parkland where waters can flow normally, reducing downstream flooding .

Impacts of Flood Control Projects

While creating more useable land, flood control projects also cause problems. Methods that move flowing water more quickly downstream often result in downstream hazards. A flood control project installed in a river section often necessitates treatment of adjacent sections.

Most forms of flood control make major changes to the structure of a river and the type of vegetation and wildlife habitat it supports. Cement channelization completely changes the river, while the less extreme measures may preserve some features. Floodplain ordinances and land purchase may maintain a river in a more natural setting.

Every urban area in Arizona relies on flood control projects to some degree. In the Tucson area, for example, all of the above techniques are used. Most of the Santa Cruz and Rillito rivers are soil cemented through Tucson, but land purchase and ordinances also are used effectively.

"Flood" applies to waters that flow outside the banks of the river. **"Floodplain"** means the area near the river where water will flow at times. In practice, Arizonans use "flood" when there is a large amount of water in the river, whether or not it goes beyond its normal boundaries. In wetter regions, water in the river is considered normal.

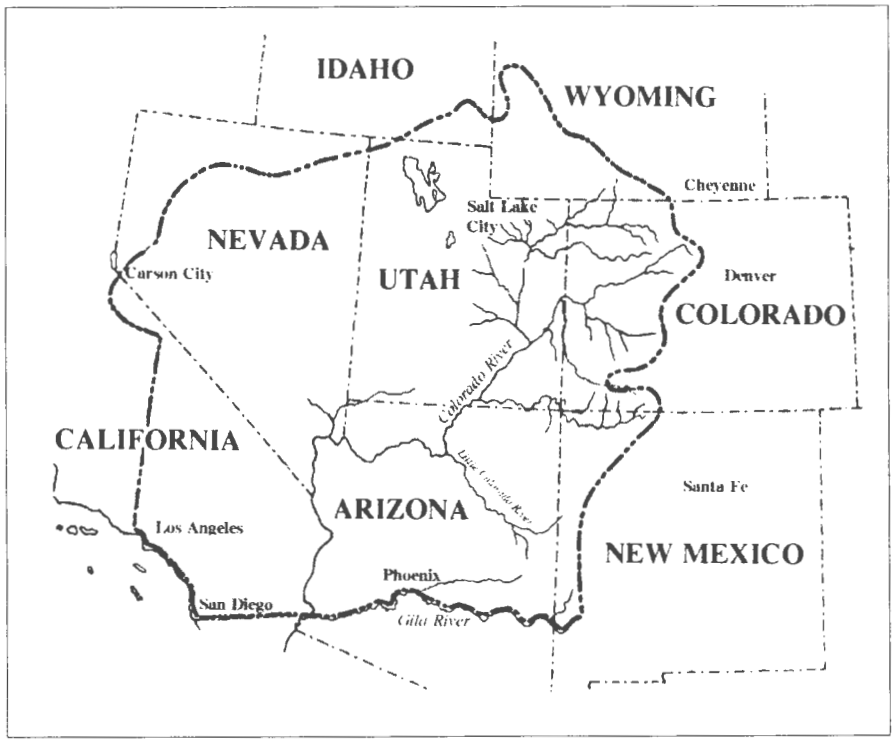
Mormon Settlement

The Mormons (Church of the Latter Day Saints) played a significant role in the settlement of Arizona, especially in the Little Colorado River basin, portions of the Salt and Gila rivers, and farther south along the San Pedro River. Their style of immigration and settlement was unlike that of any other group, and their influence on rivers was an important one.

From the middle of the nineteenth century to the beginning of the twentieth century, missionaries traveled throughout the world seeking converts, many of whom came to the West to establish farming communities. While most other missionaries preferred to convert people who would remain in their own countries, the Mormons actively sought immigrants to the United States. Under the sponsorship of the Mormon Church, more than 100,000 immigrants came from Europe in the nineteenth century. The leadership in Salt Lake City wanted to establish a Mormon state called Deseret, which would extend from Idaho east to South Dakota, west to California and south into Sonora.

Jacob Hamblin explored much of northern Arizona as well as parts of Utah, Nevada and California. When opening up new routes for Mormon settlement, he took great pains to establish good relationships with the various Indian tribes.

The Mormons were well organized and founded largely self-sufficient agricultural communities in fertile river valleys. These communities were located close enough for easy communication and travel. People starting a new community usually would come supplied with farm equipment, seeds, construction tools and other materials necessary for a complete village. People worked together to develop irrigation systems, at times building dams and ditches collectively.



The proposed State of Deseret.

Mormons Settle Arizona

Southeastern Utah had many small communities, some of which were located along the Virgin River (a tributary of the Colorado River). From these communities, settlers spread southeast to the Little Colorado River Valley and south along the Colorado River, founding such towns as Las Vegas and Callville, along routes pioneered by Hamblin. Dreams of expanded settlements to an ocean port, however, never materialized.

"It must be acknowledged that the Mormons were wilderness breakers of high quality. They not only broke it but they kept it broken; and instead of the gin mill and the gambling hell, as cornerstones of their progress and as examples to the natives of the white man's superiority, they planted orchards, gardens, farms, schoolhouses and peaceful homes. ... A people who have accomplished so much that is good, who have endured danger, privation and sufferings more than abuse, they deserve admiration." F.S. Dellenbaugh, 1908.

Near the Arizona-Utah border, an old ford originally used by the Paiutes to cross the Colorado River served as the first Mormon approach to Arizona. Called "Vado de los Padres" or "Ford of the Priests," the crossing also had been used by the 1776 Escalante-Dominguez expedition. It could, however, only be used about half the year, because water levels were too high during spring runoff. Also, the northern approach to the ford, which was by natural steps down precipices, was unsuitable for wagons.

Another downstream crossing, at the mouth of the Paria River, proved more useable. At that site, a tiny Mormon settlement, which became known as Lee's Ferry, was the major Colorado River crossing for many miles along the river. Other crossings were set up near the present site of Lake Mead. To make communication easier among the Mormon communities, an attempt was made to establish towns along a route from Salt Lake City to Sonora, with settlements at a convenient day's journey apart. Many of these settlements proved to be infeasible and were abandoned, but many such as St. Joseph and St. David have remained to this day, especially near the most reliable rivers.

These communities depended on irrigation from rivers. They often had communal irrigation systems with shared water rights. In the early years, the settlers often lacked the experience and funds to build lasting dams under Arizona conditions and dam collapses were common. Cooperative efforts often led to thriving agricultural communities when water conditions were right. Where water problems prevailed, the communities generally failed in spite of arduous efforts.

The dam at Joseph City washed out twelve times.

GILA RIVER

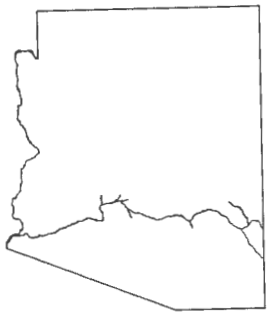
Because the Gila River crosses the state from east to west it was very important as a travel corridor. Many people traveled along the lower Gila River on their way California in the nineteenth century, starting with the 1849 Gold Rush. It has been the source of irrigated agriculture for over two thousand years. Today much of Arizona's commercial agriculture depends on the Gila River.

The River

The Gila River gathers waters from most of Arizona's rivers—the Santa Cruz, San Pedro, Salt and many other rivers. It is one of the longest rivers in Arizona, stretching some 600 miles across Arizona, from its two sources in the Mogollon Mountains in western New Mexico to its confluence with the Colorado River in western Arizona. It is Arizona's largest watershed, covering over half the state's total land area, excluding only the Little Colorado basin in the northeast, the Bill Williams River and a few small drainages along the Mexican border and in northern Arizona.

Early Indian Settlement

Although a few humans may have reached the Gila River earlier than 12,000 years ago, real occupation of the area began after 10,000 B.C. The life of the early pre-historic Indians was tied to water from the river and its tributaries. Early inhabitants were dependent on surface water and could not travel more than a few days from dependable water. Food-gathering and hunting were the mainstays of life. Because some resources were only available seasonally and over wide ranges, the early human inhabitants moved from camp to camp in search of water and food.



About 300 B.C., the Mogollon people began to settle in the narrow canyons along the Upper Gila River and its tributaries. Perennial flows in this area supported a variety of agricultural activities. Corn was grown in the Gila River watershed and later in the more arid lowlands. The Mogollon gradually settled in permanent sites using irrigated agriculture and runoff farming and built contour terraces on slopes and checkdams along upper drainages. Mogollon communities continued to grow and then declined by the mid-twelfth century.

The Hohokam inhabited the central part of he Gila River Basin and began to form community groups beginning before 800 A.D. Communities were located along the mainstem of the Gila River. By the mid-eleventh century more than 250 communities were in the watershed.

One large Hohokam population center was Snaketown, at the confluence of the Salt and Gila rivers. Another large community, Casa Grande, was on the south bank of the river near present-day Coolidge. Here, the Gila flowed perennially, except in drought years. One main canal diverted water from the river, and a series of irrigation ca-

> *"... a beautiful mountain stream about thirty feet wide and one foot deep on the shallows, with clear water and pebbly bed fringed with trees and hemmed in by mountains, the bottom not more than a mile wide. The signs of beaver, the bear, the deer, the turkey, besides the tracks of herds of Indian horses, were plain to be seen in the sand."* Abraham Johnston, describing the Gila River in 1848.

"... all its inhabitants are fisherman, and many have nets and other tackle with which they fish all year, sustaining themselves with the abundant fish and with their maize, beans, and calabashes. ..." Father Eusebio Kino, describing Pima Villages in 1699.

nals brought water to the fields. Where surface flows were scarce, the flow of washes was channeled into alluvial areas and hillside terraces. Probably most, if not all, of the summer flow of the river was diverted at the peak of Hohokam settlement.

A drought at the end of the thirteenth century caused a shift in Hohokam population. Some people who lived along the smaller tributaries moved to the mainstem of the Gila River. Here the Hohokam thrived until the mid to late fifteenth century.

The Spanish-Mexican Period

When the Spaniards arrived, they found the ruins of the Hohokam and Mogollon people, with Pimas and Maricopas living along the Gila River, probably descendants of the Hohokam. Fray Marcos de Niza led the first exploration in 1539 and crossed the headwaters of the Gila River on his way to New Mexico. He was followed by Francisco Vasquez de Coronado who also crossed the Gila River after coming up through the San Pedro River Valley. A member of Coronado's party described the Gila River as a "deep and reedy stream." No settlements or presidios were established during this period along the Gila River.

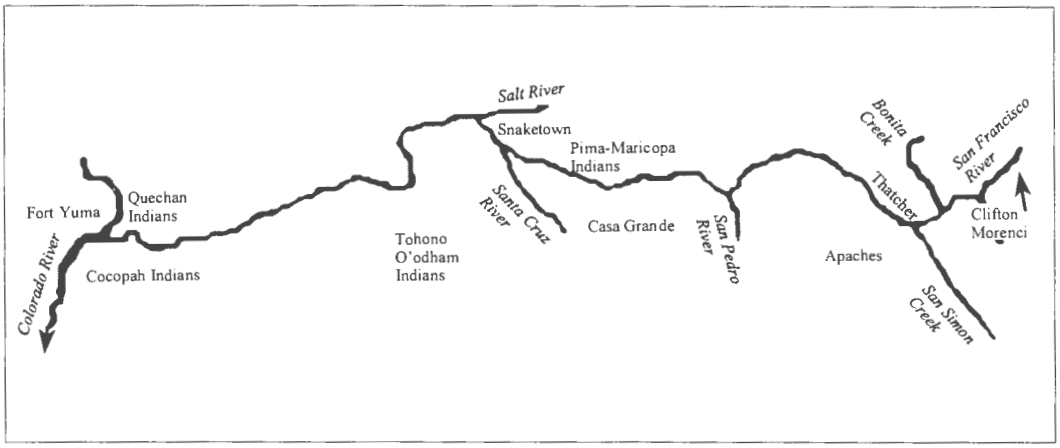
The early explorers were followed more than a century later by Father Eusebio Kino who traveled extensively along three-fourths of the Gila River between 1691 and 1702. He reported seeing irrigated crops and an abundance of fish in the river. Other missionaries noted that Pima Indians raised many crops along the river and on "an island" in the river near Casa Grande. Although he established no missions along the Gila River, Kino's influence was widespread. He brought cattle, seeds, and other items. Until Kino introduced wheat, Arizona Indians did not have any crops suitable for cultivation in the winter. The Pima Indians quickly began to cultivate wheat, and grew as much as 220,000 pounds of wheat in 1859, farming about 15,000 acres along the Gila River and provided food for the military, explorers and other Indians in the territory,

The Apaches moved into the upper reaches of the watershed and controlled much of the area in the seventeenth century. They relied primarily on raids for cattle, horses, wheat, and other foods, but did some floodplain farming.

Anglo-American Explorers

In 1825 the Patties are were among the first Americans to enter the area, trapping beaver. Beaver were plentiful. Pattie noted of the river he called the Helay, that "At this point we commenced setting our traps. The river here was beautiful, running between banks covered with tall cottonwoods and willows." He also found other wildlife, such as otters, turkeys, antelope, mountain lions, and javelinas.

Pattie noticed how the river changed near the Safford valley. Instead of steep canyons, "We



Historic sites along the Gila River.

"Leaving behind these Pima settlements and trekking down stream we came upon broad savannas of reed grass and clumps of willow and a beautiful spring with good land for pasture. ... Passing on down river another five or six leagues and keeping it always in view with its willows and cottonwoods, we came to its confluence with the Rio de la Asuncion [Salt]. ... A very pleasant country surrounds this fork of the rivers. Here the eye is regaled with creeks, marshes, fields of reed grass and an abundant growth of alders [sic, willows] and cottonwood." Sedelmayr 1744

found the river skirted with very wide bottoms, thickset with the mosquito [sic] trees. Willow, cottonwoods, and other trees lined the river." Here he trapped a rare Arizona river otter.

Pattie was one of the first Anglos to "navigate" the Gila River. Below the Salt, he described the river as "about 200 yards wide, with heavily timbered bottoms." He finished the last part of his journey on the Gila in a "canoe" he built with the help of his companions as the river was too deep to cross by horseback. At another point, under attack by Indians, "We made rafts to which we tied our guns, and pushing them onward before us, we thus swam the river." The Patties trapped beaver the entire length of the Gila, sometimes trapping as many as 60 in one morning. Pattie described the river near the Salt River as "remarkably circuitous, and has a great number of islands, on which we took beavers."

"We cut down two trees suitable for canoes, and accomplished these important objects in one day. ... On the morning of the fourth we commenced digging out our canoes, and finished and launched two. ... We continued to prepare, and launch them, until we had eight in the water. ... We started on the 9th, floating with the current, which bore us downward at the rate of four miles per hour. ... We now floated pleasantly downward at our leisure, having the abundance of the meat of fat beavers." James Pattie, 1828

In 1846, Stephen Watts Kearny led a battalion of men during the Mexico-U.S. War to survey the area, and they mapped the entire river. Lt. Emory, the expedition's official diarist, estimated the flow of the river as about half of that of the Colorado River. He also noted many fish in the river, including some that weighed between 25 and 30 pounds. They noted large-scale irrigation by the Indians through surface water diversions.

After 1846, the "Gila Trail" was well known as a route for travelers across Arizona. During the California Gold Rush of 1849, as many as 60,000 emigrants crossed through Arizona using this trail. The 49ers traded with the Maricopa and Pima Indians along the Gila River. As one traveler observed, the river was a "deep, narrow, and rapid stream of warm muddy water, with the banks covered with a dense growth of wild willow and weeds, tall cottonwoods. ... A dam has been constructed and by small canals the water is conveyed over the bottoms and thrown into the fields." In 1854, another explorer noted that the Pima Indians had diverted the entire flow for irrigation west of the confluence with the Salt. The river upstream from these diversions was again described as flowing between "steep banks 15 feet high and completely overhung with willows and cottonwoods."

These early explorers were followed by surveyors, the military and many others. John Bartlett traversed the area in 1852 and found the Gila River dry in some areas. He and his men were able to find water from four to six feet below the surface by digging two wells. He established the

"The Pima are large and fine-looking, seem well fed, ride good horses, and are variously clothed, though many have only center cloth. They have an extraordinary length and luxuriance of hair. With their large white cotton blankets and streaming hair, they present, when mounted, quite a fine figure. But innocence and cheerfulness are their most distinctive characteristics." Indians sold wheat, corn, flour, and other staples. "The camp is full of Indians of all sorts and a great many have flour, corn, beans, or some eatable to trade. ... They have watermelons for sale. For the last hundred miles all vegetation is green. There are at least two thousand people in camp, all enjoying themselves very much." Philip St. George Cooke, 1846.

"... the water was clear and palatable, flowing with a moderate current over an alternating bed of sand, pebbles, and rock. The stream was, in July, about twenty feet wide and twelve inches deep. Its banks were fringed throughout with cotton-wood and willow thickets, with mesquite at the base of the terraces. Below the gorge ... the valley opens out in a broad plain, increasing in widths the Pima villages are approached." J.G. Parke, describing the area where the San Pedro meets the Gil in 1855.

confluence of the Salt and Gila rivers as the centerpoint of his Arizona survey.

Other travelers commented on the Gila River. In 1854, James G. Bell, who was driving a large herd of cattle across Arizona, reported the existence of the "Gila Lagoons," located about three miles from the Gila River, which he described as "good cool water." (He bathed in the waters, a treat in the desert of the 1850s). Later, John Audubon reported "a great many lagoons, nearly all muddy," varying in salt content, with its quality ranging from drinkable to nondrinkable. In some places it was "a cake of pure salt."

All the early explorers believed the river to be perennial, although in some places the flow briefly disappeared, such as the area downstream from the Pima and Maricopa irrigation fields.

Mining

While the Indians and the Spaniard probably did some gold and silver mining near the Gila River, mining increased as technology improved in the nineteenth century. Silver mining began in 1859 in the headwaters area. However, it wasn't until the end of the Civil War that miners in search of gold, silver, and copper moved in great numbers to the Gila River. By 1900, three major mines operated in the Clifton-Morenci area, along the San Francisco River, a headwater stream.

The major effects of mining on the Gila River, particularly the upper region, were diversions of water, water pollution, use of trees for construction and fuel, and changes in stream channels. Many of the areas around mines were stripped of all wood. The local mines burned a cord of wood for each 5.6 tons of ore mined and milled. Miles of mesquite thickets in the lower Gila were cut and turned into charcoal in 1876 alone. Erosion increased as trees were cut and pack animals made trails in the forests.

The San Carlos Reservation

The first large Indian reservation in Arizona was established along the Gila River in 1872 as part of the White Mountain Reserve. This reservation for a while served as a "catch-all" for defeated Indian tribes from various parts of the state, mixing some tribes that were traditional enemies. The Yavapai were force-marched from their mountain homes along the Verde River to these unfamiliar lowland areas along the Gila. The Chiricahua Apaches who were first given a reservation in the Chiricahua Mountains of southeastern Arizona, were later sent to the San Carlos Reservation when the Chiricahua reservation was revoked.

Copper Mining at Clifton and Morenci

Henry Clifton was one of many gold-seekers who went to Prescott to make his fortune in 1863. Looking for greener pastures, he reached the San Francisco River in 1865, where he found a little placer gold. In his wanderings he noticed copper deposits which he reported to miners in Silver City, New Mexico. No one knows what happened to Henry, but when those miners staked out claims near the San Francisco River, they named their new town for Clifton.

They managed to raise enough money to begin mining and by 1875 they had built a smelter. The copper veins proved to be profitable and the mines were continually expanded. At least one early mining town was consumed by the growing pit. In the early days, wood cutting was so intense that the mountains for many miles around water were totally deforested and woodcutters sought trees up to 50 miles away. Copper mining and smelting requires large amounts of water and Phelps-Dodge, the current owner, had to import additional supplies from adjacent watersheds. The mines have produced steadily over the years. Production amounts and values are not publicly available. For many years pollution from the mines was a severe problem along the San Francisco and Gila rivers.

In the early years, Anglo-Americans ran cattle throughout the reservation. In 1924, however, all leases with non-Apaches were canceled to consolidate Apache control of the reservation. Tribal ranching began at San Carlos in 1937 when the federal government loaned the tribe $75,000 to start a cattle herd. Cattle ranching is a major business on the San Carlos Reservation. Agriculture is a major water use.

Ranching and Agriculture

By 1870, the Gila River valley was relatively safe from Apache attacks. In the headwaters areas, Americans began to settle along the river, drawn by the grasslands found in the upper basin. For example, Col. H.C. Hooker moved 15,000 head of cattle into the area in 1872.

Vast areas once covered with "a marvelous growth of grass" were damaged by overgrazing of livestock. Although no one knows exactly how many cattle were in the area in 1880s, clearly thousands were grazing. This, coupled with droughts, damaged the grasslands and increased erosion, especially in the upper reaches of the basin.

People have been farming along the Gila River for more than a 1,000 years. In some areas, modern canals follow the Hohokam canals. The Pima and Maricopa Indians had thriving farms along the middle Gila River by the mid-nineteenth century and sold vegetables and grains to many travelers. Agriculture greatly increased in the late nineteenth century. Mormon settlers built at least 25 canals, some as long as 12 miles, to irrigate 35,000 acres of land between Duncan and Safford before 1900. Today, farms still line the river through the Safford valley. By 1912 up to 50,000 acres of land were under cultivation.

Farmers at Florence built a canal in 1887, diverting the entire flow of the river. This left the downstream Pimas without enough water for crops. The river was then a relatively narrow stream, with occasional lagoons and beaver dams.

The Wellton-Mohawk Irrigation District

Anglo farming began in 1857 on the lower Gila River, near Wellton. The river supplied plenty of good quality water. Two canals were constructed, but by the 1880s, as the upper sections of the Gila River and the Salt River became settled, water diversions slowed surface flow considerably, often leaving nothing. To help solve the farmers problems, the U.S. Bureau of Reclamation drilled an irrigation well in 1915. By 1916, 109 wells were in operation. These were the foundation of the Gila Project, which was built in the 1930s, and later the Wellton-Mohawk Irrigation District. The Gila Project included irrigation canals and wells.

Because the surface flow was not dependable, farmers irrigated with groundwater and by 1931 they were irrigating 11,000 acres of land. Pumping caused the water table to decline, however, leaving many wells dry. Reuse of groundwater increased the salinity of the water so much that it became unusable. The farmers called for help from the federal government.

After World War II the Wellton-Mohawk Irrigation District was formed, and farmland was provided to veterans. The Gila Project, reauthorized by Congress in 1947, included provisions for canals to bring Colorado River water into the valley to relieve the salinity problem. The first canal system was finally completed in 1952, and in 1957, the project was turned over to the Wellton-Mohawk Irrigation District to irrigate 75,000 acres of land along the River.

Another problem arose, however. Because of the underlying geology, some underground water moved upwards, pushing up many years of accumulated salts. Thousands of irrigated acres went out of production when salts reached the root zone. The Bureau's solution was to transport the salty water to the Colorado River. This pumping, however, increased the salinity of the Colorado River so much that Mexican farmers were adversely impacted. Legislation in 1974 reduced the amount of irrigated acreage from 75,000 to 65,000 acres to address part of the salinity problem. A canal transports the highly saline water into a slough near the Colorado River.

In the 1980s the Bureau tried another solution to the salinity problem. Wastewater from Wellton-Mohawk was to be treated at an elaborate desalting plant in Yuma, then put back into the Colorado River at an acceptable salinity level. This plant has never been fully operational, so the water continues on to the Santa Clara Cienega where it supports a rich wetland habitat.

The District has thrived and today it is one of Arizona's major supplier of lettuce, melons and other crops.

Settlers drained the lagoons and cut the underbrush, grass and trees to create fields for cultivation. Floods, however, often eroded canals and farms along the river.

"In those days there was always a good stream flowing in the Gila River. They were never out of irrigating water and the crops were always good. ... There was always a stream of water running about two feet deep and twenty feet wide. The river bed itself was three-fourths of a mile wide with a heavy growth of cottonwood, willow, and arrow-weeds." George Webb, 1983.

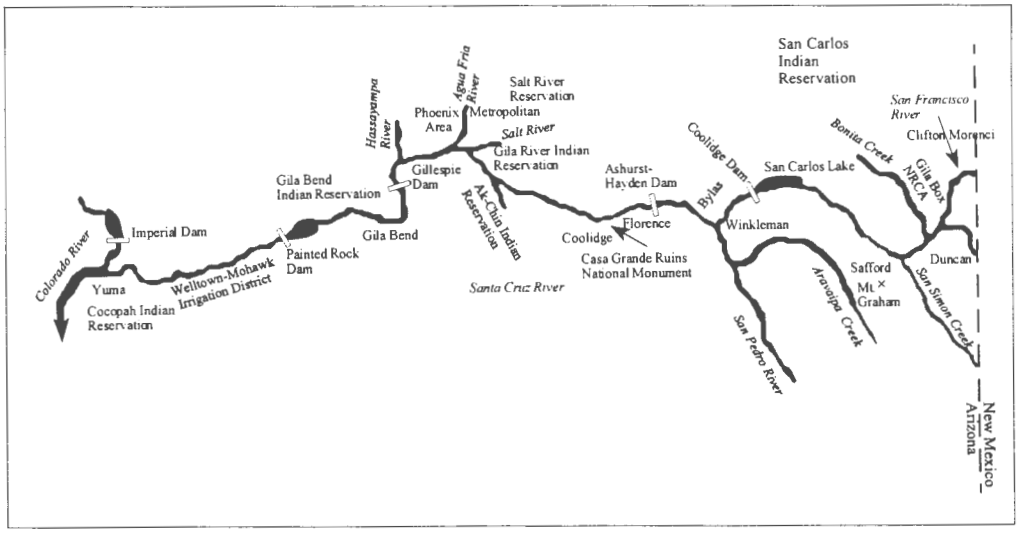
About 23,000 acres are irrigated on the San Carlos Reservation along the Gila River in the Bylas area and along the San Carlos River near San Carlos. A water rights settlement passed by Congress in 1992 settled the San Carlos Apache's claims to water from the Gila River and tributaries and allocated 200,000 acre-feet of water to the reservation. Anglo agriculture replaced much Indian agriculture, but Indian agriculture near the middle Gila River once again increased in the 1990s, with delivery of Central Arizona Project water to Pinal and Maricopa counties. The nature of agricultural activities along the river has changed. Many of the fertile floodplains in the central parts of the river, farmed for centuries by native Indians, have become severely gullied and are no longer farmed. Pumping for agriculture caused an 800-foot drop in the water table between 1924 and 1990. Severe land subsidence has resulted.

Dams

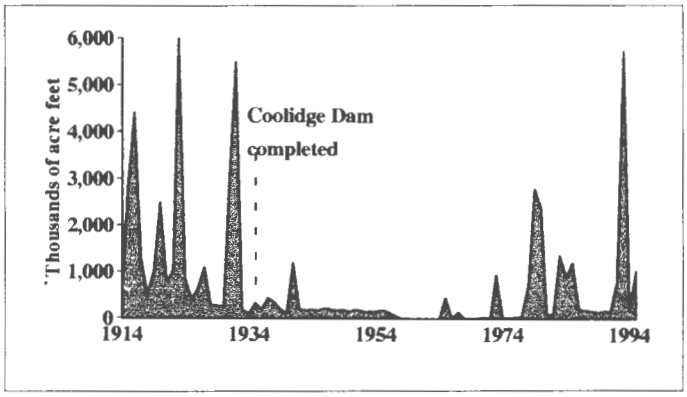
In 1863, the Pimas, who lived downstream of San Carlos, sold over 700,000 lbs. of wheat to the government and traders. By 1868, white settlers used so much of the water that the Pimas in dry years had to leave the reservation or starve. From 1869 on, the Gila River Reservation suffered from a scarcity of water. A drought later worsened the water shortage.

The San Carlos Irrigation Project, including Coolidge Dam 65 miles upstream of Florence, was proposed, in part, to deal with this problem. Built in 1929, Coolidge is the only large storage dam on the river. However, this dam has never lived up to its promises. It was supposed to create a lake 25 miles long and three-miles wide to provide water for 100,000 acres of land, one-half for Indians, one-half for non-Indians. For many years, the dam never retained much water, usually forming only a large muddy pond behind the dam. When it was dedicated in 1930, Will Rogers remarked, "If this was my lake, I'd mow it."

As George Webb, a Pima Indian, noted the dam never delivered the promised water "It took a long time for that dam to fill up and when it did, the water no longer came down the Gila. The Pimas were left without any water at all to irrigate their farms or water their stock or even to drink. They dug wells. The wells dried up. The stock began to die. The sun burned up the farms. Where everything used to be green, there were acres of desert, miles of dust, and the Pima Indians were suddenly desperately poor." Much of the water went to non-Indian farmers who often received deliveries before the Pima did, leaving Pima fields dry.



Twentieth century sites along the Gila River.



Flow of the Gila River above Gillespie Dam.

The San Carlos Irrigation Project supplies water to Indian and non-Indian farms in Pinal County, using water diverted from the Ashhurst-Hayden Dam, which was built in 1928 to serve farmers in the Florence-Casa Grande area. It is a diversion dam which diverts basically all the low flow of the river into the canals of the San Carlos Project for agriculture, ranging from 40,000 acre-feet in low years to over 450,000 acre-feet in high years.

Gillespie Dam, north of Gila Bend and built in 1921, was a diversion dam for local irrigators who grew cotton and alfalfa. A buildup of silt behind the dam created a water-logged area near Buckeye. The Wyler Greenbelt area benefits from the dam as well as return flows from agriculture and wastewater. The dam collapsed in the floods of 1993 and was not rebuilt. Powerful pumps now draw water for farms from the river near the dam site into irrigation canals.

The U.S. Army Corps of Engineers built Painted Rock Dam in 1959 to help control floods on the Lower Gila and Lower Colorado rivers. On maps, the Painted Rock Reservoir shows as an enormous lake west of Gila Bend. During the 1978 floods this lake materialized for the first time. A major flood in 1993 also filled the lake when the upstream dams had filled. Gillespie Dam had collapsed, and floodwaters were pouring from Phoenix area streets. Within a few days, Painted Rock Reservoir became the largest lake within Arizona. Indian burial grounds were flooded along with many acres of fields, roads and homes. Many fields in the Wellton-Mohawk Irrigation District were flooded, and a bird refuge along the river near Wellton was destroyed.

The major effects of the Gila River dams were the loss of water supplies downstream and the upstream replacement of flowing streams with slow moving lakes. Without floodwaters, seeps dried up, trees died and at least 29 species of birds left never to return. Other effects include changes in water temperature; loss of spawning areas; creation of conditions favoring nonnative fish and saltcedar, rather than native vegetation; depletion of sediment and nutrient supply; loss of normal spring floods downstream; and loss of habitat for many native bird and animal species.

Wildlife and Vegetation

The Gila River has little of its native vegetation. The river downstream of the Ashhurst-Hayden Dam has little or no water most of the time, so riparian vegetation cannot thrive. Old giant mesquite bosques have died, as have cottonwood-willow forests. In areas which still have plenty of water, saltcedar predominates.

Many animal species that lived near the river and its tributaries have also been affected. Beaver were starting to recover after the trapping period, when introduction of cattle and agriculture and beaver trapping provided too much competition. Beaver dams have largely disappeared in valley areas and to a lesser extent in the mountains, leading to changes in streamflow, with increased downstream flooding and erosion. The fish population has been radically impacted.

"By the first of the year 1931, five storage dams had been completed on the Gila River and its tributaries ... and such dams ... cut off the fresh water supply which normally fed the underground waters beneath the [Gila] project lands. Within 3 years thereafter the water in many of the district wells became highly impregnated with soluble salts, and since that time, excepting only during the year 1941 ... the water in the district wells has become increasingly salt ... an average 6,300 parts per million. This brought about the abandonment of many formerly prosperous farms. ... At present the farmers, because of the extremely salty water, are limited to the production of Bermuda grass and alfalfa. ..." Hugo Farmer, at Congressional hearings on reauthorizing the Gila Project, 1941.

Once a river filled with fish, including large squawfish, the Gila now supports little aquatic life in its middle and lower reaches.

The Gila River Indian Reservation has experienced a widespread loss of wildlife. Twenty-eight species that once frequented the reservation are no longer found there, including the grizzly, wolf and numerous birds. Almost all these losses are directly related to loss of riparian woodlands and marshes.

Junction of the Gila and Colorado Rivers in 1858.

Restoration and Preservation

In 1899, President McKinley established the Gila Forest Reserve which encompasses the headwaters of the Gila River in New Mexico. This area was included in the new Gila Wilderness in 1930. This designation partially protects those headwaters, although grazing and recreation are allowed.

BLM manages the Gila Box Riparian National Conservation Area, upstream of Safford, to preserve 21,767 acres of land along 23 miles of the river and a 15 mile segment of Bonita Creek for recreation and habitat restoration. BLM has nearly eliminated grazing along the river, but off-road vehicles and other forms of recreation are allowed. BLM's ability to restore this section of the river is limited by extensive upstream grazing on U.S. National Forest land in New Mexico which changes the nature of the river, its flood flows and sediment loads.

Wildlife habitat was restored upstream of Yuma as mitigation measures for agricultural activities at Wellton-Mohawk. This prime birding area, however, was severely damaged in the 1993 floods which also damaged agricultural fields. Since the floods, the riparian area is beginning to regenerate into wildlife habitat.

Changes in the River

While various Indian peoples had affected the river through irrigated agriculture, the major changes occurred as a result of Anglo-American activities in the nineteenth and twentieth centuries. In 1800, the river ran perennially for most of its length and was lined with cottonwood-willow forests and mesquite bosques. It was a well-defined stream, with marshes and lagoons at places. Arrowweed was plentiful. Groundwater levels were close to the surface, supporting riparian vegetation along the floodplain.

By the beginning of the twentieth century, the river channel had become broad and unstable and the marshes and lagoons were gone. Timber and grasslands along the river also disappeared, replaced by cultivated fields. Willows and cottonwood forests died out and were replaced in some places (especially near the dams) by saltcedar.

Agricultural diversions and groundwater pumping caused declines in the water table along much of the river, especially in the lower section. Pumping has lowered the water table along the river reducing surface flow. Surface flows are diverted before the river reaches Florence. Except for flood events, the River no longer flows to the Colorado River, increasing that river's salinity. Near Gila Bend, the River only flows in response to storm events or dam releases. The discharge of the river ranges from none to over one million acre-feet per year. Effluent from the Phoenix area dominates the river from the Salt River confluence beyond Gillespie Dam.

Dams have radically changed the normal flow of the river, forming lakes upstream and usually-dry riverbeds downstream. The Gila River bears little resemblance to the river of the 1850s, except for some mountain creeks that are tributary to the river.

FARMS, CITIES AND INDUSTRY COMPETE FOR WATER

Competition for water has been an integral part of Arizona's development. Some of the early water battles were fought with guns, but the need for laws quickly became apparent. Arizona settlers sought reliable sources of water for their homes and enterprises. Miners needed water to process gold, copper and other metals. Where both ore and water were found in the same place, the success of a mine was more likely. Ingenious methods sometimes were used to bring the two together. In some places water was shot from large pressure guns across ravines to process ore. Fights over water in mining areas could be fierce and led to the first attempts at surface water laws in neighboring California at the time of the Gold Rush. Arizona's water law followed developments in California.

As agriculture and ranching grew, so did competition for water. Farmers needed to move water from rivers onto their fields. Irrigators often competed to build bigger canals to divert large amounts of streamflow. Ranchers and homesteaders located near dependable water supplies, but soon found themselves at odds with later settlers and Indians.

Water Law and the Rivers

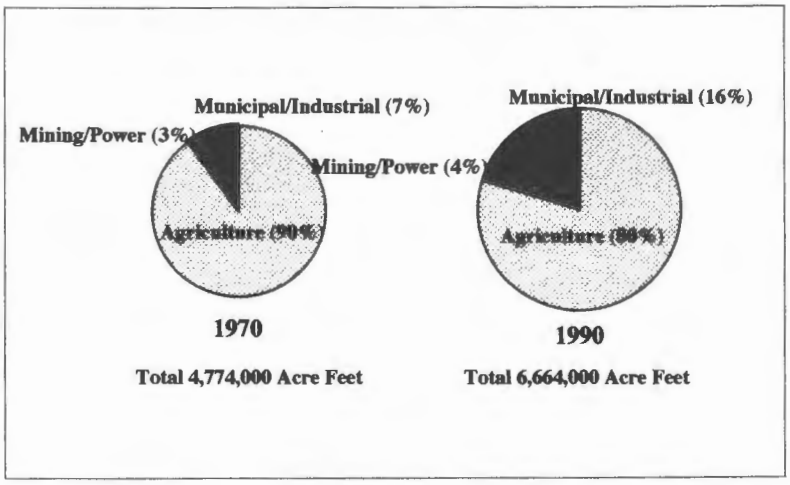
One of the most important but more obscure forces that has changed Arizona's rivers is Arizona's water law. From the beginning, the law developed to encourage water use and protect those who arrived first. Since rivers occupy only a small portion of the land, the settlement of the arid West was supported by a system that allows a user to remove water from a river, with this use protected from later users.

Surface Water Law

To settle conflicts and to avoid outright warfare, water law gradually developed that granted rights for water taken from a stream to be used elsewhere. This type of water law—the doctrine of prior appropriation—reflected the arid nature of the West. Water was not always available where it was needed, whether for agriculture, mining or urban uses. Prior appropriation allowed the diversion of water, with some certainty that its use would be protected from future diversions

In 1864, Arizona's first territorial legislature adopted an appropriation system for surface water rights. Since water use was minimal at the time, no method for filing or receiving water rights was established. However, by the late 1800s, development of irrigated agriculture along the Salt River and the onset of drought caused water shortages. In 1893, the territorial legislature required new appropriations be posted at the place of diversion and recorded at the county recorder's office. More than 15,000 water rights claims were filed before Arizona became a state in 1912.

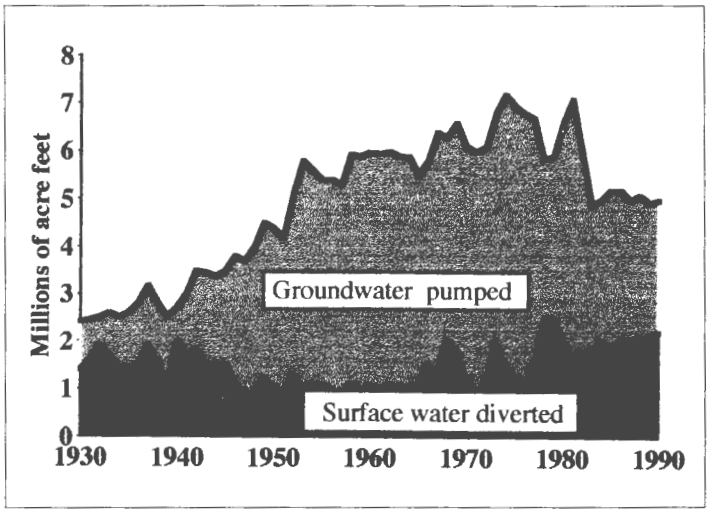
With statehood, Arizona also adopted a state water code that essentially remains unchanged. Today's law requires that people file applications



Arizona water uses in 1970 and 1990.

with the Arizona Department of Water Resources (ADWR). If all requirements are met, a permit to use surface water is issued. The resulting law (which applies generally in all western states) is the appropriation doctrine. It has three important provisions:

First in time - first in right. Users must apply for a permit to appropriate surface water. If there is enough water left after previous appropriations, a permit can be granted. Once the user has actually developed a way to use that water, a certificate is granted. If the water rights holder takes water out of the river downstream, other users may not use that water, unless it is used in the stream. This has, for example, benefited the Verde River. The Salt River Project holds major water rights on the Verde River, but pumps its water downstream near Phoenix. That SRP has these Verde River water rights means that the flow of the rivers is ensured until it reaches the Phoenix area.



Arizona water use.

Water must be used beneficially. The law sets out beneficial uses of water which (in order of priority) are domestic, municipal, irrigation, stock watering, power generation, recreation, wildlife (including fish), artificial recharge and mining. Most uses require the water to be removed from the stream. The priorities are in effect only if more than one applicant applies for the same water at the same time. Otherwise any user may get a permit for unappropriated water for any intended use

Use it or lose it. If a certificated user does not actually use the water beneficially at least once every five years, for the use specified in the certificate, other users can claim that water, although this provision is rarely used. In the case of Scottsdale and the Bill Williams River, for example, to maintain its water rights the city must pump water for agriculture at least once every five years, even if it would prefer not to. This issue is being resolved by the Department of Water Resources.

Instream Flow

Water may be appropriated for use **in the stream** for wildlife and recreation—"instream flow"—but all senior users, i.e., those with earlier water rights, have priority over later users, including those with water rights for instream flow uses. In only a few cases is unappropriated water available. To transform existing water rights to instream flow rights is not easy. Seventeen instream flow permits or certificates have been granted in Arizona.

Groundwater Law

Most surface water was fully allocated by the time advances in groundwater pumping technology appeared. Many believed the supply of groundwater was virtually endless. When pumping technology made it possible to extract large amounts of groundwater, users no longer depended on rivers and springs.

With the advent of high-power pumps and cheap electricity in the 1940s, groundwater withdrawals began in earnest. Arizona developed laws to control groundwater pumping in 1948, when conflicts arose between agricultural interests and newcomers. The first groundwater law protected prior pumpers in certain areas of intense farming and water use. No new wells could be drilled for agriculture, although wells could be drilled for other uses.

By 1980, it was clear that pumping had to be regulated, at least in certain areas, and the Arizona Groundwater Management Act (AGMA) was passed (largely to satisfy federal government requirements for building the Central Arizona

"To halt construction of Parker Dam in 1934, Arizona Governor Benjamin B. Moeur called out the Arizona National Guard. Governor Moeur, arguing the construction of the dam would be an infringement on Arizona's sovereignty, sent one major, a sergeant, a cook and three privates to the dam site. Traveling by ferry boat, horses, and cars, the Guard was sent to prevent construction of the dam. More than a hundred national guardsmen were also sent when construction on a trestle bridge began. The Governor issued a proclamation 'To Repel an Invasion' and declared martial law. Construction halted for more than a year on the dam." Philip Fradkin, 1968.

Project). The law declared certain areas Active Management Areas (AMAs) while others became Irrigation Nonexpansion Areas (INAs). AMAs had requirements and incentives for water conservation and limits on drilling of new wells. In INAs only new agricultural uses are controlled. In the rest of the state no control over well drilling and water use exists, except that the well be registered.

The AGMA only deals with groundwater. In Arizona law groundwater is considered to be separate from surface water. Water may be pumped from aquifers which contribute to streamflow, even if the river or individual surface water rights are adversely affected. The law has no incentive for conservation to protect rivers, except in the Santa Cruz AMA, which was created in part to conserve the Santa Cruz River.

Surface-Groundwater Conflicts

Conflicts over water are increasing as the connection between surface water and groundwater is realized. Although separate under Arizona water law, surface water and groundwater are hydrologically connected in most areas in the state. In some areas this connection has been severed by excessive pumping. In other areas the underlying geology separates groundwater and surface water. Groundwater pumping has affected rivers throughout the state, some more than others. The Santa Cruz River is Arizona's prime example of a situation in which groundwater pumping has dewatered a river. Both the San Pedro and Verde rivers face serious problems as groundwater pumping increases for a growing population.

In contrast, the federal government requires a contract with users to pump groundwater hydrologically connected to the Colorado River, an interstate river with federal jurisdiction. Flow of the river must not be diminished by pumping. On the Gila River, however, many farmers have drilled wells because of lack of surface water, diminishing the flow of the river. This problem is being litigated in federal court.

Indian and Federal Water Rights

Indians and the federal government hold another type of water right different from water rights established under state water law—federal reserved rights. In 1908, in *Winters v. United States,* the U.S. Supreme Court ruled that Indian tribes were entitled to enough water to fulfill the purposes for which reservation were established. Later, in another landmark decision, *Arizona v. California*, the U.S. Supreme Court set a standard to measure Indian water rights, based on irrigated agriculture.

State water law does not have precedence over Indian or federal claims. The reservation's priority date is based on the date it was established,

Irrigation pumps near the remains of Gillespie Dam on the Gila River, 1996.

and water rights cannot be lost through nonuse. Other reserved water rights for federal land such as military bases and national forests are recognized, but their scope is more restricted. The status of Indian water rights claims varies. Five tribes settled their water rights in *Arizona v. California.* The Tohono O'odham Nation, the Salt River Pima-Maricopa Community, and the Ak-Chin Indian Community chose to negotiate with non-Indian water users. Other tribes are pursuing options from filing water rights claims in court to negotiations.

Who Owns the Rivers?

In Canada and some U.S. states, rivers belong to the public. Most rivers in Arizona, however, are privately owned. When settlers first arrived, the rivers were the first areas to be claimed and became privately owned. When Arizona became a state, the federal government turned over the navigable rivers to the state as public land (Public Trust Doctrine) but rivers already privately owned remained private. The entire Colorado River is public, because it is navigable, but most other streams are not unless some public agency bought them. The U.S. Supreme Court ruled in the 1980s that any Arizona streams that were navigable at the time of statehood are in fact public and should not have been given away. A lengthy process is underway to determine which streams were in fact navigable and should be returned to public ownership or purchased at fair market value by individuals. The fact that many streams have been considered private property for years has profoundly affected them.

Settling Disputes

For the most part, disputes are settled in court. The burden of proof lies with those who believe their rights have been violated. They must gather the information and challenge the violator in court. ADWR does not enforce water rights claims. There is little in the law to protect users of groundwater from pumping by others. Nor does the law for the most part protect surface water rights holders from loss of their water due to groundwater pumping.

Surface water rights in the Little Colorado River and the entire Gila River system are being adjudicated in a lengthy court proceeding. The intent is to assign a water right and priority date for every water user in these areas, including Indian tribes and other federal lands.

The Arizona adjudications involve more than 27,000 people asserting over 77,000 water rights. Included are most of the large water users in the state, Indian tribes and independent landowners. Claims probably will not be settled until well into the next century. How the settlement acts are implemented, and how the remaining claims are settled will certainly impact Arizona rivers.

Impacts on the Rivers

Arizona encourages population growth, with its increased water use. At the same time the state has a legal system that favors prior rights holders over newcomers. In this inevitable competition for water, the rivers have often been the losers.

While Arizona's historic water laws served well to help settle the West, the result has been less and less water for riparian habitat, fish and recreation. The law has almost no incentive for water conservation to maintain river flow.

Groundwater Pumping Can Affect Rivers

Rivers can be affected by pumping of groundwater in three ways. If the water table is high and near a river, its water contributes to the flow of the stream. When the water level is lowered too far by pumping, it no longer contributes water to the stream. Pumping near a stream can also intercept water that would normally flow into the stream, thus depriving the stream of that water. Finally, when a lot of pumping occurs in an area, a "cone of depression" may form, so that the water level is lower near the pump than in surrounding areas. This can cause water to flow by gravity from the stream toward the cone of depression, further dewatering the stream.

LITTLE COLORADO RIVER

The Little Colorado River is northeastern Arizona's major river, passing across the Colorado Plateau on its way to the Colorado River. The river and its tributaries have been occupied for thousands of years by the Anasazi, Hopi, Navajo and others. The river and its tributaries have experienced dams, towns, ranching and logging.

The River

The Little Colorado River flows from its headwaters high in the White Mountains of eastern Arizona some 200 miles to its confluence with the Colorado River near the Grand Canyon. Its major tributaries are the Zuñi River which joins the Little Colorado near St. Johns and the Rio Puerco which meets it near Holbrook. Other tributaries flow into it from the north and south. Most of the northeastern corner of Arizona is part of the Little Colorado watershed, from the San Francisco Peaks near Flagstaff to the New Mexico border. About half the Navajo Reservation is in the Little Colorado watershed, with the rest of the reservation located in the Colorado River watershed.

Today the river flows perennially from its headwaters to Lyman Lake, north of Springerville, and ephemerally or seasonally from there on. The watershed extends over 21,900 square miles. Much of the watershed is home to the Navajo, Hopi and Zuñi nations. The elevation ranges from 12,633 feet at Humphrey's Peak to 2,700 at the confluence with the Colorado River.

"Fruitful, culture-rich, ground was on both sides of the river, with many ruins on which we walked, rested and meditated. ... The wandering generations in grey antiquity have left remains in this valley where all which is necessary to the existence of man are offered—beautiful drinkable water and good fertile soil, which shows signs of often in past years having overflowed its banks." Balduin Mollhausen, describing the Little Colorado River in 1858.

In 1991, American Rivers proposed three segments of the Little Colorado River system for Wild and Scenic Rivers status. These include the final 54 miles

of the river from Cameron to the Colorado River; the West Fork of the Little Colorado; and Chevelon Creek. Each of these areas has perennial waters and is relatively undisturbed by human activity. Wild and Scenic Designation was not granted, however.

Early Inhabitants

People came to the area at least 12,000 years ago, and hunted such creatures as mammoths. By about 8,000 years ago most of the large animals of the region had become extinct, and there is no evidence of human occupation during this exceptionally warm, dry period. Nomadic groups appeared about 4,000 years ago when the climate again became cooler and wetter, much like it is today. The Anasazi occupied and farmed portions of the Colorado Plateau having adequate water from at least 400 A.D. until about 1400. They experienced a long drought in the twelfth and thirteenth centuries when maintaining adequate food supplies was difficult. Many of them migrated south and east. Modern Zuñi and Hopi Indians claim Anasazi ancestry. Some Sinagua and Hohokam peoples probably moved north from the Verde

"But for all his accomplishments, the Anasazi man could not learn to live within his environmental limitations. He could not see, until it was too late, that the large metropolitan centers he had created despoiled the land, denuded the forests and consumed all the local wild plants and game animals beyond the point of restoration. He would not admit that his excessive cultivation of stream valleys set into motion a cycle of erosion that caused the water table to drop to dangerously low depths years after year.

"And then the final blow—for some 23 years (1276-1299 A.D.) the Southwest suffered through the most severe drought in history. The gods had forsaken them—their fields lay parched, their children dying. Those that could abandoned their homes and moved south to the Little Colorado River or east to the Rio Grande." Martin Link, Navajo Tribal Museum, 1973.

and Salt River Valleys to join the Hopis before the fifteenth century.

The Hopi have successfully farmed the mesa country for hundreds of years. The first Spanish missions in Arizona were established in Hopi and Zuni pueblos in 1629 north of the Little Colorado River, at Oraibi, Shungopovi and Awatovi. An Indian revolt in 1680 brought an end to these missions.

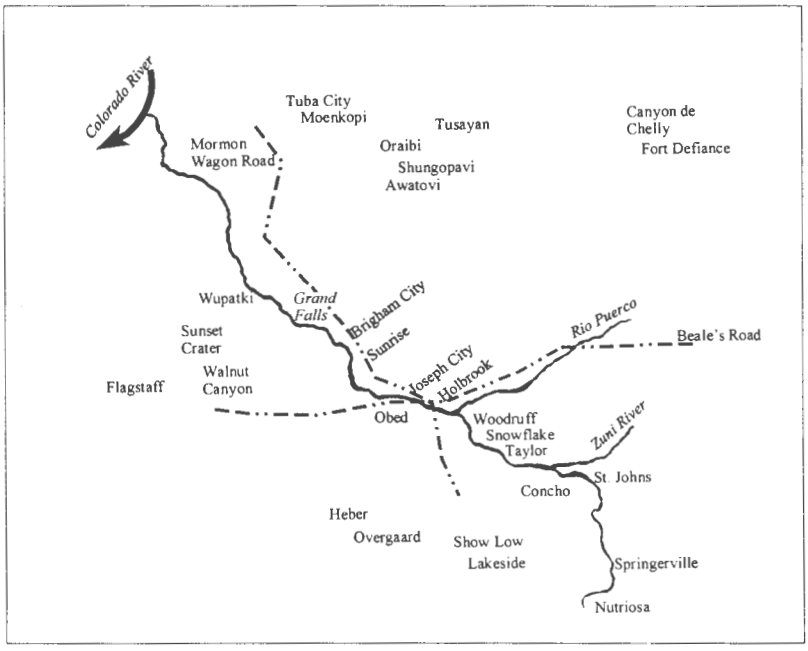
The Navajos were late-comers to the area, arriving in the sixteenth or seventeenth century. Fray Alonso de Benavides encountered Navajos in 1620. He said that their land "... extends so far in all directions that it alone is vaster than all the others." He also noted that they were very skillful farmers. The Spaniards introduced horses to the area and initiated warfare against the Indians in 1673. Warfare occurred from time to time until the end of the Spanish period in 1821.

Conflict between the Navajos and their neighbors continued for many years, long into U.S. rule of the area. The U.S. government established a reservation for the Navajos in 1868, issuing each person three sheep, one goat and farming implements, to hasten a transition to a grazing-farming way of life.

Spanish Exploration

The Little Colorado River was a natural route for travelers heading west from northern New Mexico. They could travel along the Rio Puerco and then the Little Colorado River for about 40 miles. A traveler attempting to follow the Little Colorado all the way to the Colorado River would encounter country very difficult to traverse.

What was the river like in former days? We have only tantalizing clues from times before the nineteenth century. Coronado apparently was the first Spaniard to explore the area, in search of the Grand Canyon, in 1540. He named the Little Colorado the "Rio del Lino" (River of Flax). The Espejo expedition came through in 1583. "We reached a fine, beautiful, and selected river, almost as large as the Del Norte, containing many groves of poplars [cottonwoods] and willows."



Historic sites along the Little Colorado River.

In 1598, Farfan and Quesada named it Rio Alameda for the great groves of cottonwoods. In general, however, their descriptions leave the reader wishing for more.

It was about 200 years later that the second Spanish explorer, Father Francisco Garcés, traveled along the river he called "Rio Jaquesila" or "Rio San Pedro." His description of the river does not convey much specific information: "It was running water enough, but very dirty and red, that could not be drunk; but in the pools of the border of the river there was good water. ... The bed of this river, as far as the confluence, is a trough of solid rock, very profound and wide about a stone's throw, and on that account impassable even on foot; wherefore with much travail did I enter into said bed of the following, following down a trough not so profound. ..." He probably reached the river somewhere near Moenkopi Wash, but the exact spot is unclear.

Anglo-American Exploration

The first Anglo mountain men entered the area to trap beaver in the 1820s, but they left few records to tell us what kind of river they saw. Another 30 years passed before Captain Lorenzo Sitgreaves led an expedition to explore the Zuñi River to see if it flowed into the Colorado. On September 27 he wrote, "At this point [at the confluence with the Zuñi River] the Little Colorado is an insignificant stream, divided into several small channels, flowing through a narrow valley

Lee's Ferry was the main crossing for settlers coming from Utah.

"We have seen indications of the greatest abundance of game for the past three days. Elk, antelope, and deer, besides beavers and coyotes in large numbers. ... Wood, water and grass good, and the weather warm and clear." Edward Beale, 1858.

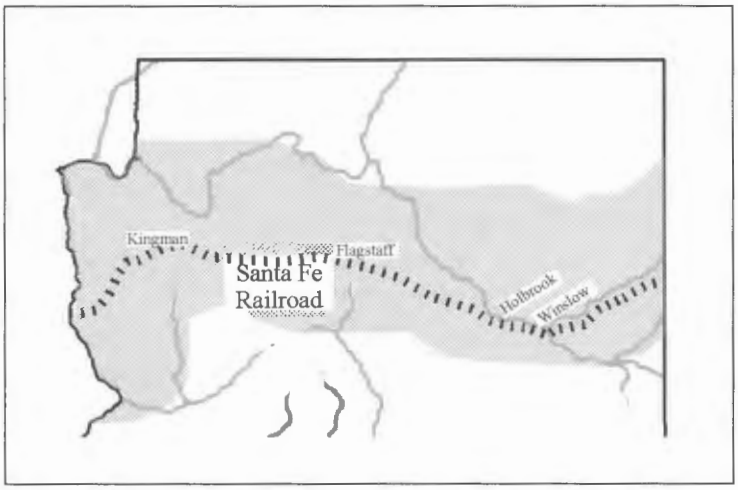
destitute of timber, but covered with a thick growth of rank unnutritious grass."

In 1853, Lt. Amiel Whipple led an expedition to survey a route for a railroad. The present Santa Fe Railroad approximately follows Whipple's route. He reported "The [Little Colorado] river is about 30 feet wide flowing between alluvial banks 8 - 10 feet high. ... The banks of the main stream sprinkled with cottonwood trees river bottom is in some places marshy, with willow thickets and in others covered with loose pulverized soil."

Joseph Ives wrote in the spring of 1858, "The river is smaller than the Colorado, but at this season, when the water is becoming high, much resembles the other at its low stage. There are the same swift currents, chocolate colored water, shoals, snags, sand bars and other evidences of a constantly shifting channel, at width fifty yards and the depths 5 or 6 feet."

Also, in the fall of 1858 Edward Beale took a camel caravan to survey a wagon road from Fort Defiance to the Colorado River and followed the river for about 50 miles. He said, "The valley of this river is 3 miles across, and grass plentiful in the bottoms, as well as on the hills, which are quite low. There is abundance of large cottonwood trees in the bottom, which resembles very nearly the bottom of the Rio Grande. ... The stream was quite shallow, not over a half foot in depth, and about 15 in width. A few cottonwoods line its bank, and served to mark its course."

None of these explorers left a lasting mark on the river, but they did leave a picture of a landscape with plentiful vegetation in the riverbed and grass on the plains, with water usually in the river.



Land granted to the Atlantic and Pacific (Santa Fe) Railroad.

Mormon settlements

Mormon settlement in the area began in the 1870s when a wagon road was laid out from Lee's Ferry to Moenkopi. Mormon explorers told of good soil, grass, water and timber. Mormons found the area appealing as an out-of-the-way place where they would not be bothered. Past experience led them to seek places where there would not be conflict. Their living style was communal, with an emphasis on self-sufficient agriculture. They organized to build dams and canals for irrigation, but the river did not submit easily to dams.

The history of Mormon settlement along the Little Colorado River is punctuated with efforts to create irrigation systems and towns, followed by major floods washing out dams, farms and sometimes even the towns. Many communities only lasted a few years. The downstream communities had the greatest problems coping with the river. St. Joseph, for example, had 13 dam failures in the 25 years between 1876 and 1900, while Woodruff had ten dam failures. The middle communities such as St. Johns, farther upstream, had a much less difficult time and had only two dam failures in those 25 years. The upstream settlements, mountain communities of Show Low and Alpine experienced almost no problems with dams, but had difficulties with a short growing season. The river was the primary water source, the life blood of these communities. Residents used trees which grew along the river and on the uplands to build their homes, fuel their fires, and for many other purposes. Such deforestation impacted the river by increasing erosion and streamflow.

Each dam and dam failure changed the river. Dams holding back water for diversion to fields meant less water could flow downstream. When the dams failed, new channels were cut, with more sediment flowing downstream.

Ranchers and the Railroad

The coming of the railroad to northern Arizona in the 1880s brought major changes to the Little Colorado River. The railroad closely follows the river, entering Arizona along the Rio Puerco then moving away from the Little Colorado at Winslow. In 1866, the federal government awarded a land grant to the Atlantic and Pacific Railroad (succeeded later by the Atchison Topeka and Santa Fe). The railroad was granted alternate sections of land for 40 miles on both sides of the railroad right of way, plus an additional ten-mile strip area, giving the railroad company a 100-mile strip along the 35th parallel through Arizona and New Mexico, some 49 million acres. Building the railway put a strain on the area, as large quantities of lumber were cut for railroad ties and fuelwood. Water was used

"When we came to Arizona in 1876, the hills and plains were covered with high grass and the country was not cut up with ravines and gullies as it is now. This has been brought about by overstocking the ranges. On the Little Colorado we could cut hay for miles and miles in every direction. The Aztec Cattle Company which left Texas because of severe drought there, brought tens of thousands of cattle into the country, claimed every other section, overstocked the range and fed out all the grass. Then the water, not being held back, followed the cattle trails and cut the country up. Later tens of thousands of cattle died because of drouth and lack of feed and disease. The river banks were covered with dead carcasses." Mormon settler, 1898.

for the crews, the steam engines and other purposes. Bridges were built to span rivers. As a result the area traversed by the railroad was impacted, as was surrounding land.

The greatest impact of the railroad was to make the area much more accessible to the outside world. One of the greatest impacts of that accessibility was the arrival of cattle ranching on a large scale.

The changes the early Mormons wrought were dwarfed by later developments. Mormon and other farmers brought cattle and sheep into the area, but with the arrival of the famed Hashknife Outfit (Aztec Land and Cattle Company) major changes took place. Starting in 1884 the Aztec Land and Cattle Company brought in thousands of cattle by rail to fatten on the lush grass when the Texas ranges failed after several years of drought. Some five million acres of railroad land was sold to Aztec.

The Aztec Land and Cattle Company, however, denies the claim that its activities had a major impact on the land. "Present-day writers are prone to compare early with present descriptions and blame the decline on what they call overgrazing, but a careful reading of all descriptions does not bear this out. By the time either the Pecos or Little Colorado reach the point we are discussing, they have passed through miles of virtually sterile country, and it was sterile for centuries before the first settler arrived. ..." Company spokesmen do, however, agree that there were "way too many cattle."

Two problems made life difficult for the Mormon farmers in the area. The land had not been surveyed, nor had Mormon land claims been submitted in time to be considered valid. In addition, the Aztec land was in alternate sections.

The Hart Ranch

"In 1878 or 1879 a few years before the coming of the railroad to Flagstaff, Mr. Frank Hart ran cattle in the valley of the Little Colorado. He built a good house on the south side of the river below a red sandstone cliff. In 1884 the house was in perfect shape and the roof intact.

"At this time Mr. William Roden arrived in the valley with several thousand head of sheep. Frank Hart left the region of Grand Falls and moved up the river with his cattle to the neighborhood of Winslow. When Roden arrived at Grand Falls the flats on either side of the river supported a find stand of old and young cottonwood trees which produced attractive shady groves, while gramma grass covered the surrounding hills. The Frank Hart house stood over a hundred feet from the river, then a narrow stream which flowed the year around. Many beaver lived along its banks feeding on the cottonwood trees. In 1884 when Roden built his house on the north side of Grand Falls, ... the nearest Navajos lived about 30 miles away up Dinnebito Wash. ...

"During the 1870s and 1880s thousands of cattle and sheep were placed on the ranges. The ranges carried them easily until a severe drought caused them to eat the grass too closely.

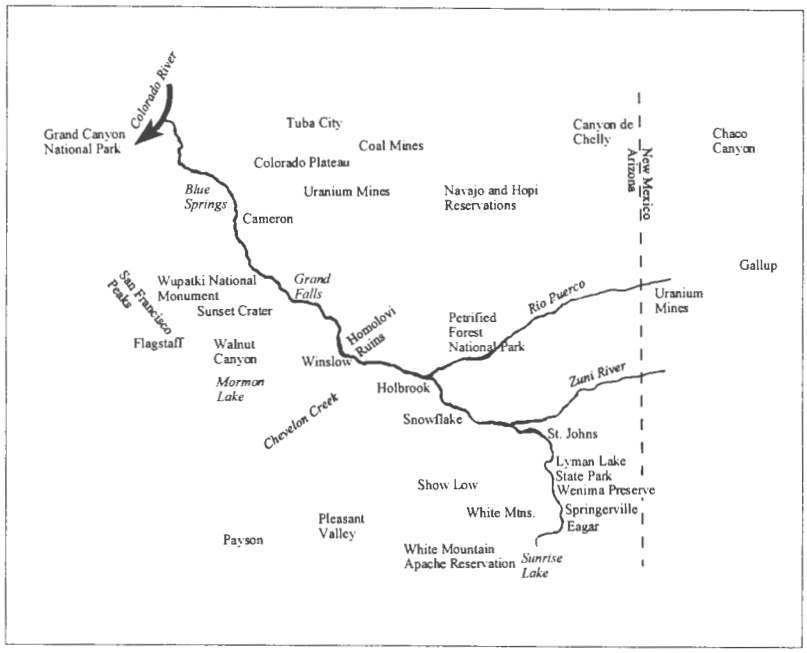
"At the time of this drought the Navajos moved into the river valleys, cutting down the young cottonwoods to feed their starving herds. When rains came once more in the early nineties, with no grass to hold the water we see the first of those disastrous floods which have followed one another at infrequent intervals over the last 40 years. The Navajos called it the 'Big Timbers' because it undermined, uprooted, and carried away many of the old cottonwood trees along the river banks and left their whitened trunks to mark the limit, to this day, of the high water 40 and 50 years ago.

"As the river bed was narrow it could not carry the flood water so it frequently overflowed its banks thus adding 30 inches of sediment on the flats below the river ... the flood poured over the walls of the house, filling the rooms with debris.

"In the summer of 1937 the author again visited the Hart House. In two years the river had cut back 14 feet and only the back wall of the house was standing. The rest had been carried away by the river." Museum of Northern Arizona Museum Notes, 1937.

This meant in effect that Aztec had twice as much land to graze, since fencing between sections was unfeasible. A great deal of conflict and even open warfare resulted between ranchers and townsfolk.

After just a few years of plentiful rain and good grazing, about 150,000 head of cattle and 120,000 head of sheep were in the area. This was followed in 1891 and 1892 by a period of drought in which tens of thousands of cattle died, after having thoroughly grazed the area. The price of cattle fell from a high of $28 per head in 1885 to $5 a head in 1893. Many ranchers sold out for what they could get, with some converting to sheep herding. In 1897 about 200,000 head of sheep and only 20,000 cattle remained. Sheep were as damaging as cattle to the remaining grasslands and erosion continued.



Twentieth century sites along the Little Colorado River.

The Herald wrote in May 1893, "We are credibly informed that the Little Colorado River for eight or ten miles south of town, is literally lined with dead and decomposing cattle. Nineteen twentieths of the residents of this place use the river water for household purposes, and if it does not breed disease, the pretended harmful effects of impure water is a fallacy."

A rancher wrote, "This section of country has not had sufficient rain to lay the dust since the middle of April. The ranges are perfectly bare and it is now too late to make grass, even if it should rain, of which there is no indication. Our cattle and sheep raisers sustained heavy losses last winter, but unless we have a remarkable favorable winter, the losses last season were light in comparison to what they will be the coming season."

The land was denuded and much soil washed away downstream in the river. Never again would the land be as productive as it had been when Beale came through. In 1939, the Office of Indian Affairs tried to trace the Beale route, photographing places which Beale had described. They found a pattern of erosion, downcutting of streams, and lack of good forage for grazing.

The number of cattle and sheep grazed in the area never again approached the numbers of the 1890s. The Navajo, however, continued to graze large numbers of sheep from 1880-1935. Since 1900, non-Indian grazing has been cut back substantially and grazing methods have changed. As a result, many tributaries now are healthy streams with populations of native fish. In other areas, grazing still contributes to erosion of stream banks causing high sediment loads downstream

The Timber Industry

Timber has been harvested in the upper watersheds of the Lower Colorado River since the late nineteenth century, especially in the Flagstaff area. Arizona's largest pulp mill is in Snowflake. Because of its heavy water use and water quality problems, the company has embarked on a project in which they reuse water for a tree nursery.

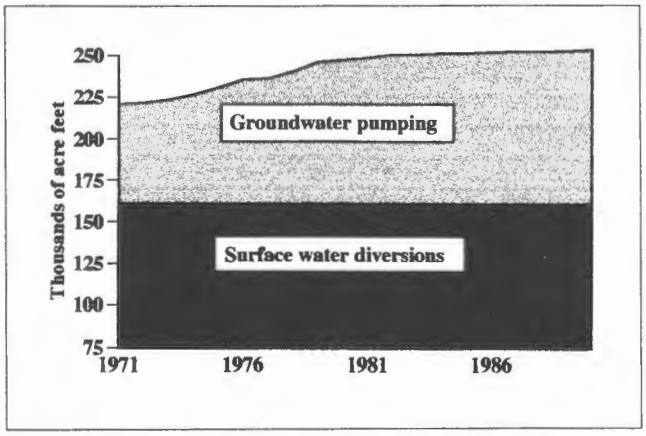
"The river is in sight on our left, well wooded with cottonwood; and as far as one can see, a level country extends to the southward and westward, covered with gramma and bunch grass. ..." Edward Beale, 1858.

Uranium Mining

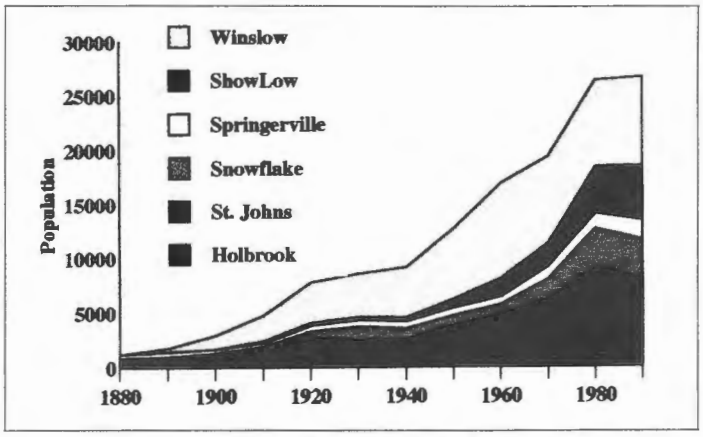
In 1979, polluted water spilled into the Rio Puerco from a uranium mine tailings pond, causing dangerous levels of radioactivity in the water. Experts consider this incident the worst U.S. uranium mining spill in history, with ninety-four million gallons of highly acidic water and 1,100 tons of uranium mine tailings traveling 50 miles down the Rio Puerco to the Little Colorado River. Bad as this spill was, much more radioactive material was gradually released over the years through routine mining activity. Mine dewatering effluent along with sewage effluent from Gallup, New Mexico, formed a continuously flowing stream for 70 miles, to Chambers, Arizona, over a 20-year period. Another uranium mine farther downstream at Cameron, may also have contributed radioactive materials to the Little Colorado River. Throughout this area, however, radioactive material occurs naturally. The U.S. Geological Survey recently found no evidence of continued river contamination from the now-abandoned mines, although groundwater and sediments may still be contaminated.

Water Use and the Growth of Towns

The population of the Little Colorado River basin has grown steadily. Some of the towns get their water from the river or its tributaries while others pump from shallow or deep wells. Water use in the area has increased with population growth. All of this increased use comes from groundwater, while surface water diversions remain steady at 85,000 acre-feet. Navajos and Hopis use another 70,000 acre-feet. Most of the surface water is for agriculture. Water also is diverted from the watershed into the Salt River drainage as part of a complex water trade for the mines in Morenci.



Water use along the Little Colorado River.



Population in selected towns along the Little Colorado River.

All water withdrawn from the stream directly affects river flow, but only some of the pumping affects the river. Some of the pumped groundwater comes from deep underground where withdrawal does not affect the flow of water in the stream, but other water comes from shallow wells which draw water from the same aquifer as the river. Other wells draw groundwater that flows toward the river and would appear as seeps or springs if allowed to remain.

Settlers were attracted to the many springs and seeps in the Holbrook-Joseph City area. They developed the springs and drilled shallow wells. By 1946, about 4,300 acre-feet of groundwater flowing towards the river was intercepted mainly for irrigation. Only 600 acre-feet was taken from wells. By 1972 11,500 acre-feet were being withdrawn from the aquifer for irrigation and power. By 1976, many of the springs and artesian wells flowed only during the winter when agricultural pumping ceased. Water levels had fallen as much as 50 feet at Joseph City, radically affecting the water supply for the river. Twenty years later water use has increased in the area and almost no

springs flow year-round. The river receives less and less water each year. The two dams on the river further affect the flow. Lyman Lake and St. Johns Reservoir impound water for agricultural diversions. Many small impoundments in the watershed are mostly used as recreational lakes and cattle ponds.

Wildlife

Early travelers mentioned seeing plenty of wildlife along their route. Specifically mentioned were deer, elk, antelope, beavers, otter, turkeys, grizzly and black bears, ferrets, bald eagle, gray wolf, coyotes, mountain lions, and many varieties of birds and fish. Experienced hunters had little difficulty finding fresh meat. Today most of those creatures still inhabit parts of the area, but in much smaller numbers, although black footed ferrets, grizzlies and gray wolves are no longer to be found in Arizona. Elk are plentiful, but only because or their reintroduction from Colorado after the native elk had been eliminated. Some evidence indicates that too many elk now occupy the area, because of the decline of the big predators and the need to share food sources with cattle.

Changes in the river mostly affected native fish. Apache trout and Little Colorado River spinedace can still be found in some headwaters streams, although fewer than in the past. The Colorado squawfish, the humpback chub and the bonytail chub (once found at the mouth of the river) are no longer found in the Little Colorado basin and are rare in the Colorado River itself. Loss of adequate water supply, loss of appropriate breeding areas from loss of shade, siltation of waters, higher water temperatures, and introduction of non-native fish are the principal reasons for the decline in native fish.

Changes in the River

Parts of the Little Colorado River have changed greatly in the past 125 years. The river has for centuries been unpredictable, with its normal moderate flow punctuated by long dry spells and major floods. Some early travelers found the river shallow and easy to cross while others had difficulty fording the river—but all agree that in many areas the banks were lined with cottonwood trees and other elements of a riparian habitat.

Today such habitat is rare on the Little Colorado and most of the "level country" has little gramma or bunch grass. People who travel the

TWO WELLS NEW MEXICO
(Rio Puerco, near the Arizona border)

AS BEALE SAW IT IN 1857:
"We encamped at the poases (wells), a grassy vega of about one hundred and sixty acres, where the water and grass are good and timber abundant—cedar and pine."

81 YEARS LATER —
THE PLACE BEALE DESCRIBED:
"Giant fingers of erosion stretch out from this water hole, upper left. Livestock, trailing to water for decades, made trails that now are gullies. The grass has disappeared and in its place has come unpalatable snakeweek. Sheet and gully erosion are at work."

full length of the Little Colorado River and its major tributaries will find great variety of vegetation and river flow. The upper and lower sections are the least changed, while the middle section is vastly different from what it was when Arizona became a territory.

Some of the mountain streams flow perennially. Most are lined with trees, with pines in the higher elevations and cottonwood and willows farther down. Some streams are heavily grazed, and some extensively used for recreation. Some, however, are little changed from the past. For example, according to American Rivers, Chevelon Creek is "a very wild and scenic stream running through a steep, narrow, twisting canyon. The canyon runs through a riparian area virtually undisturbed by human activity." The Arizona Game and Fish Department purchased two sections of the headwaters near Springerville (Wenima and White Mountain Hereford Ranch) to preserve the riparian areas and endangered fish species.

In the 54 mile downstream section from Cameron to the Colorado River, the river runs intermittently with perennial pools supporting fish down to Blue Springs (a major natural source of salt), then runs perennially for the final 13 miles. "The river winds through a tortuous course through a precipitous canyon with rims nearly 3,000 feet above the riverhead. The sheer walls of the canyon are in multicolored layers. Near the mouth, the waters are charged with calcium carbonate, resulting in a striking azure blue color, and creating travertine terraces and dams." This portion of the river had more water in the past, although even then there were probably periods when only pools remained.

This river section also has been muddied by large amounts of sediment eroded from the watershed in the middle sections of the river. Human activities have most changed the river section from Lyman Lake to Cameron. Water seldom flows below Lyman Lake. The watershed is no longer covered with grasses to slow down flows and prevent erosion. In some areas so much topsoil has been lost that re-establishment of previous types of vegetation will be very difficult. Grand Falls only "falls" during periods of high run-off. In spite of these changes, the section from Grand Falls to Cameron is still scenic and appropriate for rafting during snow melt.

Abert's squirrel.

Roosevelt Dam site before construction, the dam under construction, and President Theodore-Roosevelt dedicating the finished dam.

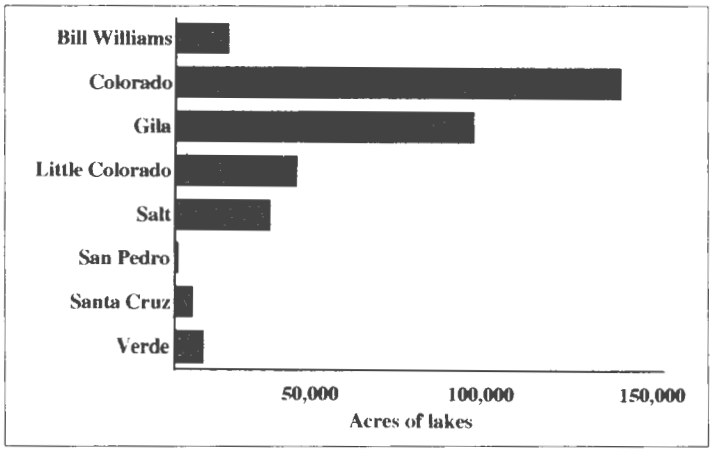
ENGINEERS CONTROL THE RIVERS

Dams have been affecting Arizona's rivers for millennia since the first beavers appeared. Beavers built dams in most Arizona rivers, creating pools and slowing down the flow. Indian farmers used check-dams as water harvesting systems to hold back water for agriculture or to divert water for use on fields. There are 431 dams registered with the Arizona Department of Water Resources, with reservoirs ranging in size from 14 acre-feet to the giant Lake Mead with more than 28,000,000 acre-feet of water.

U.S. Bureau of Reclamation

Private dam building was the start of a long tradition, although it was not until the U.S.Bureau of Reclamation (BOR), originally known the federal Reclamation Service, was formed in 1904 that dam building really took hold. Federally managed dams did not need local capital for construction. Federal funds could be used to build dams, to be paid back at low interest rates over a period of many years as the dams earned revenues.

Arizona lobbied for the agency to be formed and was ready with a proposal as soon as it was organized. Roosevelt Dam on the Salt River, the first dam ever built by BOR, was completed in 1911.



Man-made lakes along Arizona Rivers.

"Yesterday the Colorado River was a natural menace. Unharnessed it tore through deserts, flooded fields, and ravaged villages. It drained the water from the mountains and plains, rushed it through sunbaked thirsty lands, and dumped it into the Pacific Ocean—a treasure lost forever. Man was on the defensive. He sat helplessly by to watch the Colorado River waste itself, and attempted in vain to halt its destruction. Today this mighty river is recognized as a national resources. It is a life giver, a power producer, a great constructive force. Although only partly harnessed by Boulder Dam and other ingenious structures, the Colorado River is doing a gigantic job. Its water is providing for many new homes and for the growing crops that help to feed this nation and the world. Its power is lighting homes and cities and turning the wheels of industry. Its destructive floods are being reduced. Its muddy waters are being cleared for irrigation and other uses." Bureau of Reclamation, 1946.

Roosevelt was followed by other dams on the Colorado, Salt and many other rivers throughout the West. Hoover Dam, built in the 1930s, was in its day the largest dam ever built in the world. Today it is only the 18th largest, surpassed by dams in Egypt, India, Russia, China and other countries.

Other federal agencies followed BOR's lead. The Bureau of Indian Affairs, for example, completed Coolidge Dam in 1929, and the U.S. Army Corps of Engineers completed Painted Rock Dam in 1960, both on the Gila River.

A 1942 BOR map shows proposed dams within the Grand Canyon and elsewhere on the Colorado River, an extravagant plan for using the river's full water and power potential. After construction of Glen Canyon Dam in 1964, the great era of dam building essentially was over. Most of the good sites had been taken, and National Park and other environmental concerns overrode demand for more power potential.

The second largest dam in the world

The 1993 Universal Almanac lists one Arizona dam as the second largest in the world, measured in terms of volume of material used in construction. This is not Hoover or Glen Canyon dam, but the dam created by the New Cornelia tailings pond on Ten Mile Wash near Ajo. This dam, finished in 1973, contains 274,445,000 cubic yards of tailings from the copper mining operations. The world's largest is another tailings pond-dam—in Alberta, Canada.

Uses of Dams

Dams can serve four basic functions:

Flood Control Storage space behind dams stores heavy flows to prevent downstream flooding. Water later can be slowly released. Reservoirs should be kept relatively low for this purpose.

Power Generation Water flowing through power plants generates electricity. A high reservoir level ensures full generation capacity. Dams often provide peaking power to respond to customer demand.

Water Supply Water stored in a reservoir can be diverted to irrigation or municipal canals to meet demand. A sufficiently high reservoir level ensures all demands will be met.

Recreation Reservoirs offer recreational opportunities for boating—motorboats, sail boats, and houseboats—water skiing, fishing, swimming, camping and other activities. Relatively stable water levels are needed for boats to use landings and to prevent mud flats from developing.

Dams range in size from the huge Hoover Dam to very small dams for stock-watering purposes. Most dams serve more than one purpose, although dams are operated differently for different purposes. For example, a dam that maintains full capacity will not provide flood control.

Impacts of Dams on Rivers

A dam's impact on a river depends on the dam's type, size and location. Every dam has some downstream and upstream river impacts. The following impacts do not affect every Arizona river.

Upstream impacts of dams

- Changes a river from a narrow flowing watercourse to a wide slow-moving lake.
- Drowns native vegetation and wildlife habitat, including spawning areas for native fish.
- Provides conditions more suitable for the growth of saltcedar and other exotic plants.
- Fluctuating reservoir levels cause muddy shores, with vegetation either drowned or left dry, and uncontrolled by annual cycle.
- Raises water temperature at the surface during certain times of the year.
- Decreases oxygen and nutrient levels causing fish kills and lower fish populations due to decreased food supply.
- Increases surface evaporation causing higher salinity levels and loss of water.

Downstream impacts of dams

- Reduces water levels and even dewaters streams, damaging habitat, with occasional high-level, above-average seasonal flows occurring to meet power demands.
- Blocks rivers preventing the flow of silt and debris so that little new sediment is available to rebuild beaches and to enrich alluvial soil with nutrients.
- Provides conditions more suitable for the growth of saltcedar and other exotic plants than for native trees.
- Slows down rivers and creates lakes which support very different vegetation and wildlife than do flowing rivers.

Detention and Retention Dams and Settling Basins

These dams are generally designed for flood and/or erosion control purposes. They are generally on a relatively small scale and hold back water for a brief time. A detention dam evens out flood peaks by holding back water then releasing it gradually. The same amount of water flows down stream as without the dam. A retention dam holds water for much longer periods, often so that water can recharge or so that sediment can settle to the bottom and help rebuild the streambed. In some metropolitan areas, such as Phoenix, settling basins (often created using small dams) hold runoff from streets reducing flood peaks and contributing to recharge.

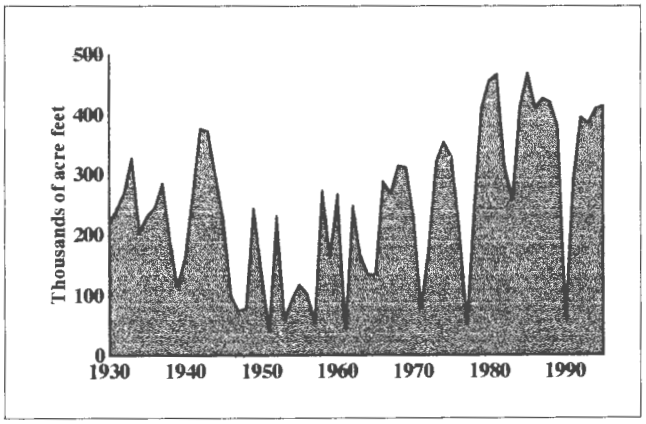
125 135

Diversion Dams

Another important kind of dam diverts water from the river for use elsewhere. Ashhurst-Hayden Dam on the Gila River near Florence and Granite Reef Dam on the Salt River upstream of the Phoenix area are examples of major Arizona diversion dams.

The impacts of large diversion dams are obvious to the casual observer, as they remove large amounts of water from the river, changing it drastically downstream. The Gila, for example, changes abruptly from a deep flowing river to a dry channel at the Ashhurst-Hayden Dam.

- Changes water temperatures because water for power generation is often drawn from the cold depths, resulting in changes of temperature, unsuitable for native fish.
- Changes timing of flows, from heavy spring flows and then lighter flows the rest of the year to highly variable flows depending on power, diversion and flood control demands.
- Increases salinity because of evaporation from reservoirs.



Diversions from Ashhurst-Hayden Dam.

The Glen Canyon Controlled Flood Project

In the early 1980s, a group of scientists, environmentalists, members of the river rafting business and others were alarmed at what Glen Canyon Dam was doing to the Grand Canyon. Large daily fluctuations in flows were damaging beaches and creating havoc on raft trips. A reduction in native fish populations was partly due to the effects of dam releases and party to the introduction of non-native fish.

As a mitigation measure for power plant changes, a large interdisciplinary team made up of state, federal and tribal agencies and scientists worked together on the Glen Canyon Environmental Studies Program. The program was created to study the impacts of Glen Canyon Dam on downstream areas, especially within the Grand Canyon. The studies revealed that vegetation, wildlife, and beaches have changed markedly.

Before the dam, periodic large floods tended to reduce vegetation near the river except in wide areas where beaches were established on inside curves. Since the dam was built, many problem non-native plant species have invaded the canyon, including saltcedar which does well under the new flow regimes.

Sediment which used to move down the river and form beaches during floods, has backed up in Lake Powell. Few new beaches have been formed. Backwaters have filled with sediment since floods no longer wash out accumulated materials. This reduced native fish populations, as the habitat for breeding and living was no longer ideal.

Between the dam and Lee's Ferry, water released from the depths of Lake Powell is cold enough for an important cold-water trout fishery to have developed. The area now is less suited for warm-water native fish.

After years of research, including 13 months of controlled research flows, the study group recommended reduction of the wide daily and weekly fluctuations in water levels. The reseaerchers recommended occasional large releases timed to mimic the natural spring floods.

Evaporation from Reservoirs

In the Colorado River Reservoir system, more than 2 million a.f. of water are lost annually to evaporation. Lake Mead alone evaporates more than 300,000 a.f. annually. Reservoir evaporation accounts for about 800,000 a.f. of water used in Arizona. One effect of this evaporation is to increase salinity in the lake and downstream. Salinity in the Colorado River is naturally high, but increases the farther one goes downstream, until it reaches about 800 parts per million in Lake Havasu, a level high enough to cause problems for plants and people.

Implementing the recommendations would have an impact on power production; e.g., the ability to produce peak power on demand for cities like Los Angeles where power use is less on weekends. Also summer air conditioning requires heavier flows in the summer than in the spring.

An experimental flood was released in 1996 to mimic the effects of a spring flood on a smaller scale than the historical floods. Results are being evaluated. If the project is successful, similar floods may be used on other rivers with similar problems.

Granite Reef Diversion Dam .

Stock Reduction "Saves" Hoover Dam

Hoover Dam, which provides energy for southern California and parts of Arizona, may seem unrelated to the Navajo Nation which is far to the east of it. However, the interconnectedness of rivers is illustrated by the stock reduction program on the Navajo Reservation which began in 1934. When Hoover Dam was being built in the 1930s, engineers were worried that silt deposits behind the dam would decrease storage capacity. The San Juan and Little Colorado Rivers, running through the Navajo Nation, supplied 14 percent of the water in the dam, but almost half its silt. The conclusion was obvious. Overgrazing on the Navajo Nation, with its consequent erosion and siltation would have to stop if the dam was to be saved.

As one federal official explained to the Indians, "Down there on the Colorado River is the biggest, most expensive dam in the world, the Boulder Dam now being built which will furnish all Southern California with water and with electric power, and the Boulder Dam will be filled up with your fine agricultural soil in no great number of years if we do not stop erosion on the Navajo Reservation ... and thereby injure the population of all Southern California and a good deal of Arizona as well." The Soil Conservation Service concluded that if overgrazing was not halted, "the entire alluvial fill of most of the valleys of the Navajo Reservation will be deposited behind the dam...." Even before construction, the Bureau of Indian Affairs forester had reported that 1.3 million sheep and goats were grazing less than 12 million acres, about twice what the land could support.

As a result, about half the grazing animals (many of the goats) were destroyed from 1935 to 1946. Unfortunately, while changes in grazing practices were necessary for range health, the way the program was carried out resulted in enormous hardships for the Navajos, especially after the droughts of the 1930s. Some Navajos starved because goats were a mainstay of their diet and the last refuge when other food sources failed. Livestock and agriculture, which accounted for 54 percent of total Navajo income in 1936, dropped to 10 percent by 1958. Stock numbers have never approached former levels.

The effort, however, failed to reduce silt buildup behind Hoover Dam. By the 1950s silt was still coming down the river as it had for centuries, and building up behind the dam. Overgrazing was only one source of silt. One of the reasons for building Glen Canyon Dam was to solve the Hoover Dam silt problem. Silt now builds up behind Glen Canyon Dam and isn't available to replenish soils and beaches downstream.

BILL WILLIAMS RIVER

The Bill Williams River has high scenic and wildlife value today along much of its length, with much of the river in public ownership. Mining was an important industry in the nineteenth century and is why a steamboat landing is located at the junction of the Colorado and the Bill Williams rivers.

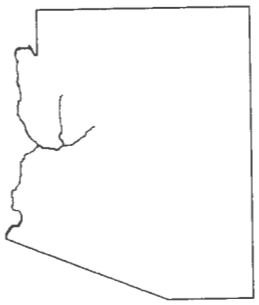
The River

The river system consists of the Santa Maria and Big Sandy rivers joining to form the Bill Williams. A wide, deep alluvial plain occurs at Planet Ranch. In most of the rest of the watershed, the alluvium is shallow and the streambed rather narrow, making it unsuitable for agriculture.

Open land grazing is the principal land use in the headwaters, with mining in the Baghdad area and small (mostly abandoned) mines scattered throughout the headwaters region. Alamo Lake is a popular state park, with boating and fishing facilities. Farther downstream, the City of Scottsdale owns agricultural land at Planet Ranch bought for its water rights, along a river section with a deeper alluvium and broad floodplain suitable for farming. From there to the Colorado River the river is entirely within a National Wildlife Refuge. Six wilderness areas are within the watershed and prohibit motorized travel. The wilderness areas are open to grazing but closed to mineral entry and leasing.

"Following down Williams river, with these interesting animals still for our companions, we continued our march towards the great river of the west. The beautiful stream sometimes emerged suddenly from the earth a bold rivulet, leaping playfully over its gravely bed for several miles, and then would as suddenly disappear again beneath the sand ... ducks and geese were continually frightened from the stream or neighboring lagoons, of which a large number of interesting specimens were added to our collection." C.B.R. Kennerly, a zoologist with the Whipple expedition, 1858.

Explorers



Although it was not as heavily traveled as the Gila or Santa Cruz rivers, some early travelers left images of the Bill Williams River. In 1605, the Spanish explorer, Don Juan de Oñate, merely said, "They arrived at the river of little water; it is called San Andres. From here the country has a hot climate. There were many pitahayas (saguaros) and different kinds of trees. They traveled along it 24 leagues and arrived at the large river [the Colorado] which they had sought because of the report which the Indians had given." Fray Francisco Garcés arrived at the river in 1775 on his travels along the Colorado River. He said, "I came to a river that I named the Rio de Santa Maria. Its bed is very wide, but at this time it was only half full of water. Along its banks are pasturage and every sort of riverland tree. ..."

In 1858 Lt. Amiel Whipple spent several weeks in the area surveying a railroad route. He recorded the river was about 12-feet wide and one-to-two-feet deep, except for a dry stretch five-to-six-miles long. He said the entire valley was filled with cottonwood, willow and mesquite.

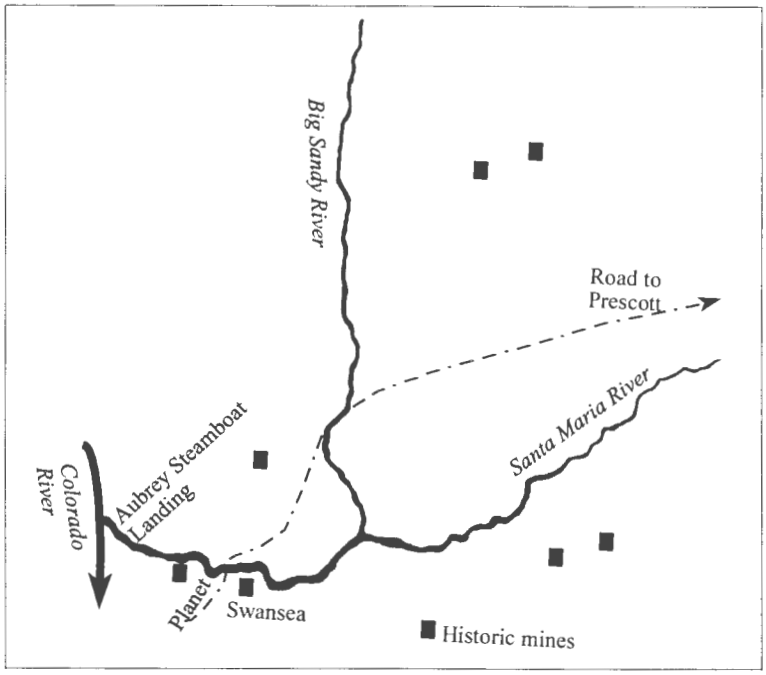
Balduin Mollhausen, a German artist and naturalist, traveled with Whipple. They had come from the east traveling along the Little Colorado River, then over to what is now Flagstaff, and reached the Bill Williams River via the upper tributaries. Mollhausen was particularly impressed with the greenery after traveling the

much more sparsely vegetated areas on the Colorado Plateau.

Mollhausen wrote: "The trees and the reed thickets were in full bud, fresh grass more abundant, good water was always close by so our animals had plenty to eat and drink, so that they had again in a short time become healthy and no days passed in which one or more of these could not be found.

"At first the sand was firm, but then the ground became less firm; the valley narrowed down and we had to leave the river and find a way through wild confused undergrowth and finally the whole valley was under water. It seemed like a big flood and finally we came to a number of dams, which were built with such skill and such intricacy, that the impounded water did not go over a certain height, but also the water level in the pond didn't change. I went back and forth through the high water on my mule and delighted in the skillful construction of the industrious beavers (then in a beaver-house which lay before us). It attracted the attention of some of the soldiers who too marveled at the works and could hardly believe such zeal as half a nation of men could desire. It is natural to mistake the construction of this beaver castle made by these wild creatures for the works of men's hands. It is easy to see why someone who had never seen beavers at work could mistake this beaver castle for human construction."

Joseph Ives, who had traveled with Whipple, came back to the area in 1858. As he traveled up the Colorado River he found a very different river than the one they had seen before. "As we approached the bank I perceived a small dent and after landing repaired to the spot, and found a very narrow gully, through which a feeble stream was trickling, and this was all that was left of Bill Williams Fork. The former mouth is now filled up, and overgrown with thickets of willow. An unusual drought must have prevailed for 2 or 3 years past in the regions that furnish its supply." Apparently Whipple's expedition with its hundreds of sheep, horses, mules and dozens of people left little if any impact on the vegetation, at least at the junction with the Colorado River.



Historic sites along the Bill Williams River.

Mining

In 1864, copper was discovered about 12 miles from the Colorado River and one-half mile south of the Bill Williams. A prospector named Ryland staked five claims for copper and began work in 1865, at the first copper mine in Arizona. Three years later, J. Ross Browne wrote that the Williams Fork District was the best known copper region in Arizona. At first the ore was sent to Swansea, Wales for smelting. In just a few

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"Twelve miles from this place and directly on the road between here and the McCracken mine is where Col. D. E. Buel is erecting his smelting works. The Col. has a large force of men making building material, burning charcoal, getting wood and doing a hundred other things. ... Already there is a town site surveyed and lots are selling at $50. ... I should judge there are about 250 inhabitants." Letter to the Weekly Miner, June 10, 1875.

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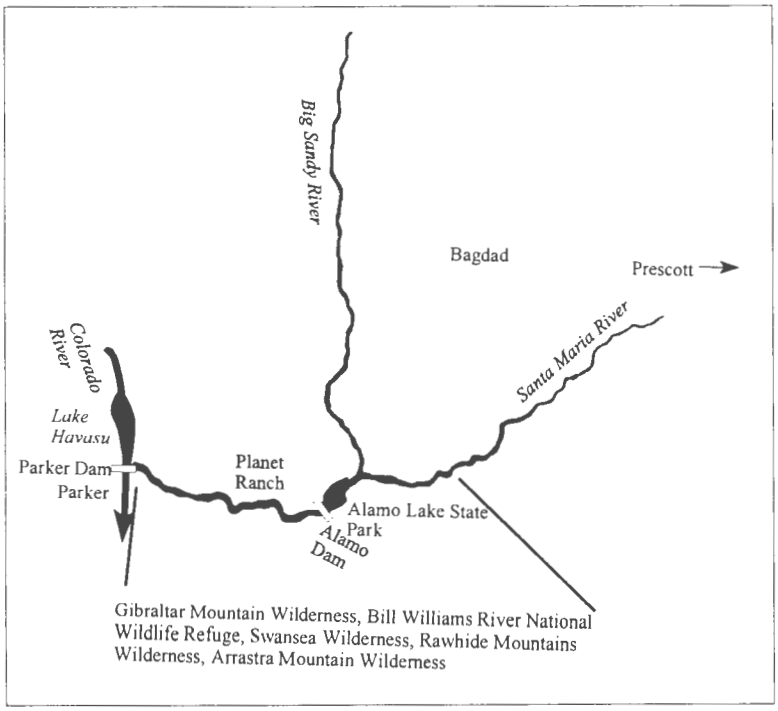
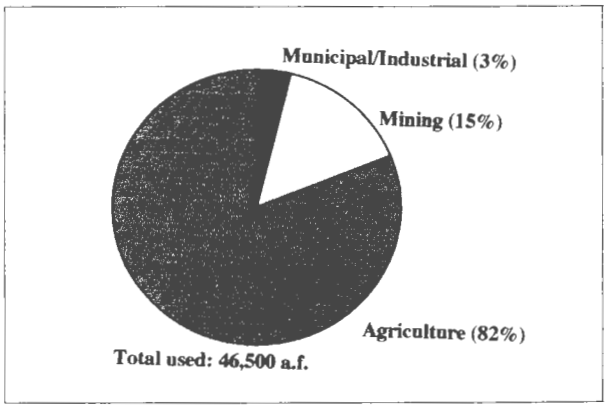
years, a smelter owned by the Great Central Company smelted materials from Eliza mine (near the Planet Mine) turning out 91-96 percent fine ore. The town of Planet had about 500 miners at its peak in 1867. The main road from Yuma to Prescott crossed the Bill Williams River at Planet and continued along the river to the Santa Maria junction, finally crossing the toll road. Many people followed the road through the area. Although the area was largely mined out by 1873, one-million dollars worth of copper had been mined by the time it finally closed in 1917. The Planet post office closed in 1921.

Other notable mines in the area were at Swansea, which mined copper and gold from 1908 to 1934, and the McCracken Mine which opened in 1874. Aubrey City or Aubrey Landing was founded in 1864 at the junction of the Colorado and Bill Williams rivers. It served as a streamboat landing on the Colorado River and a location for mines to ship their ore. When the railroad was completed and steamboats no longer plied the river, Aubrey lacked a reason to exist and quickly closed. The site today is beneath Lake Havasu.



Twentieth century sites along the Bill Williams River



Water use along the Bill Williams River.

Agriculture

Most of the river is not suitable for agriculture, but in the Planet Ranch area and a few headwater locations, alfalfa was grown. Acreage farmed grew from 2,000 in 1931 to 9,000 in 1965. The river's flow decreased as agriculture increased and used more water. Construction of Alamo Dam reduced flows by a third. By 1973, the dry wash was more than one-half mile wide, covered with grass and alfalfa and heavily irrigated by Planet Ranch, a large cattle operation. The City of Scottsdale today continues to grow some alfalfa but is quickly phasing out that operation. Since Scottsdale purchased the land for the water rights, the city has continued to pump water for agriculture to maintain its rights.

Alamo Dam

Although most of the time the Bill Williams River, like many Arizona rivers, flows at a leisurely rate, it occasionally has very large flows. The maximum peak flow in 1891 reached 200,000 cubic feet per second (c.f.s.) past Planet Ranch. Seven times between 1884 and 1927, the peak flow was above 100,000 c.f.s. These occasional high flows had a beneficial flushing effect on the downstream riparian community and provided almost instantaneous recharge to the underground water supply.

In 1941 the U.S. Army Corps of Engineers first proposed building a dam on the Bill Williams

River at a spot known for its large cottonwoods or alamos. It was not until 1969 that the dam was actually completed. Its primary purpose was flood control for lower Colorado River communities downstream from Lake Havasu, although recreation also was a consideration.

Once the dam was completed, the river's flow pattern changed dramatically. Until partially filled, the dam released almost no water, except for occasional flood releases. The maximum lake area is 16,400 acres and provides a productive warm water fishery for largemouth bass. Since the dam's completion, the maximum downstream flow has been 7,000 cfs. By 1978 riparian areas had decreased by 70 percent from historic levels. The dam has completely changed the character of the river upstream by forming a lake. The dam captures upstream sediment, with the result that less sediment is available downstream to rebuild beaches after floods. The level of the lake frequently changes. After major storms the lake level may rise by many feet in a short time, flooding out nests.

"When the Bill Williams River Basin was first occupied by white men, the hills and valleys were covered with grass, shrubs, and scattered trees. In subsequent years the promiscuous cutting of trees and the burning of timber and brush, in addition to overgrazing, have reduced the vegetal cover so that now the vegetation is relatively sparse, except in small areas at the higher elevations." U.S. Army Corps of Engineers, 1944.

Another dam, this time downstream, also has affected the river. When Parker Dam on the Colorado River was completed in 1938 forming Lake Havasu, the mouth of the Bill Williams River for about four miles upstream changed from the creek Ives had observed in 1858 to a wide marshy area, with silt accumulating behind Parker Dam.

A birdwatcher enjoys the Bill Williams Refuge, 1994.

Wildlife

Historically a great variety of wildlife was found along the river. Travelers reported large flocks of waterfowl and turkey, enough for feasting. They also reported antelope, deer, beaver, bighorn sheep, wolves, and coyotes. Along today's river 251 bird species have been reported, 34 reptile and amphibian species, and 26 mammal species of which ten are bat species and most of the rest rodents. Beaver still build dams along the river, but not of the size Mollhausen described.

Preservation and Restoration

In recent years many miles of river have been preserved and restoration has begun. The new marsh created by Parker Dam contains some 100 acres of cattails which have proven to be ideal habitat for over 100 bird species. In 1941, the Lake Havasu National Wildlife Refuge (including much of the present Bill Williams Refuge) was established as mitigation for loss of riparian habitat along the Colorado River. It now extends nine miles from the Colorado River to Planet Ranch, covering 1,900 acres.

"The shallow water was covered by thousands of birds, who usually sported on its surface undisturbed, but at the approach of our procession they fled; and shot after shot was heard in all directions, echoing among the rocks and hills. I happened to be one of the foremost of our party, and had thus an opportunity of obtaining a fine harvest of various kinds of ducks, many of them with splendid plumage, that would be an ornament to our collection." Balduin Mollhausen, 1855.

In 1991, seven state and federal agencies formed the Bill Williams River Corridor Technical Committee to develop recommendations for improved dam operation to benefit the river and the wildlife refuge, while maintaining the flood control characteristics of the dam and lake. A target lake level was agreed upon to protect upstream and downstream species. Dam releases are to be timed to help regenerate the cottonwood-willow forests downstream and will to some extent, mimic the natural flows of the river, with spring flows adequate for cottonwood seedling establishment. It is projected that these changes along with reduced pumping at Planet Ranch will result in a greatly restored riparian habitat. The final recommendations are being implemented and have done much to restore the integrity of the river and riparian area. BLM manages wilderness acres along and near the river.

Changes in the River

The Bill Williams River (named after explorer and adventurer, Bill Williams) has had far fewer long-term changes than most other low-elevation Arizona rivers. This is because it is remote, being inacessible by roads and railaroads, and it is unsuitable for use in urban or agricultural development. For a relatively short time mining impacted the river, but its long-term impacts have been less here than in many other areas. While there has been some pollution from abandoned mines, the greatest long-term impact is the result of deforestation of the surrounding hillsides, with resulting soil erosion. Overgrazing in the upper watersheds also has led to increased erosion and soil loss. Also agricultural water use impacted the river at Planet Ranch and downstream, but with agriculture using significantly less water the downstream vegetation is recovering.

Alamo Dam provides the major continuing impact to the riparian area. By altering the operation of the dam, this impact now is being mitigated to some degree. Arizona State Parks, U.S. Bureau of Land Management and the U.S. Fish and Wildlife Service own much of the river from Alamo Lake downstream. Through public ownership the river is being preserved and restored.

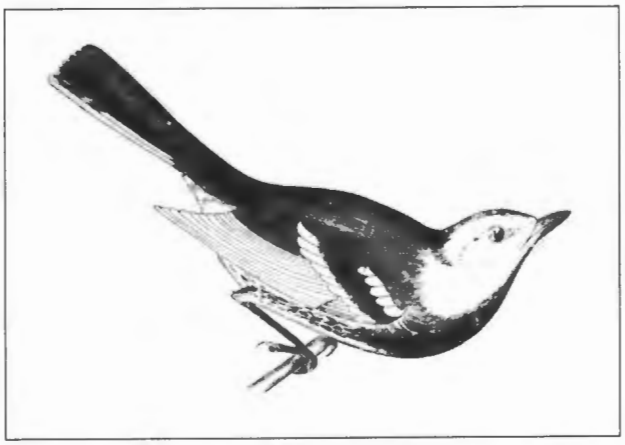
"After breakfast B. and I take our guns and by way of a tree-trunk cross the 'Bill Williams' river which falls into the Colorado just below Aubrey. It has little water at this season; its size is almost the same as that of the Loire at its point of emptying into the Arve.

Its banks are covered with mesquite trees, willows, and cottonwoods. We cross a little sandy plain in which we notice a small field of wheat ... the 'Bill Williams' valley is very pleasant; everywhere there are handsome cottonwoods and forests of willows and mesquite ... we go down to the river bank to follow its course back to Aubrey, but it is all sand and the walking is tiring. We take off our shoes, roll up our trousers and, attracted by the clearness of the water and the fineness of the sand, we walk in the middle of the river for nearly half an hour. ..." Francis Berton, 1878.

Walnut tree leaves, drawn in 1854.

RIPARIAN AREAS, CIENEGAS, AND WILDLIFE

To determine the change in vegetation and wildlife information must be pieced together from many sources that often are sketchy at best. Before historic records, information about wildlife and vegetation is inferred from studies of archaeological excavations, prehistoric art, pollen analysis, and fossil packrat middens. Historic records often contain information about vegetation and wildlife, especially when travelers noted species they had never seen before. Their descriptions, however, were often incomplete and inaccurate. Species that could be eaten were more likely to be recorded than insignificant species such as native fish. Eliott Coues was one of the first scientists to carefully record wildlife and vegetation in Arizona. Balduin Mollhausen and C.B. Kennerly were other gifted artist-scientists. Until the twentieth century, however, few systematic surveys of vegetation and wildlife were conducted. Despite these difficulties, many conclusions about change still can be reached.



Black-throated green warbler drawn in 1878.

Riparian Areas

Riparian areas often are visible from a distance as a thin line of green vegetation, very different from the surrounding desert plants. Riparian areas are found along streams with vegetation and wildlife. Most natural rivers provide water and land for species of trees and other plants needing more water than the dry desert provides. Riparian areas may be associated with streams that flow all the time—perennial streams—or with those that flow only part of the time, or even flow underground. Even apparently dry desert washes support narrow ribbons of green vegetation.

The typical picture of a healthy riparian area includes huge cottonwood trees, willows and shrubs. While this represents one important kind of riparian area, other valuable riparian areas may contain few or no trees. For example, in the 1880s Cienega Creek, a tributary of the Santa Cruz River, had fewer cottonwoods than it has today, but had extensive sacaton meadows and marshy areas with aquatic plants. Sacaton is a tall bunching grass, once much more common than it is today. At higher elevations sycamore trees may line the streams, along with walnuts, ash and others. At the highest elevations, trees such as ponderosa grow both along the river and in the surrounding forest. In the dry washes of the deserts, hackberries, acacias, and palo verdes may predominate, relying on occasional streamflow.

A non-scientific description

"The body is as large as a flour barrel, five feet up it forks into four stems, the whole highth [sic] is not less than 20 feet. Take a bundle of rods, 2 inches in diameter, tie them together, paint a delicate green, stick some pins, point outward in the center of each rod the whole length, and you have a pretty good idea of this species of cactus. ... One of the stems was broken off, the whole tree looked as if the slightest wind would blow it down."
James Bell, 1854.

Cienegas

Cienegas are marshy areas that support aquatic plants and animals. They often are fed by one or more springs or by a geological formation which forces groundwater to the surface.

Cienega vegetation has few trees, but many lower plants—bulrushes, reeds, cattails, sedges, seep-willow, arrowweed and others. Cottonwoods and willows often grow along the edge of cienegas. Like riparian areas, cienegas support a great diversity of plant and animal species. At least 40 species of aquatic plants are commonly found in southern Arizona cienegas, along with more than a 100 other semi-aquatic and riparian plant species.

Cienegas are biologically very important areas. Many species of fish, frogs, and snails are found in cienegas as remnant populations from times when riparian areas were more extensive.

In southern Arizona, the most important cienegas were in the San Simon Valley, Sulphur Springs Valley, San Pedro Valley, Santa Cruz Valley, Arivaca, Cienega Creek and the Gila River. Some of these cienegas are discussed in the chapters dedicated to those areas.

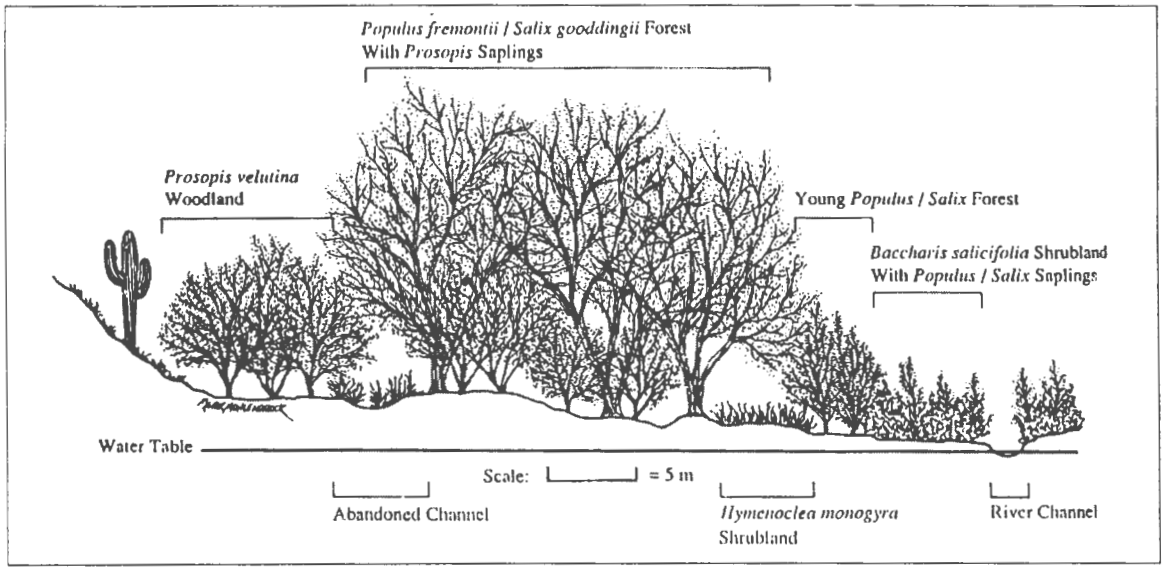
People who settled near cienegas often found them objectionable because they correctly associated them with diseases such as malaria. Cienegas seemed to serve no useful purpose. Some, such as the cienega at Fort Buchanan, in the headwaters of the Santa Cruz River, were intentionally drained for health purposes. Others, such as the one at San Xavier, emptied when water supplies were used. Overgrazing and subsequent arroyo cutting damaged others.

"The present scattered distribution of cienegas makes them aquatic islands of unique habitat in an arid-land matrix. Among rapidly disappearing aquatic habitats of the Southwest, cienegas have a definite potential for perpetuation, and should be given high priority as a unique remnant of our natural Heritage." Hendrickson and Minckley, 1981.

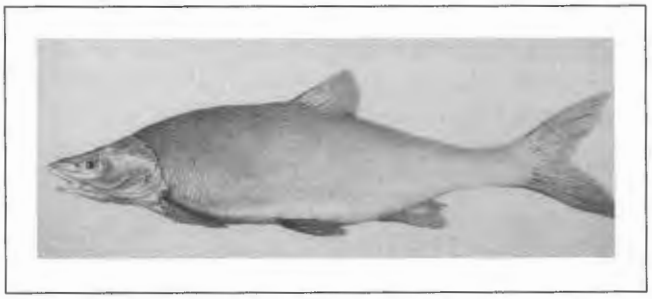
Riparian Areas and Cienegas are Important to Wildlife

Arizona has a great diversity of habitats. Some of the hottest deserts in the world are found within the state. Yet despite the heat and dryness, the desert is not a desolate moonscape—it is a place full of life.

Hot deserts are only one of Arizona's many faces. In contrast, the northern part of the state has mountains that provide a completely different environment, a different face. Southern Arizona also has mountains. A series of separate moun-



Riparian vegetation zones.



"Gila trout" drawing, 1846.

tain ranges stretches south of the Gila River, from west of the Santa Cruz River to the New Mexico border. These "sky islands" are forested and relatively cool and moist at the higher elevations. The riparian areas that extend from these mountains into the desert act as corridors for traveling wildlife. Less mobile animals, though, have remained relatively isolated by a sea of desert over geologic time. Sky islands act as harbors for many species, some that cannot be found anywhere else on earth. Plants and animals in these remnant habitats are particularly sensitive to disturbance.

Arizona's rivers provide an important harbor for many species. Literal oases, rivers and streams cut through mountains and deserts. Especially in the deserts, waterways act as corridors, shelters, and foraging areas. Riparian areas are the most productive ecosystems in the desert. Riparian vegetation efficiently converts the sun's energy into leaves, seeds and wood, to be used by many creatures. Riparian vegetation produces huge volumes of food used by a great diversity of animal species. For example, over 450 species of birds can be found at the San Pedro Riparian National Conservation Area.

The productivity of riparian areas even extends to dry washes which contain as much as ten times more species than the surrounding uplands. Fish and amphibians are clearly dependent on water. Not so obvious, perhaps, are the needs of some mammals (the beaver) and many birds (ducks and shorebirds).

Compared to pre-settlement times, many aquatic species are scarce or absent. This also is true of other animals that are not strictly aquatic but use riparian habitat for nesting, foraging, shelter, or migration. The loss of such wildlife is one indicator of our troubled waters.

Arizona's diverse habitats attract diverse wildlife. There are 788 native and 74 non-native species of vertebrate wildlife in the state and thousands of species of insects. Many of these are dependent on Arizona's rivers for part of their life cycle, for foraging or for shelter. In the Southwest, 60 percent of all species are directly dependent on riparian areas (riparian obligate). Another 10-20 percent use riparian areas for part of their life cycle, but not all of it (facultative users).

Fish

Although the definitive study of changes in Arizona's fish species is in the processs of being written by Dr. W.L. Minckley, of Arizona State University, and records of former fish populations are limited, scientists have enough information to consider native fish highly threatened in Arizona, and their numbers much reduced from previous times.

The Colorado River Basin contains more endemic native freshwater fish species, than any other river in North America. Endemic species are found in one area and nowhere else. This means if one of these fish species is lost from the Colorado Basin, the species is extinct.

Fish caught by Carl Miller on the Colorado River, 1918.

Historic beaver lodge.

The Colorado, Gila, Salt, Little Colorado, and San Pedro rivers all sustained healthy native fish populations during pre-settlement times. The Colorado squawfish, or "salmon," once was found extensively in the Colorado Basin, wherever moderately deep water occurred. It is one of the world's largest minnows, reported to have grown as large as 6 feet long and 100 pounds. Until the early 1900s, the squawfish was abundant within the basin. They drifted into irrigation ditches, and were scooped out by the hundreds for use as fertilizer. They also were an important food fish for Indians who dipped them out of the river with nets. Squawfish require fast-moving, swift water and cannot coexist with dams and reservoirs. Overfishing and the damming, diversion and dewatering of the squawfish's native habitat led to extirpation of the fish within the first century of Anglo-American settlement. The last known natural Arizona specimens of squawfish were collected in 1969, although some natural populations remain in the Upper Colorado River.

The humpback chub was found in the warm, fast waters of the Colorado River and its tributaries. Today, it is the rarest of Colorado River fishes, almost extinct in the wild and persisting mostly through hatchery breeding programs.

The Gila topminnow and the Yaqui topminnow (both subspecies of the Sonoran topminnow) once were found throughout the Gila River Basin. The Gila topminnow was the most common fish in the Gila watershed, but now is limited to 11 natural and a few reintroduced populations. The Yaqui topminnow persists only in the San Bernardino National Wildlife Refuge.

Refuges and other protected areas are essential harbors for other species besides the Yaqui topminnow. The Quitobaquito pupfish, one of the two pupfish subspecies native to Arizona, is found only in Organ Pipe Cactus National Monument. The other is the desert pupfish. It was extirpated from Arizona in the 1950s, and attempts to transplant it from Mexico have not succeeded.

The Sonoran topminnow has been the subject of one of the most intensive reintroduction programs in Arizona. More than 350 attempts at restocking have been made since 1982, but populations continue to decline because of habitat loss and competition with non-native species, like the western mosquitofish.

Dams, the loss of water, and the introduction of exotic species have had similar effects on many of Arizona's native fish. A summary of the condition of the fish fauna in some of Arizona's rivers in 1961 showed how exotic species were replacing native fish. Arizona was the only southwestern state with more exotic fish than native ones (28 native and 37 stocked). In the San

Reintroduction of Beaver

Historically, beaver lived throughout the state, almost anywhere perennial water and appropriate vegetation could be found. After the trapping period, beaver numbers were greatly reduced, but bounced back by the time the first American settlers arrived. New pressures once again reduced beaver numbers—overgrazing of riparian areas, loss of water supply, extermination policies and conversion of lands to new uses, such as agriculture and towns.

Mrs. Della Bohn Etz, who lived along the San Pedro River 22 miles north of Benson, Arizona, said that beaver on the river were mostly trapped out by 1883. But, she adds, the drying of the river by agricultural diversion, livestock pressures, and "the drought of 1891-1892 finished everything."

"Johnny Beaver and his mate, Betty Beaver are the construction engineers of the animal kingdom according to the bed-time stories and their ability is recognized by the Arizona state game department. Twelve beavers will be placed on the streams of the Chiricahua mountains to protect trout. The animals will be caught along the banks of the Black River in the White Mountains and moved to the southern part of the State. The beavers will build numerous small dams along the streams, it is believed, and thus keep the fish from going down with the high waters in the spring. The dams will impound them until they will be of such size as to furnish ample sport for Arizona Isaak Waltons." Tucson Citizen, September 13, 1932.

Beaver ponds raise the water table so that in times of low rainfall, water seeps from the banks and there will be more water in the river longer. The riparian strip is wider, so grasses and trees grow farther out. This creates more wildlife habitat, and since much of the native wildlife in Arizona persists only in the presence of a healthy river this is a meaningful accomplishment. The increase in vegetation also helps slow erosion. Lots of small ponds farther up on tributaries slow water down in times of flood, holding silt near the source. Large human-made dams on a river capture silt from many miles upstream, and it settles underneath the reservoir. Beaver ponds fill up with rich soil and are responsible, over long periods of time, for creating wide, moist, fertile meadows. The shallow ponds behind the beaver dam might have fish and other aquatic species, perhaps even ducks floating on the glassy surface.

In order to bring back some of the benefits of beaver dams, in the 1940s the Arizona Game and Fish Department trapped beaver in the Colorado River, the most reliable population in the state, and transplanted them into the Hassayampa River, Mineral Creek, and some mountain tributaries of the Santa Cruz and San Pedro Rivers. In the 1950s, "Operation Beaver Lift" transplanted nuisance beavers from irrigation ditches into rivers. Neither of the programs, however, had great success and no follow-up studies were published. One area where reintroduction was successful was along the Mogollon Rim. No beavers survive in the Chiricahua Mountains,

"During the last 10 years Arizona authorities have relocated more than 500 beavers, especially in the central and southeastern parts of the State. Officials express enthusiastic approval of the results. In the wild Mogollon Rim country, for example, the animals have not only survived but prospered. Where seeps trickled in springtime, beaver dams now store water. Where topsoil washed away during heavy rains, lush meadows now grow. Where grass previously was parched by midsummer, the water table has risen and keeps the sod wet. Where wildlife and livestock once watered at stagnant pools, they now drink from natural streams." National Geographic Magazine, May 1955.

One aspect of the San Pedro Riparian National Conservation Area's 1993 Habitat Management Plan is to reintroduce extirpated species. Beaver will be one of the first species reintroduced. Plans are underway to introduce sterilized beaver into Aravaipa Creek. They will be sterilized to ensure that numbers don't increase to the detriment of vegetation, until results can be evaluated.

Pedro River, 11 native fish species were identified in 1890. By 1950 the number of native fish species had dropped to three. On the Colorado River near the Gila River confluence, seven native species were present in 1854. The carp had been introduced by 1890, and the native flannelmouth sucker had already been extirpated. In 1950, all seven of the native fishes were gone. Two new fish native to the basin had entered the river, the machete and the euryhaline striped mullet. Both new appearances were attributed to the loss of the predatory squawfish. All seven of the native fish from pre-settlement times were replaced by 12 new exotic species and no longer inhabit some rivers.

This pattern of species extinction or displacement has been widespread. In many cases, non-native fishes have been purposefully introduced for sport fishing. Others entered rivers that once had competing native fish to exclude them (as in the case of the squawfish, described above). Still other non-native fish thrive in the new habitat created behind Arizona's many dams.

The Arizona Game and Fish Department lists 30 native freshwater fish, two native saltwater fish, and 50 non-native fish species. Eighty-one percent of this state's remaining native fish are proposed or listed as threatened or endangered. Since most of Arizona's rivers have been modified by dams, channelization, or dewatering, the prospects for natural recovery are poor.

Cook's Lake near the San Pedro River in 1990.

The recovery of native populations will only occur through intensive management programs.

Amphibians and Reptiles

About 80 percent of amphibians found in the Sonoran Desert require riparian areas for at least part of their life cycle. A frog living in desert water is a particularly vulnerable creature. Springs, cienegas, and even stockponds can be home to a population of frogs or fish that will be eliminated if the water disappears.

Reptiles generally are not as dependent on riparian areas as amphibians. In Arizona, two turtle species, one lizard, and three snakes need riparian habitat.

Amphibians and reptiles also are suffering from the loss of habitat and the introduction of non-native species. For example, the bullfrog, the largest frog in North America and native to waters in eastern and central United States, has been introduced to the waters of the West. This has led directly to the decline in native frog and snake species, including the Yavapai and Chiricahua leopard frogs and the Mexican garter snake. Crayfish, introduced by fisherman who use them for bait, are a major threat to native frogs in northern Arizona. In some areas these voracious creatures have eliminated native frogs.

Birds

Arizona has a diversity of avian life that rivals almost any other state. The number of bird species documented in Arizona is 502. One of the three major migration routes that vertically split the continent cuts through Arizona. The San Pedro River Valley, directly on the route of birds which migrate to the tropics of Central and South America, has recorded more than 450 species. Birdwatchers come here from across the world to catch a glimpse of many unusual birds.

During the migratory season in Arizona, even some experienced birdwatchers may see more species in one day than they had observed all their previous years combined. Even the small riparian reserves across the state are exceptional birding areas. Over

200 bird species have been seen at the Patagonia Nature Preserve on Sonoita Creek and at the Hassayampa Nature Preserve.

As riparian habitats and cienegas have disappeared over the last century, the diversity of bird life also has dropped. On the Salt River near the Verde River confluence, 32 species of breeding birds dependent on the riparian cottonwood forest have disappeared between 1930 and 1980. Twenty-five riparian-dependent species on the Gila River Indian Reservation have been extirpated since the early 1900s. This loss of diversity can be attributed to the dwindling riparian habitat.

The last grizzlies in Gila County about 1912.

Pelicans, egrets, herons, ducks, geese, and swan were reported to be found in significant numbers across Arizona. Warner's Lake, a small reservoir created by damming the Santa Cruz River at Tucson between 1870 and 1890, had so many ducks and geese that shooting rights were sold to a local sport-hunting group. Waterfowl were plentiful on the Gila, Salt, and Colorado rivers.

Today the distribution of many birds is limited relative to pre-settlement times. Arizona's streams, rivers, cienegas, and other natural waters have been reduced in number and quality, with the result that birds dependent on them have suffered as well. Not only do riparian species diminish, but some of the many migratory species that travel through Arizona also may be affected. One study determined that 20 bird species have reduced their range in New Mexico and Arizona and 36 species have increased their range, of which 6 were introduced from elsewhere (most notable starlings). Increased ranges are primarily in the moutains, rather than along lowland riparian areas.

On the other hand, some human-made wetlands offer new habitat. Reservoirs behind dams also provide new habitat areas for waterfowl. Along the Colorado River, backwaters created by dams are good waterfowl habitat. Some of the best bird-watching in the state is at wastewater treatment ponds. It is important to keep in mind, then, that trade-offs exist. Some riparian areas are reduced while others are created.

Mammals

In 1867, Dr. Elliott Coues published his field notes on the mammals he had observed or had some reason to believe existed in Arizona. He said approximately 70 species of "quadrupeds" are found in the territory, but that naturalists were just beginning to study the native fauna. Among the animals he described were eight kinds of bat, an unknown number of shrews and voles, the cougar, ocelot and jaguar. Bobcat were quite abundant, but did not rival the canines in number.

Mexican wolf were present, as were the grey fox and kit fox. The most numerous animal in the territory, though, was the prairie or barking wolf, otherwise known as the coyote. Coues reported that it was by far the most numerous carnivore in Arizona and probably every other part of the West. The noisy creature was "... so annoying, that a variety of means are employed to destroy them." Coues' list was hardly complete. Journals of other early naturalists confirm the presence of black and grizzly bears, as well as bighorn sheep, antelope, and several kinds of deer. It is difficult to define what effects a changing river would have on some of these mammals.

The coyote still is a common animal in Arizona, having adapted relatively well to life with

humans. The grizzly bear, wolves, and some of the cats are no longer found in Arizona. During the settlement period, and even well into the 1900s, predators were shot on sight. The philosophy was that the predators were dangerous to human life, livestock, and game species. This attitude led to the loss of some species.

Another reason for mammal species lost is habitat destruction. We do not always understand how important riparian habitat is to bears, wolves, and some other species. However, it is clear that some mammals are water dependent. Beaver, river otter, muskrat, and the water shrew must have a dependable water supply for survival. Other mammals found primarily in riparian areas are some bats, ringtail cat, raccoon, Arizona gray squirrel and Apache fox squirrel.

The muskrat, like the beaver, once was commonly found in cienegas throughout Arizona. Its current distribution is limited to declining cienega habitat. The Colorado and Gila rivers, as well as their major tributaries, were all home to a southwestern subspecies of river otter. The otters in Arizona were quickly affected by changing rivers after settlement. No clear records exist, but it is likely that very few, if any, native otters have existed in Arizona since 1960.

Some species of bats, like the red bat, use riparian areas for roosting during the day. Many others use the waterways as foraging grounds. Loss of vegetation or water would make these areas unsuitable for these bats. In fact, the riparian corridor is an essential area for traveling, hunting or shelter for many mammals. Like bats and otters, many mammals suffer when rivers lose water or vegetation.

Fourteen mammal species have increased their range since 1890 in Arizona and New Mexico, most notably rodents, squirrels, coyotes, mule deer and elk, primarily in the mountains. Eleven introduced species became established including several rodent species, burros, horses, and goats.

Threatened and Endangered Species

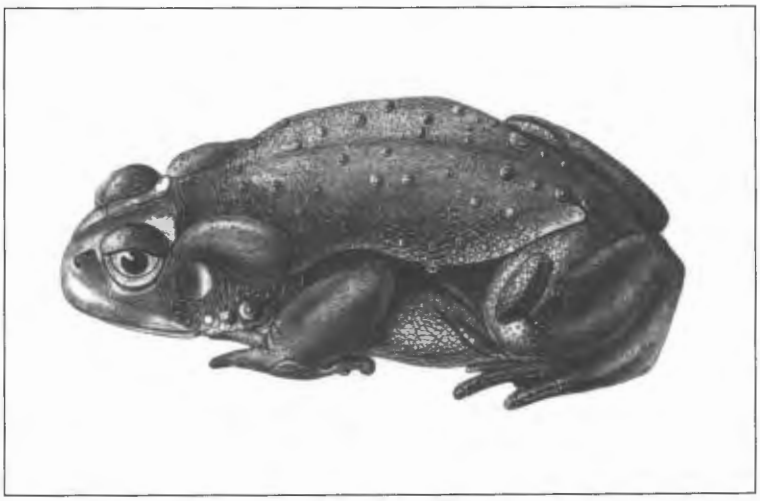
An animal that depended on Arizona's waters and now is extinct is the Monkey Springs pupfish. Found only in Monkey Spring in Santa Cruz County, the fish became extinct in 1971 because of habitat loss and predation by exotic largemouth bass. The relict leopard frog was thought to be extinct for some time, but recently was found to be persisting in Nevada.

In 1988, the Arizona Game and Fish Department identified 26 fish and nine amphibians to be proposed or listed as threatened or endangered. All of these species rely on healthy water sources for survival. Seven of the listed fish and amphibians are no longer found in Arizona. Others are limited to small, remnant populations.

	Candidate	Threatened	Endangered	Extirpated	Extinct	Total
Fish	2	7	17	5	1	**32**
Amphibians	4	1	4	0	1	**10**
Reptiles	7	1	2	0	0	**10**
Birds	20	11	11	0	0	**42**
Mammals	3	4	14	4	6	**31**
Plants	90	5	10	0	4	**109**
Total	**129**	**29**	**58**	**9**	**9**	**234**

Loss and decline of plant and animal species in Arizona.

Journals and diaries from the early days of exploration show that many riparian birds were more plentiful before Anglo-American settlement. Arizona Game and Fish lists 42 species of birds as threatened or endangered. At least 25 of these are directly dependent on riparian habitat. Many other migratory species use riparian areas as corridors for migration. The loss of foraging and resting areas could be devastating to dozens of species of migrating birds.



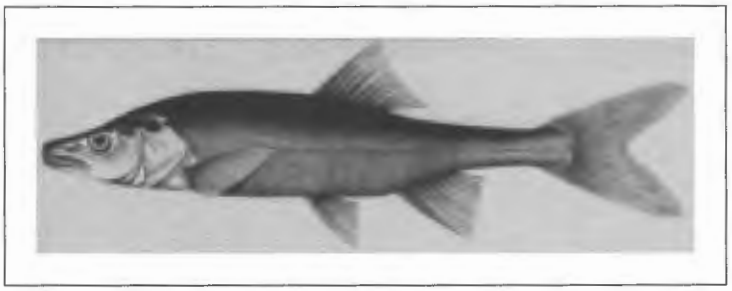
Colorado River toad drawn in 1858.

Four of the 24 listed mammals are found primarily in riparian habitats. These include the water shrew, the Hualapai Mexican vole, the southwestern river otter, and the red bat. All of these species are in danger because of threats to Arizona's rivers, streams, and cienegas. That aquatic species are the most threatened is particularly disturbing because they often are basic to a healthy biotic systems. Recent studies by The Nature Conservancy showed that aquatic species are becoming extinct much faster than other species. The study identified the same causes as listed above: habitat loss, the introduction of exotic species and pollution.

Arizona has far fewer riparian areas and cienegas than before it became part of the United States. Some have become lakes and some no longer have reliable water supplies. The obvious impacts on wildlife have been discussed above. Another less obvious impact is the loss of corridors between areas. Birds can still migrate, but many terrestrial animals have become marooned and isolated, with a loss of genetic diversity necessary for strong populations.

Being marooned often means that populations of animals become isolated and have a smaller genetic pool for healthy reproduction. Large predators need extensive territories and may not be able to find mates they are not related to in these shrinking habitats.

Conflicts between wildlife and humans have accelerated as human populations increased. Roads are one of the most obvious problems for wildlife as can be seen from frequent road kills of deer, javelina, coyotes and other mammals.



Fish found in the San Pedro River in 1858.

Riparian areas, even dry washes, often serve as important corridors for mammals and reptiles as well as birds. Loss of riparian areas, then, can have even greater consequences than just loss of a particular feeding or nesting area. The problems are compounded when those areas have extensive growths of non-native vegetation that many species cannot use.

New Plants Reach Arizona Rivers

Most of Arizona's native wildlife developed with the native plants, eating them, making nests in their branches and using their wood or leaves. Thousands of new plant species, however, have been brought into Arizona in the past century. Most of them cannot thrive in the desert without human care, but more than 325 plant species brought from other continents have become naturalized in Arizona. Some have become agricultural, range, or garden weeds; some have had little effect; and a few have greatly changed Arizona's rivers and their watersheds.

Saltcedar

Saltcedar has changed Arizona's rivers more than any other exotic plant. Introduced in the nineteenth century for landscaping and erosion control, saltcedar was found along the Gila River by 1898. By the 1930s, it was considered a major problem, crowding out native cottonwood and willow and using large amounts of water. Its tendency to clog channels increases flooding. Saltcedar germinates easily and produces thousands of seeds which can germinate for months. Cottonwoods in contrast have specific germination needs, related to the normal spring floods. Seeds are only viable for about a month at the time when winter snow melt reaches the valleys. They need moist soil to germinate, but then need drier conditions as the seedlings grow. In areas where this natural flow pattern is altered—often upstream and downstream of dams—saltcedar germinates when cottonwood cannot and soon dominates. Grazing favors the growth of saltcedar.

Exotic Species: a kind of plant brought (usually from another continent) by humans to a region where it did not grow previously.

Major Introduced Invasive Plants on Arizona Watersheds

Bermuda grass
Buffel grass
Camelthorn
Filaree
Johnson grass
Lehmann s lovegrass
Mediterranean rice grass
Red brome grass
Russian olive
Saltcedar (Tamarisk)
Speedwell
Sweet clover
Tree of heaven

Saltcedar-dominated rivers support different wildlife communities than do cottonwood-willow dominated rivers. White wing doves do well in saltcedar, but few other species do, although the endangered Southwest willow flycatcher is adapting to saltcedar. Beavers will use saltcedar in their dams, but generally avoid eating it.

Grasses and Other New Plants

Many of the exotics in the watersheds are grasses or other forage plants, brought to replace native grasses lost to overgrazing. They often are aggressive and outcompete native plants. In some areas fires have increased because of the prevalence of these new grasses. This is a big problem in the Sonoran Desert where cacti are not adapted to fire and where grass did not previously grow so profusely. Revegetation of damaged or burned areas often is done with exotics that grow faster and more predictably than the natives.

COLORADO RIVER

The Colorado is one of America's great rivers, traversing seven states. Its long, colorful history goes back thousands of years and includes fishing, farming, mining, and steamboats. Today its commercial importance is closely linked to dams that provide power and water for millions of people in the West. The river also contains some of the most spectacular scenery in the United States, from the canyon country of Utah to the Grand Canyon of Arizona.

The River

The Colorado River's watershed drains 242,000 square miles in seven states, about one-twelfth of the area of the continental United States. The river originates high in the Rocky Mountains and empties into the Gulf of California, some 10,000 feet below. It has long been a highly unpredictable river carrying more than 24,000,000 acre-feet of water towards the ocean in some years and less than 5,000,000 in others. The name "Colorado" ("red" in Spanish) comes from the color of its waters that carry sediment from colorful sandstones and other rocks. At one time sediments gradually moved downstream with spring floods, forming beaches and the Great Delta where the river meets the ocean. The spring floods often caused changes in the course of the river.

Most of this chapter deals with the river downstream from the Grand Canyon, the segment most affected by human activity, focusing only the human impacts on the Arizona and Mexican sections of the river. To go farther afield would require an entire book.

Early History

The story of the river goes back millions of years when thousands of feet of rock layers built up and were subsequently cut through to form the Grand Canyon. This geological history, although a fascinating story, is far beyond the scope of this chapter. Our history begins with the people who first settled near the river in Arizona, perhaps 10,000 years ago. The earliest settlers primarily lived by hunting and gathering. Agriculture later developed, with seeds planted after the spring flood to take advantage of the moist soil and the fresh sediments that the floods carried. This made the soil highly fertile. In some years there was too much water, and the seeds could not germinate. In other years too little water came to create a good flood field. In such years the farmers depended more on hunting and gathering. The best farm land was limited, and there was considerable competition for the best flood fields. Over the centuries warfare was more a way of life along the Colorado River than in many parts of

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"Planting was begun when the mud of the sloughs began to cake at the surface. This coincided with the dawn rising of the Big Star, xamacevetai, which was early in spring ... planting cannot begin until after the inundation has dropped sufficiently to free the plots from stagnant water. In normal years the land was in fit condition for planting when the Pleiades first appeared in the east in the morning, (late June). All plants should be in the ground before Orion first appeared at day, for plants sown later would not get enough water from the ground. A little corn and some melons were also planted in February in damp places. The Spanish introduced wheat as a winter crop."
Cyril Forde, 1931.

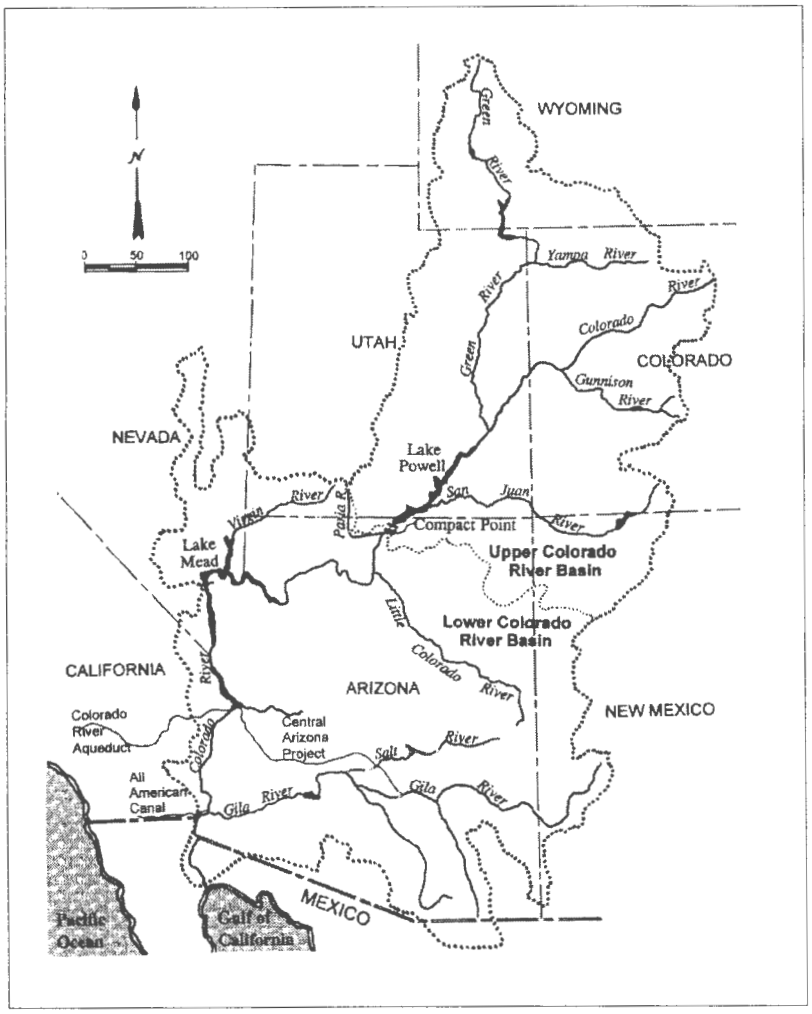
Arizona, with changing groups occupying new areas.

About 5,000-6,000 Cocopah inhabited the southern-most part of the Colorado River Valley, from the Coachella Valley to Cerro Prieto in Baja, living around the shores of a large lake that dried up sometime in the fifteenth century. Much of the Great Delta was under water when the Spaniards initially arrived. Freshwater and ocean fish were an important part of the Cocopah diet as were agricultural crops grown with flood irrigation. Their boats ranged in size from one that resembled a big square bird nest made of willow or cottonwood roots, to larger log rafts on which people lived, with clay floors for the hearth.

"Single cottonwood logs were sometimes used by the Yuma to carry a small party or load down the river. Large pottery vessels were also used to ferry goods and children from one bank to the other, the swimmer paddling the receptacle in front of him. Individuals would also travel considerable distances on half-submerged floats. A bundle of rushes and canes was attached to the fore end of a relatively slender pole; the man sat astride the other end, which sank down, and propelled himself with his arms." Cyril Forde, 1931.

The Quechan (Yuma) Indians lived much the same way a little farther north and took advantage of the annual spring flood for their crops. Their lifestyle was not as water-oriented as the Cocopah, but they too navigated the river.

The Maricopas farmed along the Colorado River but migrated to the Gila River about the sixteenth century, when competition for available land made survival difficult. Farther north the Mohaves occupied the area south of what is now Lake Mead, while the Havasupai occupied areas farther upstream. All of these people practiced some flood farming. They also hunted and gathered wild foods.



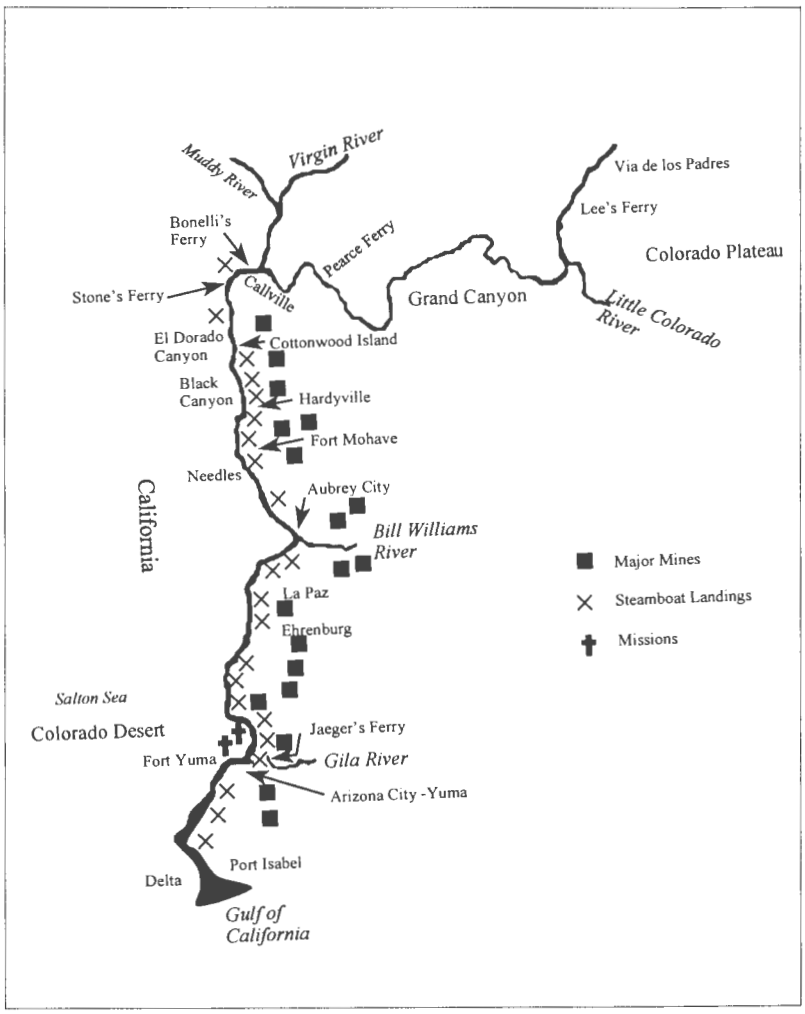
The Colorado River Basin.

Arrival of Spaniards

Spanish ships first reached the Colorado River in the mid-sixteenth century. In 1775, Father Garcés traveled up the river to a spot north of the Bill Williams River. He wrote of the Colorado: "There is no place where it can be forded on horseback except, when it is low, in the land of the Yumas, and here fording is dangerous and irregular. ... Everywhere it has groves of willows, cottonwoods, mesquites, and screwbean mesquites, except where it passes between rock walls. Although it is wanting in pasturage it does have some short grass and an abundance of reed grass, swamps of rushes, wild amaranth, and other tall fodder grasses. The land along its banks is good except here

and there an alkaline stretch. All sorts of crops are to be found, and in places the cultivable lands are so extensive that they can support the inhabitants and many others besides."

The Spaniards attempted to establish missions near the mouth of the Gila River in 1780. The Quechans (Yumas) soon revolted, thus ending the short-lived mission period. The Spaniards introduced new crops, such as wheat, that could be grown in the winter, and some livestock, but otherwise had little lasting influence. American beaver trappers came through beginning in the 1820s and trapped extensively along the Gila River and up the Colorado River. Although they reduced beaver numbers in the short run, the trappers too had little long-term effect on the river. Beaver populations recovered. Later their numbers again were reduced, but for other reasons.



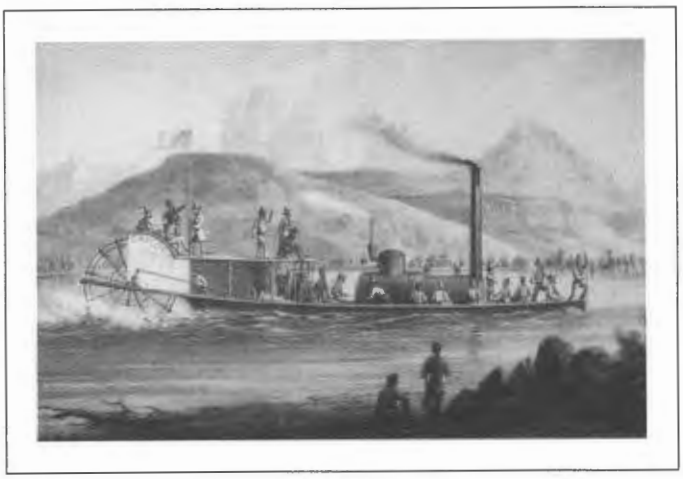
Historic sites along the Colorado River.

Miners and Steamboats

Many travelers crossed the Colorado River, but with the discovery of gold in California and the acquisition of Arizona by the United States the pace of events increased, thus changing the river. A busy ferry was set up at Yuma for California crossings. The California Gold Rush of 1849 brought business, and as the gold rush ended, miners began to explore mining areas along the Colorado River. Military posts were established to protect the miners and the river crossings. Mormon farming communities were established along the Virgin and Muddy rivers and farther south, with ferry stations set up at Callville and Pierce. Hopes of a Mormon seaport never developed when it became clear that regular steamboat service to the Mormon communities was not feasible.

These activities created an incentive for steamboats to ply the river. The steamboats served Fort Yuma, delivered supplies to the miners up the river and carried minerals to markets. The river route was cheaper than traveling overland. Woodcutting to supply the steamboats probably had the most lasting effect on the river during this period. Landings were established at convenient locations for ships to take on wood to fuel the engines. With the vegetation along the river gone, the Cocopah and Yuma cut wood some distance from the river. Boats had to navigate sand bars at low water times and turbulent waves in high-water times.

Arrival of the railroad in 1877 led to the demise of the steamboat trade. The mines were pretty much played out by 1900, and the river seemed to be returning to "normal," serving more as a crossing than as a focus of activity. This state of affairs, however, would not last long.



Steamboat passing Chimney Peak on the Colorado River in 1861 from a sketch by Mollhausen.

Probably the most long-lasting effects of the short-lived mining era were deforestation of hillsides and riparian areas for fuelwood and introduction of burros. The burros have survived in watersheds such as Burro Creek, where they have often seriously damaged riparian areas by eating and trampling vegetation.

If no further human activities had taken place, the river would probably soon have reverted to its former state, with great cottonwood-willow forests and periodic floods to rearrange the river's course and its beaches. But a new chapter in the river's history opened up with the arrival of the railroad. Areas became more accessible, and new markets were opened.

Modern Agriculture

In 1865, after the U.S. military conquered the Indians, the Colorado River Indian Tribes Reservation was established along the river. Since the reservation contained much less land than the Indians' ancestral hunting area, survival was not possible without irrigated agriculture. As a result, the federal government directed the Indians to dig an irrigation canal. With great labor the canal was completed, only to quickly wash out due to poor engineering. The canal repeatedly washed out until construction of the Headgate and Parker dams in the 1940s made irrigation in the area possible. At present 85,000 acres are cultivated on the 265,000-acre Colorado River Indian Reservation.

In the 1890s a few farmers saw great possibilities for agriculture in the Colorado Desert in California, west of Yuma, which they grandiosely renamed the "Imperial Valley." If the area were reliably irrigated, crops could be grown throughout the year and the land made habitable. A group of pioneer farmers envisioned a massive irrigation system to bring a constant source of water to fields many miles from the river. Several crops a year then could be grown instead of just the flood crops planted by the Indians. Noting that the Imperial Valley was below the level of the Colorado River, the farmers figured it would be fairly simple to channel water from the river to be used in the fields. The Imperial Valley had once been part of the Colorado River Delta and had been cut off as more and more silt built up, creating a sort of natural dam. The soil was remarkably fertile, with a deep build-up of sediments which the Colorado River washed down in past years. Those who drilled for water found it brackish, unsuitable either for drinking or growing crops. Clearly water must be brought from the river.

Agricultural Water Diversions

The first attempts at bringing water to the fields were successful. The first diversion gate, however, was installed too high, and water only flowed during the summer high-flow periods, not in the winter. To solve the problem a dredge was

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"By the public at large, the level plain formerly known as the Colorado Desert was regarded as utterly worthless, until about four years ago. Travelers coughed their disgust of it, with alkali dust, as they sped from Yuma to Banning on the Southern Pacific. They said it had no possible utility except 'to hold the earth together.' To traverse the region by team or on horseback was always a disagreeable and sometimes a dreadful experience, occasionally ending in the death of man and beast by thirst in the pitiless heat." Bureau of Reclamation, 1942.

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used to dig eight miles of canal to the old channel of the Alamo River. This river had been formed by previous overflow of the Colorado River and followed a circuitous course dipping into Mexico.

The first water arrived in 1901 and started a great land boom. Would-be farmers came from all over. Vegetable gardens and young fruit trees flourished in the fertile soil. The temporary structures that delivered the agricultural and domestic water needed refurbishment to last. Problems repeatedly plagued the irrigation district which responded with more makeshift arrangements. Water supplies did not arrive reliably in the winter of 1903. The canals begin to fill with sediment. A new cut was made to bypass the silted-up canal, with all too effective results. Water began to pour down the new waterway in late 1904.

In the winter of 1905, the Holtville "Tribune" reported that the Alamo River was running 50-feet deep and not more than 400 yards from the newspaper office. The water continued to pour into the valley. The canal company and residents worked frantically to close the gap with a dirt dam, using brush mats held down with 10,000 sacks of sand. The water kept pouring in. Four more attempts were made, but all were unsuccessful. The water kept flowing downhill into the valley. By this time the entire valley was flooded. Farms and towns were destroyed. Water had flowed to the lowest point—what is now known as the Salton Sea.

"But here among the hills bare and red,
A violent precipice, a dizzy white curve falls
hundreds of feet through rock to the deep canyon bed;
A beauty sheer and clean and without error
It stands with the created sapphire lake behind it,
It stands, a work of man as noble as the hills,
and it is faith as well as water it spills.

Not built on terror like the empty pyramid,
Not built to conquer but to illuminate a world;
It is the human answer to a human need,
Power in absolute control, freed as a gift,
A pure creative act, God when the world was born!
It proves that we have all built for life and built for love
And when we are all dead, this dam will stand and give."
May Sarton on Hoover Dam

"Southern California has but one navigable river, the Colorado. And this is not 'navigable' by courtesy but actually navigable — in spite of its tortuous channel, changing almost by the hour so that no pilot attempts to run by memory; in spite of its bars of mud and broad shallows. The boats, built specifically, are almost as good on mud as on water. They turn and wash out, with the big stern wheel, a channel where there is none, swing on their center and wriggle off a bar, or slide over it with little slackening of speed — making on the whole, remarkable time." T.S. Van Dyke, 1895.

Finally in October 1906 the Southern Pacific Railroad took over the repair efforts. Progress was made, and over $4 million was spent. In December, however, the Gila River flooded and more water poured in. The old Colorado River was dry, with no water flowing in the old channel into Mexico. The river again was flowing into the Imperial Valley and the Salton Sea. By February 10, 1907, the railroad finally succeeded in closing the gap by dumping many tons of rock between two trestles.

The flood had been stopped and optimistic farmers wanted once again to reclaim the land. The U.S. Reclamation Service was offered its first real challenge. It built dams and canals to safely remove water from the river. The Imperial Valley again prospered.

The Imperial Irrigation District (IID) takes 2,500,000 acre-feet (a.f.) of water from the Colorado River each year. It produces much of the country's winter vegetables, especially lettuce, on one-million acres. Problems of salinity and poor drainage were partially solved by using the Salton Sea as a collector for agricultural run-off.

The loss of this much water reduced the size of the delta by many acres. In low-water years very little water passed below the intakes for the Imperial Irrigation District and the Metropolitan Water District.of Southern California. This limited the ability of Mexican farmers to grow their crops, until the Morelos Dam was built by Mexico to irrigate thousands of acres of Mexican farm land.

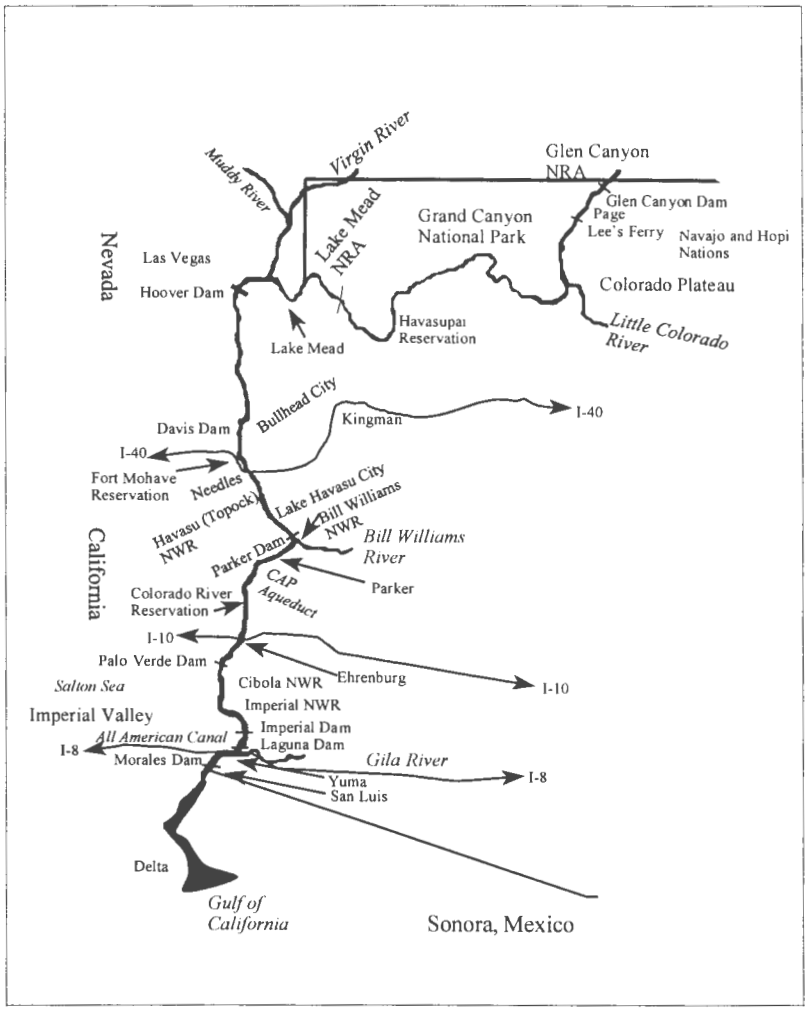
The Imperial Valley is the most massive irrigation water diversion project on the Colorado River, but is not the only one. About the time plans were being made for the Imperial Valley, projects already were being carried out in the Grand Valley of the Gunnison River in west-central Colorado. Starting in 1881 settlers dug ditches to irrigate the lowlands. By 1886 the Grand Canal was finished, and the system expanded to serve 45,000 acres. By 1917 the Grand Valley had been expanded further to include a diversion dam, a power plant and canals able to divert 800,000 a.f. of water.

Another early project was the Uncompahgre Project, also in west-central Colorado. Its first water was available in 1908 from the Uncompahgre and Gunnison rivers to irrigate 76,000 acres. It includes nine dams and 128 miles of main canals and now can deliver 521,618 a.f.

A much more recent project is the Navajo Irrigation Project on the Navajo Nation along the San Juan River. The treaty of 1868 allowed the Navajos to return to their homeland. It was almost a 100 years, however, before a federal irrigation project was authorized. Sprinkler systems can irrigate 110,630 acres with 330,000 a.f. of water.

Another major project finished in the 1970s was the Frying Pan-Arkansas Project which moves water from the Colorado Basin to southeastern Colorado for irrigation, recreation, municipal and industrial uses, power generation, etc. It delivers 69,000 a.f. through five major dams and reservoirs, 17 smaller dams, canals and a tunnel through the continental divide.

Arizona projects on the Salt and Gila rivers are described in the chapters on those rivers. By 1945, almost 800,000 acres in the Colorado River Basin were irrigated through projects built wholly or partly by the U.S. Bureau of Reclamation, most of them in Arizona.



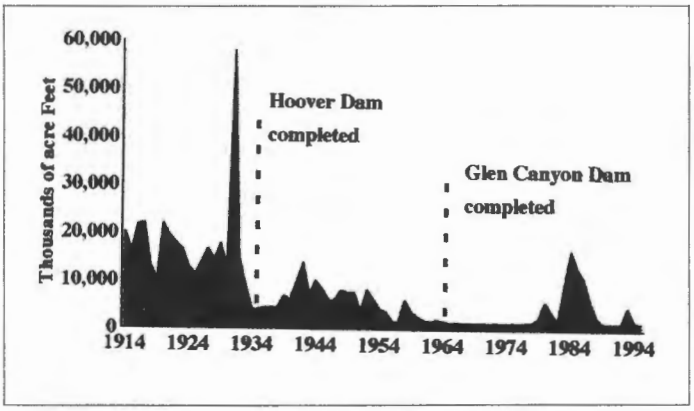
Twentieth century sites along the Colorado River.

In total, agricultural diversions in the basin remove 6,000,000 a.f. annually of Colorado River water from the river and tributaries.

Municipal Water Diversions

The Metropolitan Water District takes about 2,440,000 a.f. of water for use in the Los Angeles and San Diego areas. The Salt River Project in Arizona takes over 900,000 a.f. from the Salt and Verde rivers for urban and agricultural uses. Other municipal water diversions go to Las Vegas (300,000 a.f.) and parts of Colorado (56,000 a.f.).

The Central Arizona Project, completed to Phoenix by 1985 and to Tucson in 1992, can deliver 2,500,000 a.f. of water. Since some of this water includes water



Mean annual flow of the Colorado River at Morelos Dam at the Mexican Border.

California had been using all along, the amount does not entirely represent new demand on the river.

Together, municipal diversions (not including evaporation losses, spills, etc.) totaled more than 2,500,000 a.f. in 1991. The diversion capacity of municipal and agricultural projects on the Colorado River and its tributaries is more than 18,000,000 a.f. Removal of this much water has profoundly affected the downstream portions of the river as well as some of the tributaries, since this is more than the average annual flow of the river at Lee's Ferry.

Sixty Years of Dam Construction

In the 66 years after the establishment of the U.S. Reclamation Service (later to become the U.S. Bureau of Reclamation), the most massive series of dams the world had yet seen regulated the Colorado River. Both the Salt and the Colorado rivers got their first dams within that first decade of the Bureau's existence. Six more dams were built in the 1920s, completely changing the character of both rivers and the ability of people to live in water-scarce areas. These first dams made irrigation along the river—as well as at distant areas—possible. Major floods no longer destroyed human-made projects—nor did they refertilize the soils

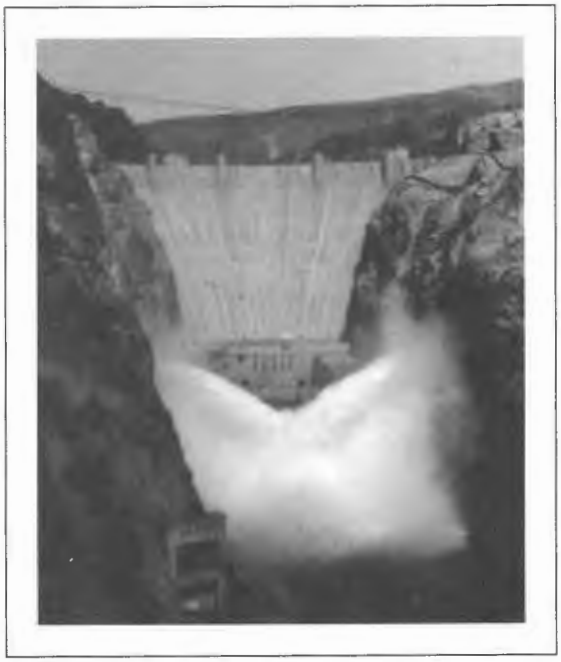
But the greatest work was yet to come. Hoover Dam's completion in 1935 dwarfed previous construction projects. By 1968 the last dams on the river had been built. Lake Powell behind Glen Canyon Dam in northern Arizona could contain almost as much water as Lake Mead. The Bureau had planned to build at least six other dams, including two in the Grand Canyon, but by 1970 the great age of dam building was over in the American West.

By the 1960s, some negative impacts of dams began to be felt. Sediment collecting behind dams was causing some concern. The delta had dried up. Millions of acre-feet of valuable water were lost to evaporation. Experts began to study these problems and seek mitigation measures.

The Delta

For many thousands of years the river cut through soil and rock, eroding away millions of tons of material. Each spring flood carried more and more nutrient-laden sediment downstream towards the Sea of Cortez. Enough silt reached the mouth of the river each year to add another foot of earth to the delta area. The resulting delta was one of the richest estuaries in the world, supporting a great variety of bird life and providing important spawning areas for life in the Sea of Cortez.

The Imperial Valley, almost at sea level, often had flooded, but was somewhat protected by the natural berms in the delta. As the level increased, however,



Hoover Dam in 1936.

more flood control was necessary, to prevent the river from again breaking through to the Imperial Valley which was becoming an agricultural area. Several crops a year could be grown with irrigation, whereas only one crop could be grown under the old flood irrigation methods. But irrigated agriculture required controlling those floods as well as diverting water from the river.

Upstream diversions eliminated this rich delta. A small remnant remains in the Santa Clara Cienega, formed by tailwater from the Wellton-Mohawk Irrigation District. The water is too salty to return to the river, so a bypass canal delivers the tailwater directly to Mexico. The U.S. Bureau of Reclamation built a desalting plant in Yuma, to treat the tailwater for delivery to Mexico via the Colorado River, under treaty obligations. Once Arizona uses all its share of Colorado River water, the plant is scheduled to be activated. The Santa Clara Cienega then will no longer receive tailwater, to the potential loss of wildlife. At the cienega a community of salt-tolerant plants hosts a great variety of birds, both migrants and residents. Mexico is preserving this remnant delta which was declared a Biosphere Reserve in 1994.

Robinson's Landing at the mouth of the Colorado River in the 1860s.

Wildlife Habitat

Early travelers to the lower Colorado River often reported plentiful fish, birds and other wildlife. James Pattie reported plentiful beaver in "small lakes" along the river. He said that near the Mohave Valley, "We killed plenty of mountain sheep and deer, though no bears." When traveling in the delta he noted, "Of birds there are great numbers, and many varieties, most of which I have never seen. We killed some wild geese and pelicans, and likewise an animal not unlike the African leopard, which came into our camp. ... It was the first we had ever seen." The beaver, generally trapped out by the mid-1830s, had mostly recovered by the time Aubry came through in 1853.

In 1865 Elliott Coues, an amateur naturalist with the military, described looking for ibis south of Yuma. "... it is hard to push along; the bushes are thick and determined enough to hold us back, even were they such well-disposed and respectable members of the vegetable kingdom as grow in civilized countries; even the oaks have prickly leaves. ... Abert's Finches rustle in every tangle; in the green willow clumps Orange-crowned Warblers are disporting and sipping dew from leafy scroll-like cups. Now the path grows soft and

The Santa Clara Cienega in 1990.

oozy—we must take care, and leap from log to log, or we shall sink up to the knees. ..."

The Grand Canyon

The river was a barrier to travel through or across the Grand Canyon. Between Lee's Ferry and the Callville crossing the river was very difficult. Another crossing was the Vado de los Padres at the location of Glen Canyon Dam. Early explorers tried unsuccessfully to find a navigable route to the ocean from the Little Colorado River. When Spaniards and later the Americans were settling parts of Arizona, the Grand Canyon and other Colorado River areas were left largely undisturbed for the Indian inhabitants.

The Havasupai and Walapai grew crops using spring irrigation in the depths of the canyon. At other times of the year the Havasupai traveled to the uplands for hunting and gathering foods such as pine nuts. Explorers described descending into the canyon on long wooden ladders.

Major John Wesley Powell was the first white man to fully explore the Colorado River. Coronado had reached the south rim of the Grand Canyon in 1540; Escalante forded the river at present-day Glen Canyon dam; and others reached the lower canyon. Powell, however, was the first to travel from what is now Green River in Utah to Lee's Ferry, to where he left the Colorado River to travel to St. George, Utah. In 1869, Powell and his small party of men pushed off into the Green River in Utah and floated 538 miles to the junction with the Grand River and Colorado Rivers, and subsequently down the Colorado River through the Grand Canyon. After Powell's two trips through the canyon, other explorers were convinced the river was unnavigable, either up or down through the canyon. Surveys were made to find a railroad route along the river to avoid the harsh winter weather on the Colorado Plateau. Lee's Ferry was the most frequently used crossing point until a bridge was built near the old Mormon crossing.

"Ours has been the first, and will doubtless be the last, party of whites to visit this profitless locality [the Grand Canyon]. 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." Joseph Ives, 1861.

During the first half of the twentieth century, dams were built downstream, with small diversions upstream. In 1919, the Grand Canyon had become a National Park, popular with visitors and generally protected. By the 1940s, the U.S. Bureau of Reclamation envisioned a series of dams along the river, including three in the Grand Canyon. The power these dams produced were to help pay for other Bureau construction projects in the basin. The outcry against flooding the Canyon was strong enough the Bureau put the dams on hold, although they remained in the overall vision for the basin.

In 1964, Glen Canyon Dam upstream was completed, flooding canyons many people considered valuable scenic areas. Even Senator Barry Goldwater, once a Glen Canyon Dam supporter, later said he regretted

"It was almost midnight before we heard a low distant moaning which we at once recognized ... as the burro [tidal bore]. The moaning gradually increased to a roar which brought back to my mind the equally alarming racket of a great herd of stampeding cattle. Then we were suddenly involved in chaos, with a maelstrom of swirling water all round about us. Our snubbing device fortunately worked admirably, bringing us head around before we were capsized, and starting us fairly up the steep wave front, which suddenly appeared close aboard us. Then our drift-stump pulled loose. ... The first frontal wave was quickly followed by several rollers, each of which seemed to lift us several feet higher into the surrounding blackness. Our solitary lantern, which we had hung on a log on our foremast, had been violently extinguished either by spume or the rush of air which accompanied at the onslaught of the water, and so we had to guess at what was happening round about us until we were able to relight it. We then found that we were being carried swiftly along in a general direction which our compass, the retarding pull of our draft and occasional fleeting glimpses of almost submerged clay banks, indicated was Northwestward. ..." Glenton Sykes, 1944.

Glen Canyon in 1869.

the loss of Glen Canyon. Even as people protested the drowning of Glen Canyon, few envisioned the impacts the dam would have on the Grand Canyon, since the same amount of water would flow downstream once Lake Powell was full. It was only after several years of operation that the downstream impacts became fully clear. Glen Canyon Dam is operated for power production. Peak power demands resulted in large water releases with river fluctuations daily and weekly and during seasons when high flows did not occur on the undammed river.

No longer did large spring floods rush through the canyon flushing sediments downstream and clearing out old growth while building beaches for new growth. No longer could fish depend on calm spawning pools at other times of year. Rafters were the first to object to the new regime. This new business that had developed because of the dam was in trouble. Rafts tied up in the evening could be out of reach in higher water in the morning, or be stranded on mud flats if the water level sank. Good camping beaches became scarce. Sudden unexpected changes in water level during the day could be quite dangerous for boaters and anglers.

Starting in 1982, the U.S. government initiated a major interdisciplinary study of the impacts of Glen Canyon Dam, with a view towards changing the way the dam is operated to protect the wildlife and recreational values of the river.

Ives prediction about future visitors proved to be wrong. By 1923, 100,000 people a year were visiting the canyon. These numbers continued to grow, until in 1995 five million visitors came the canyon. Many hiked down to the river or rafted on it. By the 1980s, more than 20,000 rafters floated the river annually, leaving behind litter, and polluting the stream and its beaches with excreta and other substances. The U.S. Park Service then set limits on the number of boats to travel the canyon and enforced strict rules on waste disposal. This has reduced visitors' impact, but with the scarcity of good camping beaches, the few ideal beaches are overused with resulting problems for vegetation and wildlife during the summer rafting season. Hikers also impact the canyon and are more difficult to control.

Preservation and Restoration

The river has changed so drastically over the past century, especially from Lake Mead downstream, that restoration of prior conditions is close to impossible. Efforts are being made, however, to restore some native vegetation along the lower Colorado River and utilize existing river conditions to benefit wildlife. Many parts of the river are primarily preserved as recreational areas.

The Grand Canyon National Park, established in 1919 and later doubled in size, is only one of many federal preserves along the river. Two national recreation areas, at Glen Canyon and Lake Mead, offer recreational opportunities. At these areas habitat preservation and restoration are low priorities.

"We are now ready to start our way down the Great Unknown. Our boats tied to a common stake, are chafing each other, as they are tossed by the fretful river. ... We are three-quarters of a mile in the depths of the earth, and the great river shrinks into insignificance, as it dashes its angry waves against the walls and cliffs, that rise to the world above; they are but puny ripples and we but pigmies, running up and down the sands, or lost among the boulders." John Wesley Powell, 1869, describing his trip through the Grand Canyon.

"Here the mighty Colorado that has brawled its way through the Grand Canyon twists slowly among broad sand bars and tall cottonwoods before disappearing completely into the diversion dams at Morelos Dam." Arizona State Parks, 1989.

Three national wildlife refuges along the lower river, Cibola, Imperial and Havasu, protect habitat for many species of waterfowl, both resident and migratory. In the backwaters of these refuges thousands of birds live and raise young.

Changes in the River

Early explorers would recognize few sections of the Arizona portion of the Colorado River. Except within the Grand Canyon, the river, tamed by dams, has become a series of lakes rather than a free-flowing river. Glen Canyon, Black Canyon and other magnificent works of nature are submerged under many feet of water. Cottonwood Island, near modern-day Needles, is gone. Of an estimated 5,000 acres of pure cottonwood-willow communities between Camp Mohave and Yuma in the 1600s, less than 500 acres remain today. They have been replaced by saltcedar, cleared for farming, or drowned by lakes. New marshes and backwaters have formed in such areas as the mouth of the Bill Williams River.

Even within the Grand Canyon, the river is a very different river than it once was, although the massive canyon walls remain much as they were. The great floods of the past no longer sweep down the canyon, tearing out vegetation, depositing soil for new beaches and new vegetation. Secure spawning grounds are rare and the native fish are threatened or endangered.

The canyon now is much visited, and the traveler is likely to meet many other visitors. Glen Canyon Dam created valuable recreational opportunities for rafters through the canyon which previously was scarcely usable for rafting. People preferring motor boats gained Lake Mead. Before the dams, few recreational travelers visited either area.

People who cross the river at Yuma today may wonder where the mighty Colorado River went. Now people usually can wade across. They will not recognize the mighty river in the concrete canals leading to Los Angeles, Phoenix and the Imperial Valley. They might wonder why someone named the river "Colorado" since the water is clear and carries little of the sediment which gave the river its name. The miles of cottonwood and willow forests are reduced to a few thousand acres, replaced by lakes and by saltcedar.

The Great Delta is no more. No one uses the life-giving annual floods for farming. The only floods are rare devastating floods such as one that came down the Gila River in 1993. The hordes of birds once found in the delta are gone. Only in the Santa Clara Cienega can a vestige of this former community be found.

Moving away from the river, travelers would be amazed to see rich agricultural fields where settlers and their cattle formerly went hungry and thirsty. They would be amazed at the size of cities kept alive by water from the Colorado River.

"Nowhere in the United States can such a quantity and assortment of 'baybirds' be seen today as on the shores of the lower river and of the Gulf of California. ... the trip is one of great interest for the novelty of the navigation ... and the scenery, unlike anything along the rivers of either coast ... and when you tire of gazing at eddying water, the mirage of the desert beyond the bottom lands will often furnish all the silvery lakes, with timbered shores and wooded isles, you care to look at. There are the reflections of the trees in the water as plain as you ever saw them, and the timber is as green as the dense willows that nearly brush the board, or the rank cottonwoods you can almost touch as the steamer swings into an eddy. ..." T.S. Van Dyke, 1895

The first tourist lodge along Oak Creek, in the 1930s.

SOME RIVERS ARE PROTECTED OR RESTORED

Because of changes to Arizona's rivers, many efforts to preserve and restore them are underway. Some began early in the twentieth century, while others began as late as the 1990s. Some rivers were restored through a natural process after disruptive human activities stopped. For example, some forests grew back after woodcutting ceased.

The Grand Canyon became one of America's first national parks in 1919. Casa Grande ruin was one of this country's first national monuments. Many preserves were set aside in the late 1920s and 1930s, despite a severe national economic depression. During the 1930s, the Civilian Conservation Corps worked on numerous projects throughout Arizona. Projects included trail maintenance, construction of recreational areas and campgrounds, stream restoration, building of check dams and soil conservation.

Preservation projects aim primarily to protect a river with relatively healthy riparian conditions, while restoration projects restore a man-altered river to an earlier condition. Some projects protect areas especially for their wildlife value. Other projects aim to transform a changed river into a park rather than to its original conditions, to make use of rivers values for recreational or commercial purposes. Projects designed mainly for recreational value may protect a river, but not as the primary goal. In some places constructed wetlands are creating new habitats. In many situations balancing conflicting uses is a problem.

Civilian Conservation Corps workers building a small dam on the San Simon in the 1930s.

This chapter describes various projects of local, state and federal agencies and nonprofit groups as examples of what is being done in Arizona. It is by no means a comprehensive list. For the most part, the projects described here are not otherwise discussed in this publication.

Funding Opportunities

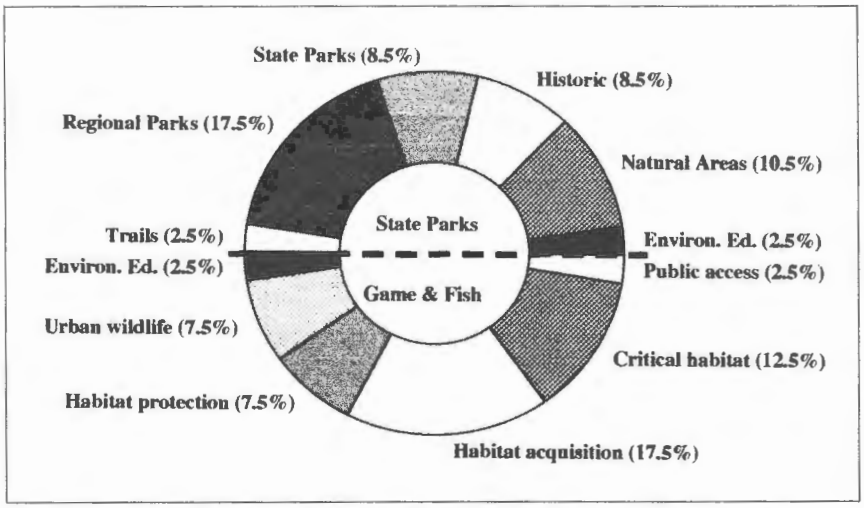
Various federal sources provide funding for preservation and restoration projects. For example, the Environmental Protection Agency funds projects that deal with nonpoint source pollution problems. The U.S. Fish and Wildlife Service, through its Partners for Wildlife Program, works with property owners on specific restoration projects to benefit wildlife habitat. The U.S. Bureau of Reclamation funds several types of projects, including constructed wetlands. The Federal Duck Stamp Program funds projects to benefit waterfowl habitat in which hunting is allowed.

The two Arizona funding sources described below are relatively unique to this state. These sources, however, can fund only a small percentage of the proposed projects.

The Arizona Heritage Fund

In 1990, 62 percent of Arizona voters approved an initiative to earmark part of the state lottery proceeds to wildlife and recreational purposes. The Arizona State Parks and Arizona Game and Fish departments each receive $10 million a year

for specified purposes. Some of the money is spent directly by the two departments, and some is granted to various groups through a competitive process. This program has funded such projects as the purchase (from willing sellers) of part of Sonoita Creek and some crucial headwaters of the Little Colorado and Verde rivers. It has funded wildlife studies as well as mapping of the state's perennial streams, an environmental education program at a state park on Oak Creek and many other projects. Despite attempts by the Arizona Legislature to divert the funds elsewhere, citizen support has kept this program going.



Annual distribution of the Arizona Heritage Fund.

The Arizona Water Protection Fund

The Arizona Legislature established this program in 1994 to provide about $5 million per year for riparian restoration and research projects. The Arizona Department of Water Resources manages the program with a citizen oversight committee. In 1995, $6,861,490 was awarded to fund 24 projects. These included restoration projects on Sycamore Creek, Picacho Reservoir, West Turkey Creek, the Gila River, Fossil Creek, Sabino Creek and others.

The Godwin Family enjoys Wenima Preserve, 1995.

Examples of Arizona Projects

Wenima Preserve

Arizona Game and Fish Department used Arizona Heritage Funds to purchase about 1,000 acres of land along the Little Colorado River north of Springerville to protect endangered fish. The department worked closely with local residents to ensure support for the project, demonstrating to them that increased tourism would more than offset the small amount of tax money this former grazing land contributed to the tax base. The land had been destined to become part of a subdivision with a golf course along the river.

The Patagonia-Sonoita Creek Preserve

The Arizona Nature Conservancy, a non-profit group, buys land with unusual vegetation or wildlife values, to preserve those values. The Sonoita Creek Preserve northeast of Nogales contains a perennial stream with ancient trees, about 250 bird species and 300 plant species. The Conservancy intends to restore a former sacaton grass meadow, now overgrown with non-native grasses. Experiments with cattle and with prescribed burns will test the ability of native grass species to revegetate the area. The Conservancy also has riparian preserves on the Hassayampa River, Aravaipa Canyon, and tributaries of the San Pedro River and Oak Creek.

Hikers at Cienega Creek Preserve.

West Fork of the Black River Restoration

Trout Unlimited, a nonprofit group of fishermen and fish enthusiasts, assembled a large cooperative effort to restore degraded fish habitat on U.S. Forest Service land in the Salt River watershed of the White Mountains. The area had suffered from years of overgrazing, but the chosen stream had some remaining good fish habitat. The group collected about $750,000 from private donations and agencies, assembled hundreds of volunteers to build small catch dams, plant trees, build fences and do many other chores. The creek is recovering well, and fish are beginning to thrive.

The Rio Salado Project

An elaborate multi-agency project, the Rio Salado Project is to use Central Arizona Project water to create a flowing river along the Salt River through the heart of Tempe. This project does not aim to recreate the nineteenth century river, but to use a flowing river as the heart of a parkland and commercial complex. Both public and private investment funds will pay the more than $1 billion needed.

Cienega Creek Preserve

Pima County owns almost 4,000 acres along Cienega Creek, a tributary of the Santa Cruz River, in eastern Pima County. Flood control money was used to purchase the land to prevent downstream flood problems that otherwise would have occurred if developers built a subdivision in the area. The creek is perennial at this point with high wildlife and scenic value and is open to the public on a very limited permit basis. The county works closely with the U.S. Bureau of Land Management who operates the Empire-Cienega Preserve upstream (also including Cienega Creek) and the U.S. Forest Service that manages the headwaters areas. This cooperative arrangement has ensured no upstream pollution will degrade the creek as it flows through the two preserves.

The Upper Santa Cruz River

Effluent from the Nogales International Wastewater Treatment Plant nourishes a lush riparian area in the Santa Cruz River. In the nineteenth century this was an area of perennial flow, with a series of marshes interspersed with flowing stretches. The river later dried up and was without much vegetation until 1972 when the wastewater flow began. Since then a cottonwood forest developed. Residents of the area formed Friends of the Santa Cruz River to defend this habitat against various threats. Most of the area is in private hands, but includes a state park, national historic park, and a four-mile river trail. This cooperative effort is unique in Arizona, with private citizens, government agencies and nonprofit groups working together.

Jacques Marsh

This constructed wetland in Pinetop in the White Mountains uses treated wastewater from the Pinetop treatment plant to create a habitat for waterfowl and other wildlife. Hunting is allowed during hunting season. This prime birdwatching area is on U.S. Forest Service land. The Arizona Game and Fish Department manages the habitat.

Oak Creek

Oak Creek, mostly on U.S. Forest Service land in north central Arizona, is an extremely popular recreation area. This perennial tributary of the Verde River is set in scenic views of red, buff and black cliffs. Wildlife include ringtail cats and bald eagles. Slide Rock State Park, located along Oak Creek, is one of the most popular of Arizona state parks. Second home development in the Sedona area strains the area's water supply and threatens water quality. The trout stocked in the river delight fishermen, but are detrimental to native fish species.

Oak Creek is an example of a prime riparian habitat being "loved to death." The parking problem confronting the U.S. Forest Service is a symptom of this condition. With more people at times wanting to use the area than the existing parking areas can accommodate, people end up parking along the winding two-lane road. Building more parking facilities, however, would eliminate streamside habitat and further strain the area. This dilemma confronts an increasing number of recreational areas. The tourism that supports the local communities threatens to damage the environment people come to see.

The Upper Santa Cruz River near Tubac.

Wildlife Habitat Plan on the Colorado River

In 1994, the U.S. Fish and Wildlife Service designated the Colorado River Basin as critical habitat for four endangered fish species. "Critical habitat" is a specific area, within or outside a species geographical range at the time of its listing under theEndangered Species Act, which contain essential physical or biological features for conserving the species and which may require special management or protection.

Since the basin provides power to over 20 million people, any changes in water use could have consequences for people and wildlife. To address this problem, a regional partnership was formed involving federal and state agencies and Indian tribes. The purpose of the program is to work towards recovery of more than 100 species and to supply water and power. The projected cost of the three-year planning period is about $4.5 million, to be supported by public and private funding.

Cibola National Wildlife Refuge

This 16,267-acre wildlife refuge along the lower Colorado River protects backwater areas along many miles of dammed sections of the river. Up to 25,000 Canada Geese winter here, along with sandhill cranes, egrets, herons, pelicans and many other bird species. The river in this area bears little resemblance to the historic river, but provides valuable habitat, with food supplies for birds in nearby farmland. The U.S. Fish and Wildlife Service operates the rufuge primarily for habitat value, although it is open to the public on a limited basis.

Lake Mead National Recreation Area

Formed by Hoover Dam, this lake on the Colorado River is managed by the U.S. National Park Service primarily for recreational uses. Boating is the most popular activity, along with fishing, water skiing, camping and hiking.

Recreation and the Rivers

People love to visit rivers and lakes. An Arizona State Parks survey of Arizona citizens found that the most popular recreational activity was visiting outstanding scenic areas. Camping, fishing, hiking, picnicking, and swimming in lakes and rivers were among the top 12 favorite activities (out of 42 listed activities). Included in the list but among the bottom 12 were ATV and 4-wheel driving, hunting, skiing, golfing, jogging and tennis. The activity people would engage in more if they had the chance was "fishing in a natural setting."

These activities bring valuable income to areas such as the Salt River Indian Reservation and Sierra Vista. Recreation has a severe impact, however, in some areas. Although Arizona has millions of acres of public land, only a small percentage is reached by vehicles. In some areas access to hiking trails is limited. Camping areas are scarce and usually full at peak holiday times such as the Fourth of July. All of these visitors can put enormous strain on the very resources the people come to enjoy.

Impacts on Rivers

Fishing impacts rivers through the introduction of non-native fish, usually to the detriment of native fish. Stocking by Arizona Game and Fish and accidental introduction of bait species has affected native species. Crayfish, an exotic species, are one of the greatest dangers to native frogs in northern Arizona.

Off-road vehicle driving impacts vegetation, especially in areas that become popular and attract large numbers of vehicles. Sections of Tonto Creek, for example, have been severely impacted.

Second-home developments impact rivers in much the same way as towns do, straining water supplies, lowering water quality from untreated sewage, littering, land clearing for homes and building roads.

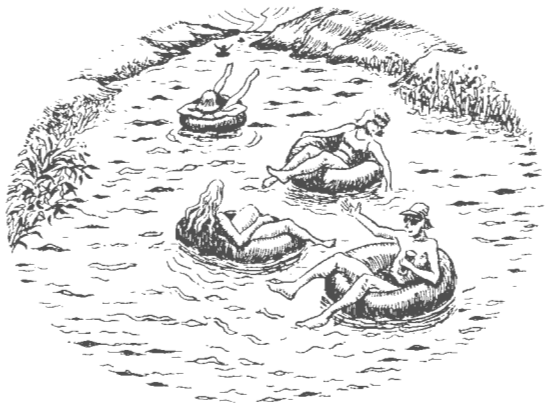
Camping and hiking can impact rivers when too many people use an area, trampling and destroying vegetation. The need to clear land for parking lots and campgrounds means a loss of habitat. Wildlife is disrupted by the presence of large numbers of people and their vehicles.

Rafting and tubing can impact rivers when beaches are overused for camping and picnicking and when precautions are not taken to control litter and feces.

All of the above activities may result in problems such as litter, the discarding of six-pack rings or fish lines that choke birds, accidental fires, and urine and feces in areas without latrines.

In some places the number of people allowed in an area at any one time is restricted. For example, only 15,000 people can raft the Grand Canyon per year, most on professionally guided trips. Permits to hike Aravaipa Canyon are limited to 50 people per day. Only ten vehicle permits per day are granted to Cienega Creek. The Hassayampa Preserve trail is designed to lead people away from the river banks to protect streamside vegetation.

Arizona's population has increased many-fold in the past 50 years, but river recreational facilities have not kept pace. This crowds more people into the few available places, further stressing fragile riparian areas.

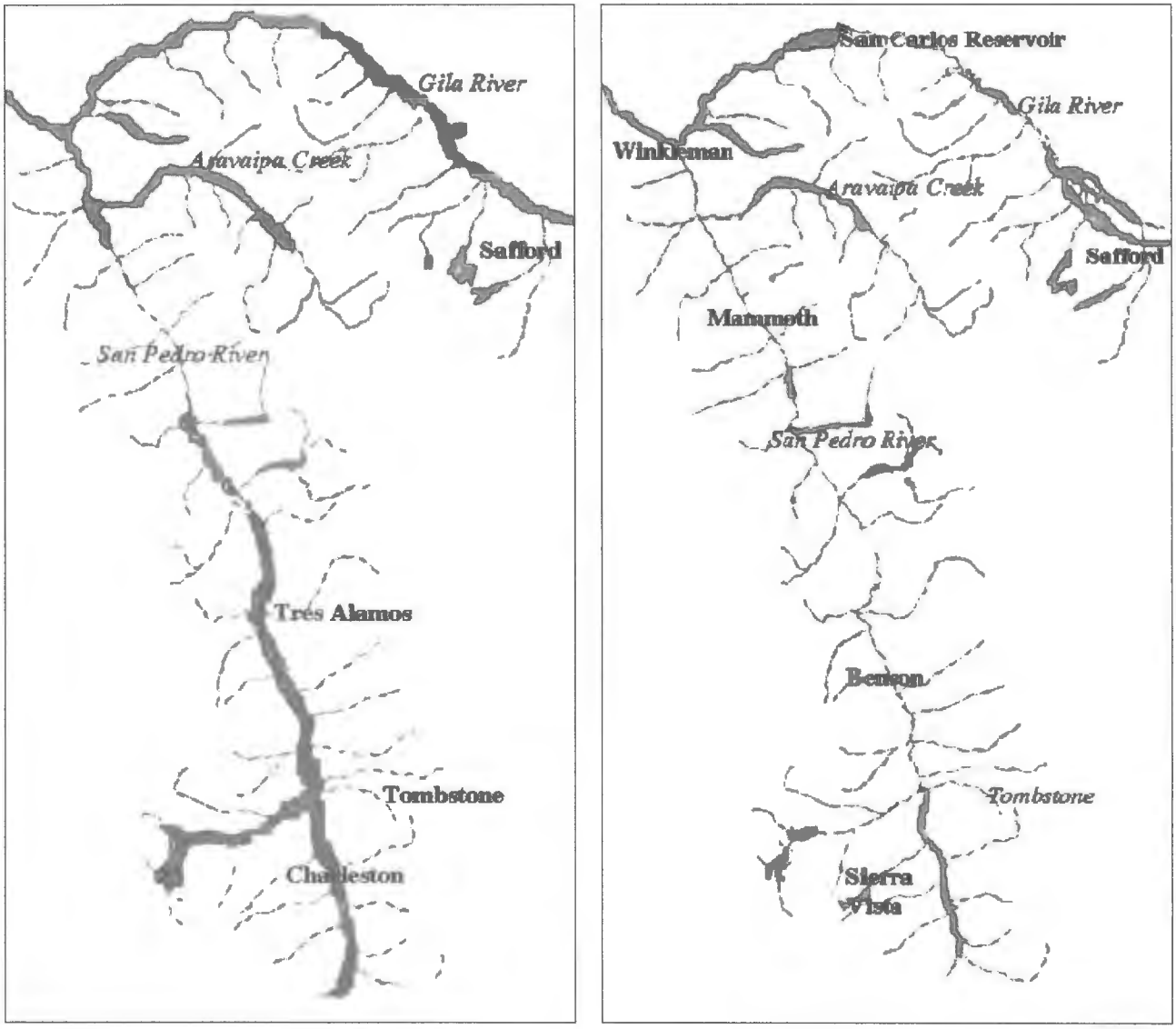


Powell's party shooting the rapids on the Colorado River in 1869.

Tourist party shooting the rapids on the Colorado River in 1989.

Arizona's major river-based public lands

This map shows public lands centered around rivers. **Blue** indicates national wildlife refuges; **yellow** national parks and national monuments; **red** Nature Conservancy preserves; **magenta** Wild and Scenic River; **tan** state and local parks; and **green** wilderness areas.



1880 1980

Changes in riparian areas and cienegas in the San Pedro Valley

This map, adapted from a study by Hendrickson and Minckley of changed riparian areas and cienegas in Southern Arizona, shows how much these areas have changed over the past century. Cienegas are in **green**, riparian areas in **light blue** and manmade lakes in **dark blue**.

CHANGED RIVERS—SOME CONCLUSIONS

The preceding chapters described many ways people have changed Arizona's major rivers and tributaries, from the earliest times to the present. These changes range from the very significant and obvious, such as those resulting from the building of Hoover Dam, to much less apparent changes, e.g., those that occurred when bullfrogs were introduced to an aquatic area. All of these changes result in rivers very different from those of 150, 500 or 2,000 years ago. Although humans affected rivers before 1850, those impacts are not evident today. In this final chapter, the combined effects of many of the changes of the past 150 years described in the earlier sections are assessed. Many of these were intentional changes to support agriculture and urban development in a desert environment. Others, however, were unintended consequences of various human activities. The many small creeks and washes are not included in this survey.

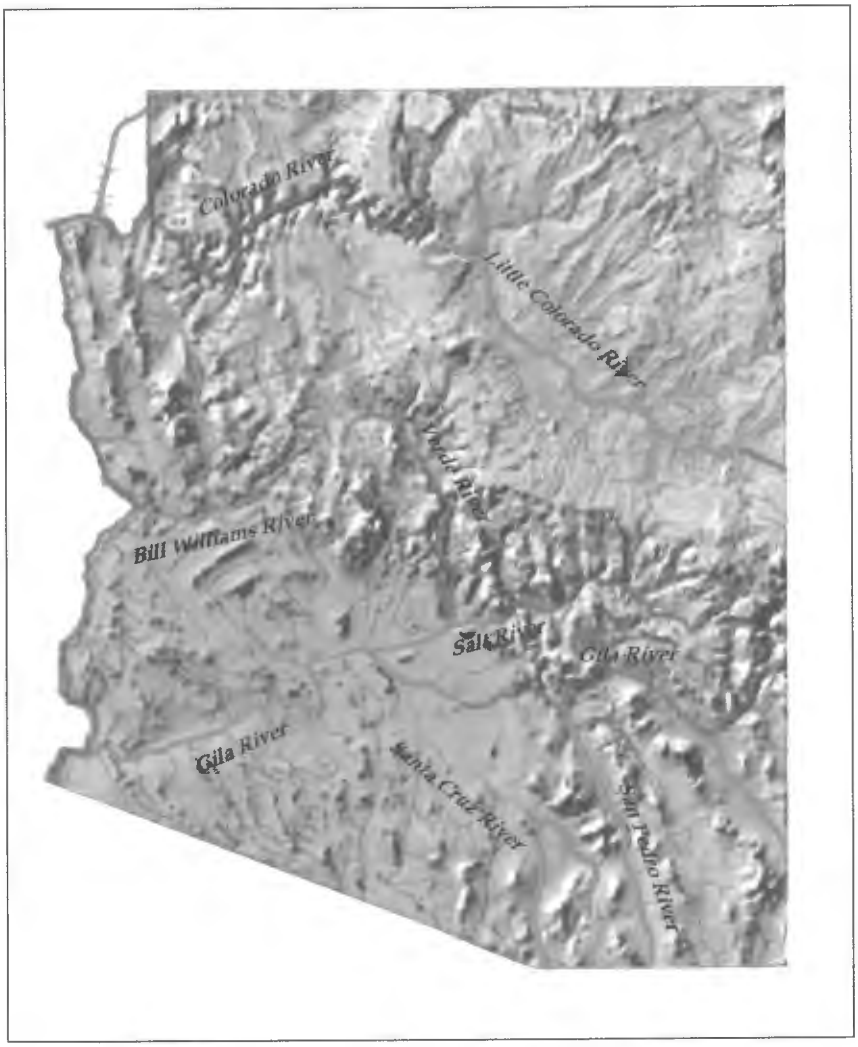
The following maps portray a very general picture of the continued effects various past and present human activities have had on Arizona rivers. Full detailed mapping of most of these impacts has not been done. Some impacts cannot easily be mapped, such as the impacts of overgrazing, which may be minimal along one section of a river and major on the next. Late nineteenth century over-grazing affected most of the state, except the lowest deserts.

Green denotes sections of rivers that always flow even in drought years.

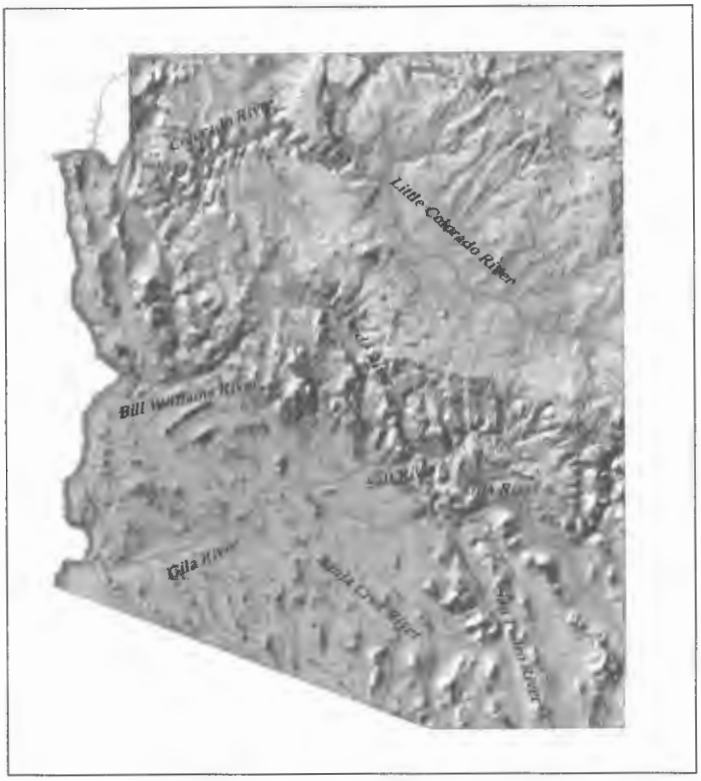
Blue denotes areas with surface flow except in drought years. The water table is high enough to support riparian vegetation even if the flow temporarily disappears.

Magenta denotes areas with surface flow alternating with cienegas and/or places where the river goes underground, but with a high enough water table to support riparian vegetation in most areas.

Gold denotes areas that are usually dry except during floods and have no high water table to support riparian vegetation.



Probable condition of the major rivers in 1800.



Rivers that were changed by dams.

People Dammed the Rivers

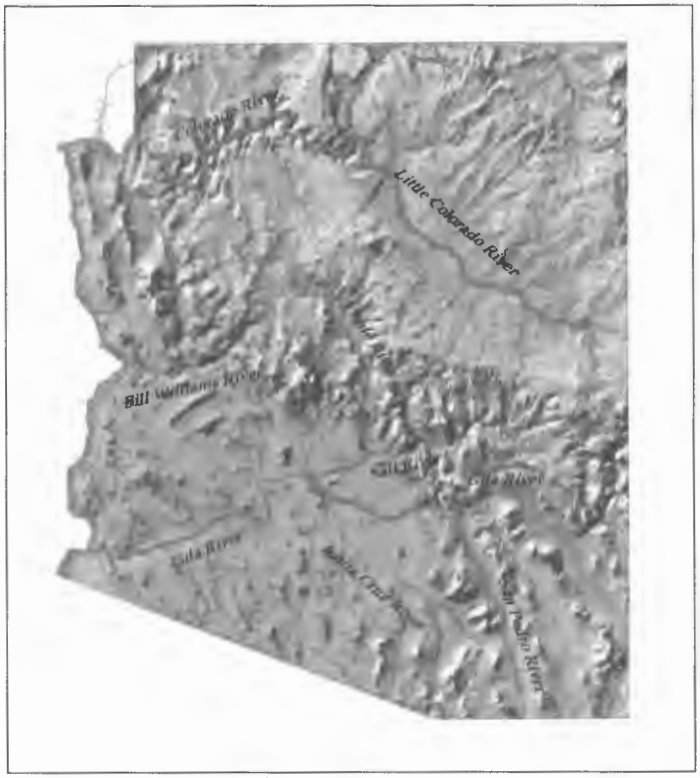
Arizona has approximately 430 dams of various sizes, with 24 of them major dams. Dams replace continuous streams with lakes and dry stretches of rivers. They change the flow of water, affecting the amount in a streambed and determining what animals and plants grow in and along a river.

The map only shows the largest dams and man-made lakes. Sections impacted upstream are shown in **green**. Sections impacted downstream are shown in **blue**. And sections impacted both upstream and downstream are shown in **red.**

People Took Water from the Rivers

People have diverted surface water to use away from its source, leaving some rivers with little or no water most of the time. They pumped groundwater that was often connected to the water that fed rivers. Some rivers dried up entirely in normal times, while others flow with less volume.

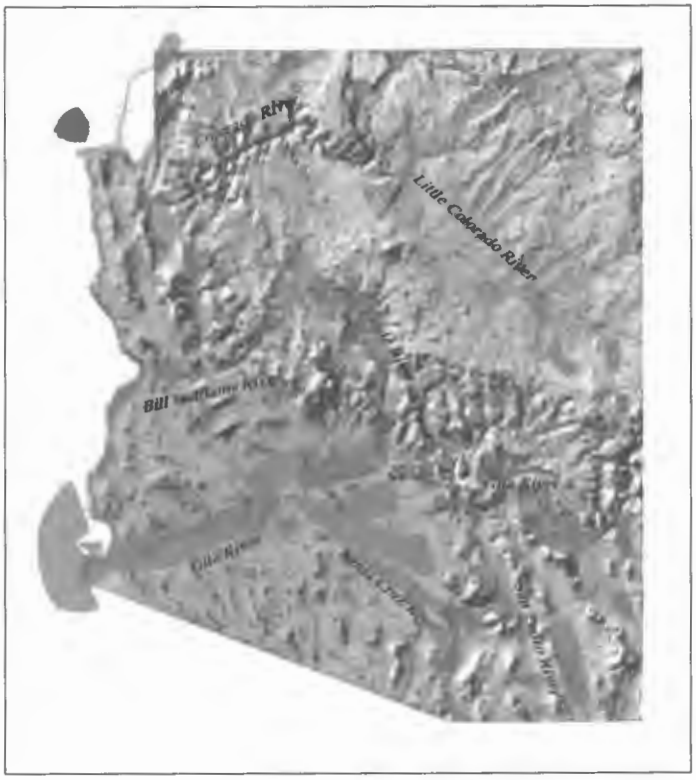
The map shows rivers that have been depleted in **green**; rivers with much diminished flow in **gold**; rivers with only moderately diminished flow in **blue**; and river flow increased by effluent in **red.**



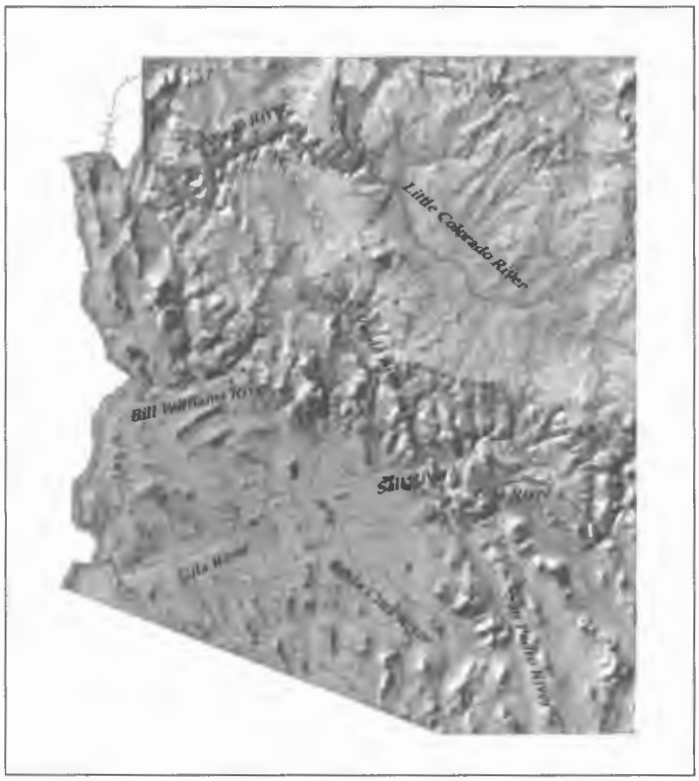
Rivers that were changed by pumping or diversion.

People Cleared Land Near Rivers.

People cleared land near rivers and their watersheds for agriculture, to build towns and mines, along with many other purposes. Urban areas are in **red**; major mines in blue; and agricultural areas in **green**.



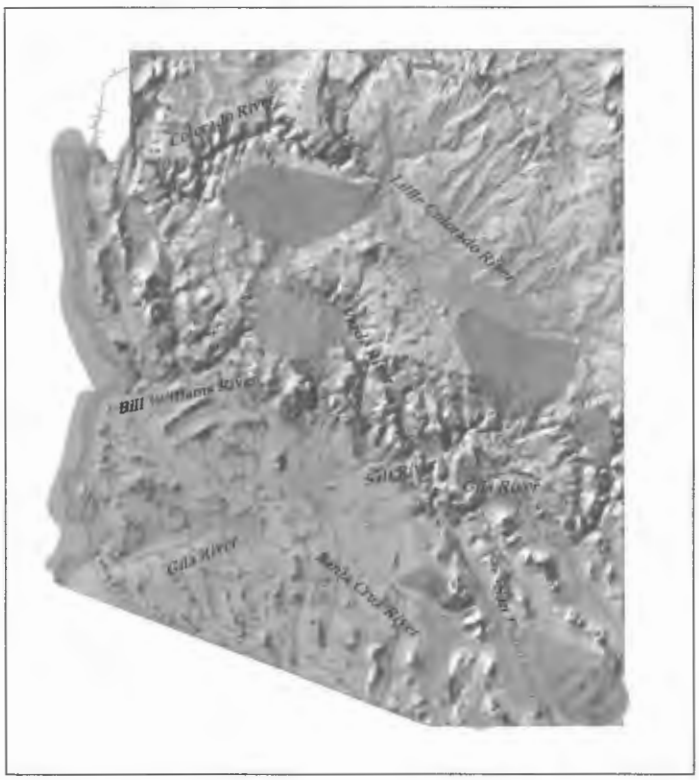
Rivers that were changed by land clearing.



Rivers that were changed by exotic plants.

People Introduced New Plant Species

New kinds of plants, especially saltcedar, completely changed the vegetation along some rivers and the wildlife that thrives in those areas. Areas with a significant percentage of its vegetation consisting of saltcedar are in **blue**, with areas of Russian olive shown in **red** and those where tree of heaven has begun to invade in **green**. Not show on the map are the many exotic weeds and grasses, such as Bermuda grass, that have spread throughout the state.



Major areas where rivers were changed by woodcutting and timber harvesting.

People Harvested Trees

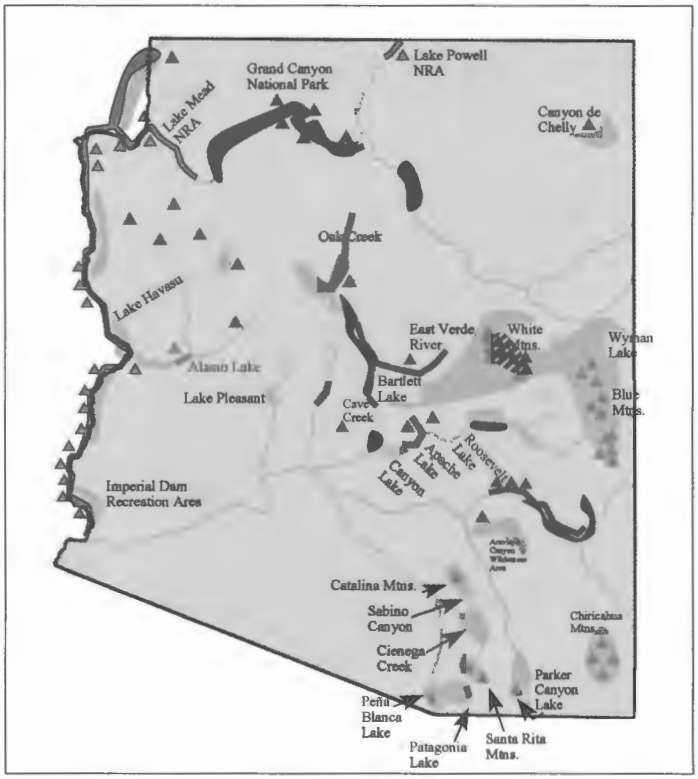
Few old-growth forests remain in Arizona. Most were harvested for fuelwood or lumber in the nineteenth century, and many areas were harvested for lumber throughout the twentieth century.

Blue areas were cleared during the nineteenth century. Most of these have grown back, at least to some degree. Areas in **green** have been major timber producing areas in the twentieth century.

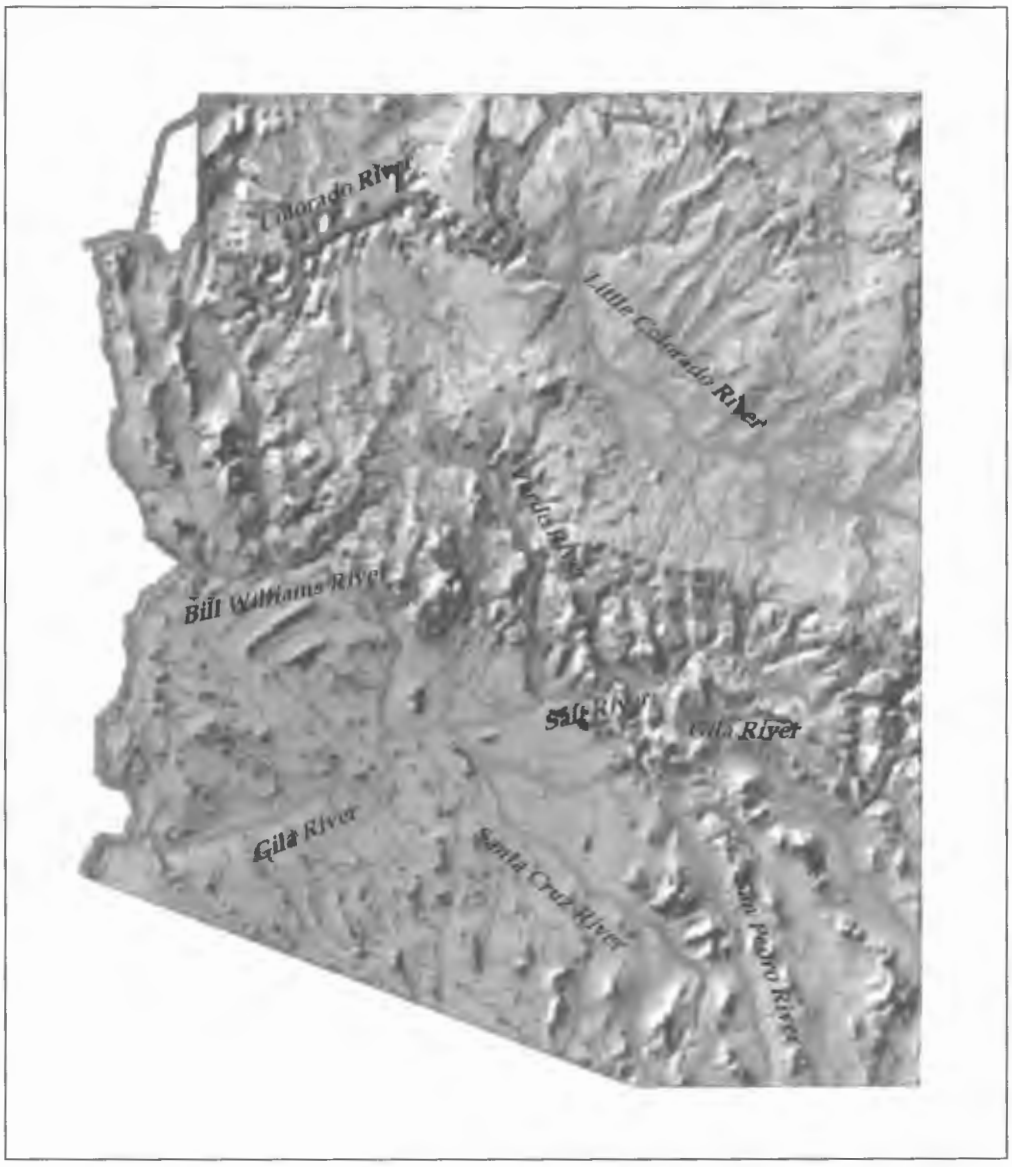
People Use Rivers for Recreation

People use rivers, lakes, and riparian areas for rafting, kayaking, canoeing, motorboating, fishing, hiking, camping, birdwatching, photography, swimming, picnicking, hunting, off-road vehicle driving, second homes sites, and other purposes. Recreational uses can change rivers through trampling of vegetation, increased demand for water, and by lowering water quality, especially if a town is expanded to accommodate increased numbers of people.

This map shows areas heavily used for recreational purposes, with **green** for boating, fishing, and lake activities; **red** for camping areas; **gold** for hiking and birdwatching; and **blue** for rafting and tubing.



Major areas that were changed by recreation.



Changed rivers.

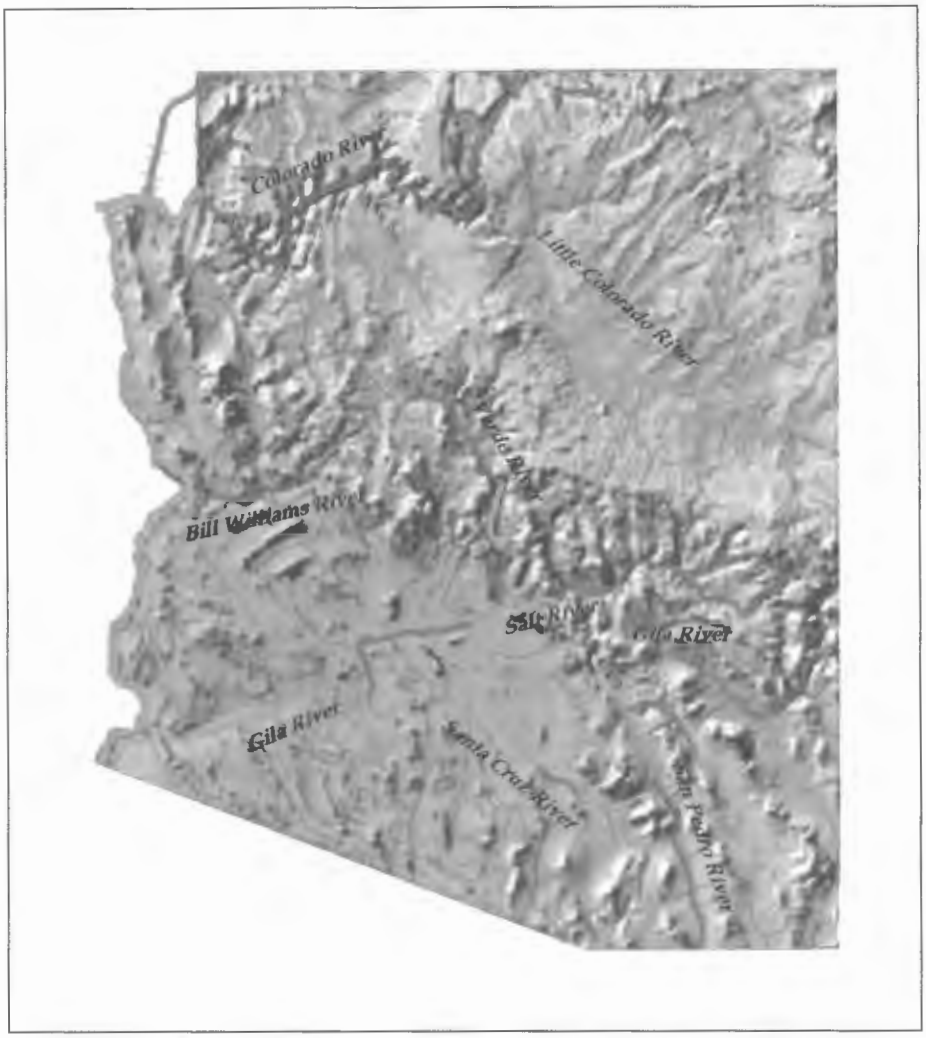
Rivers Have Changed

Most of Arizona's rivers are very different than they were in prehistoric or historic times. We cannot say exactly what percentage of Arizona's rivers have changed, but we do know the change has been statewide. Rivers undoubtedly will continue to change as the population increases in some areas and decreases in others, as farms go out of production, as subdivisions replace ranches, or as new industry arrives. Long-term climate change also may affect rivers in ways no one can predict. New preserves may restore some rivers. One thing is certain, however, Arizona rivers have changed and will continue to change.

This map shows which rivers have been impacted by one or more of the changes depicted on the preceding maps. Heavy impacts are shown in **blue** and light impacts in **green.**

The Rivers Today

The state of the rivers in 1996 is shown in very general terms in this map. **Green** indicates that the river always has flow. **Turquoise** shows rivers which are dominated by dams and reservoirs to form lakes. **Gold** indicates rivers that are ordinarily dry, except for flood times. **Red** indicates effluent dominated streams.

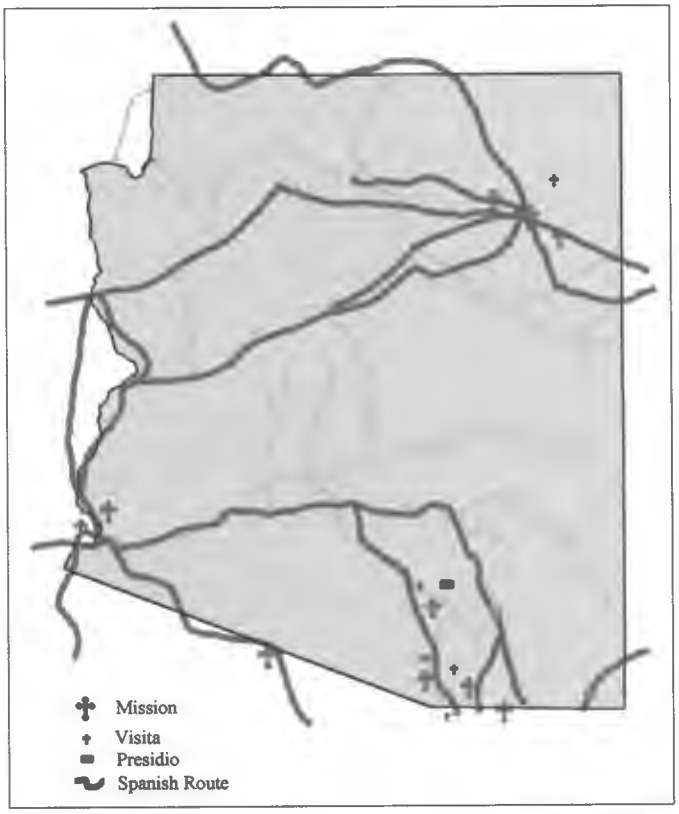


Condition of the rivers in 1990.

"Since 1870 riparian wetlands have lost their once-luxuriant aspect. The rivers and streams that flowed in the nineteenth century now have a much decreased surface flow, deeply entrenched channels in parts, and banks that support little of the native vegetation that once dominated. The cienegas, mesquite bosques, and forests of cottonwood and willow that once punctuated the floodplains and streambanks have been badly degraded or eradicated, consequently they have either disappeared or been replaced by tamarisk. ...

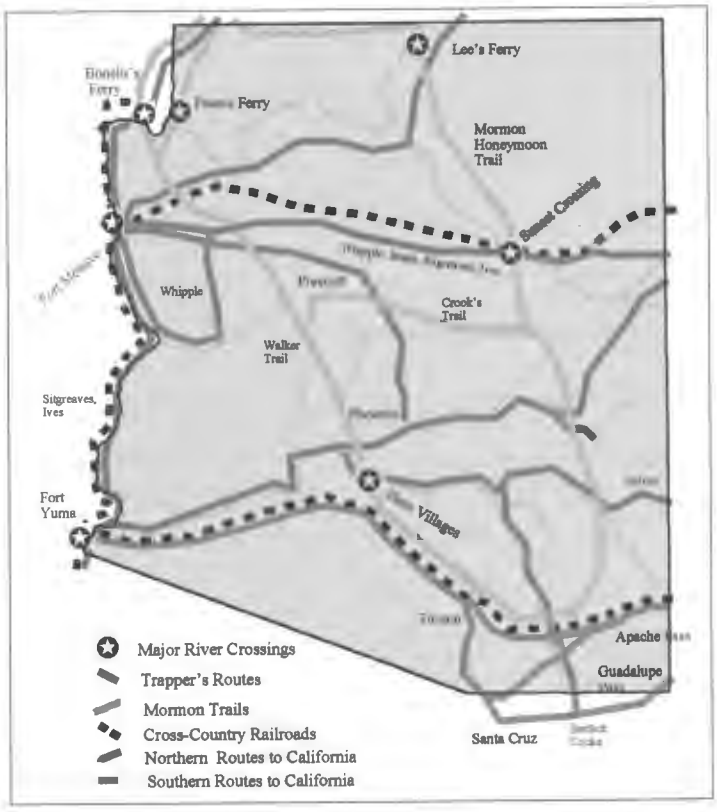
"The major changes have resulted from continuing human impacts—the diversion, damming, and channeling of surface waters and the pumpage of groundwaters so essential to maintaining riparian wetlands. These factors, along with woodcutting, agricultural clearing, construction of transportation corridors, waste disposal, grazing, concentrated human settlement, and a host of other human activities, have made riparian habitats, especially along the primary streams and rivers, the region's most disturbed and degraded habitats." Conrad Bahre, 1991.

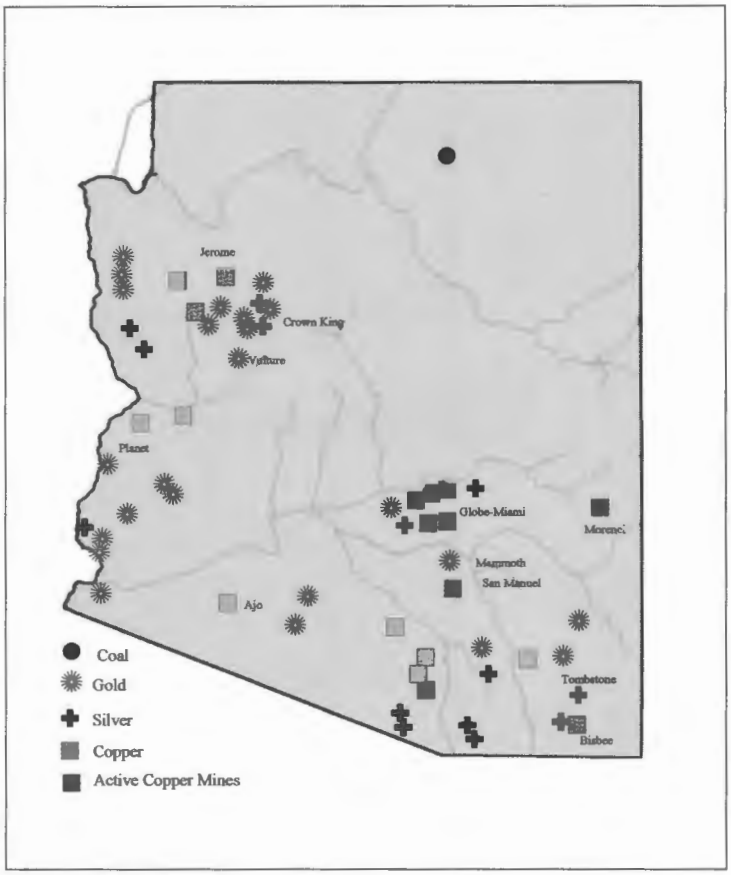
COLOR MAPS AND CHARTS



Routes and settlements of Spanish explorers and missionaries.

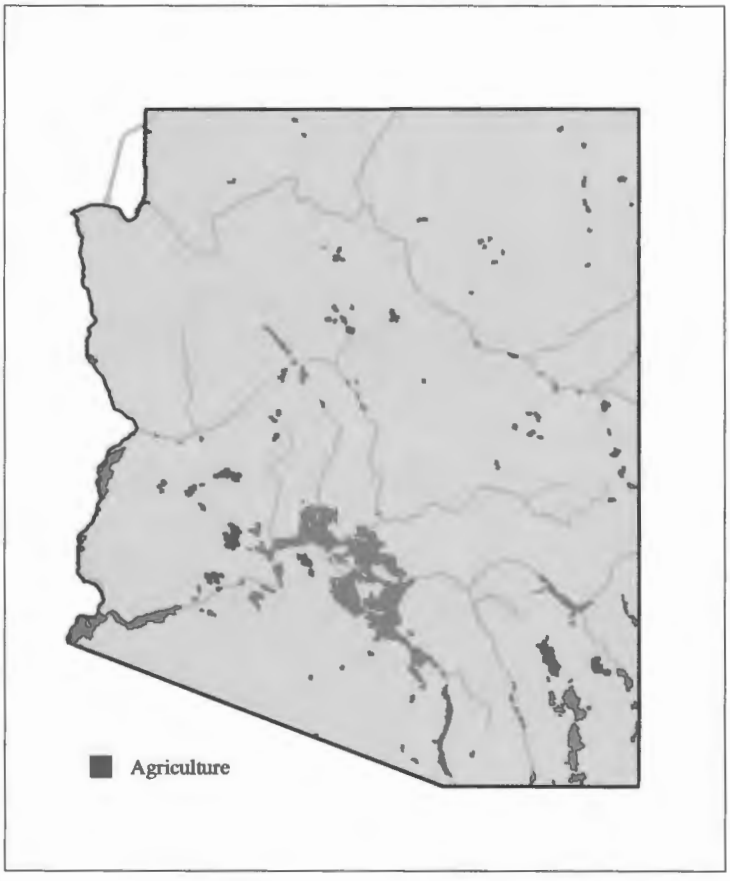
Anglo-American explorers' and travelers' routes.



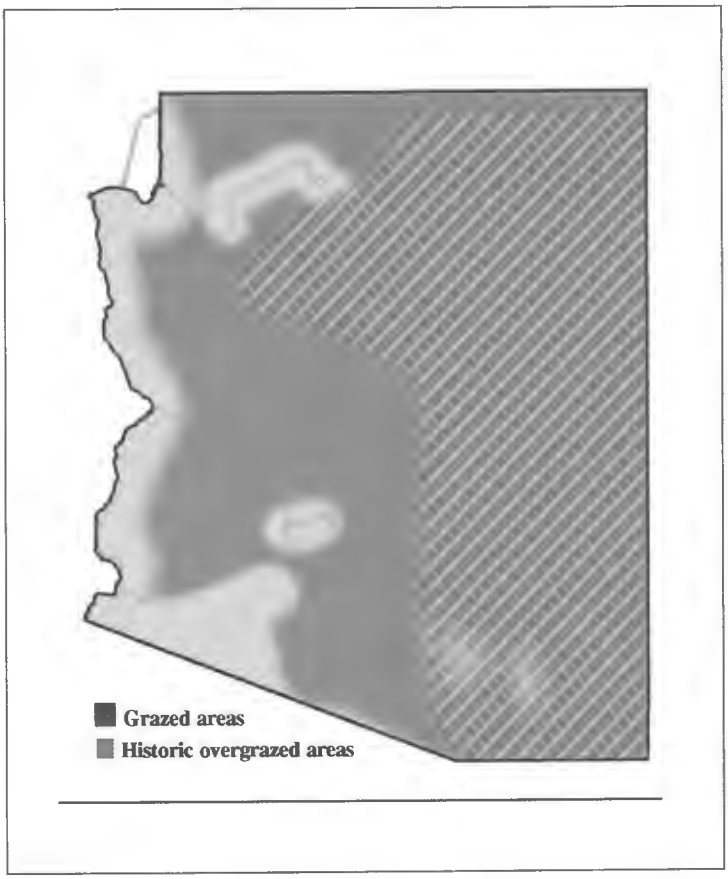


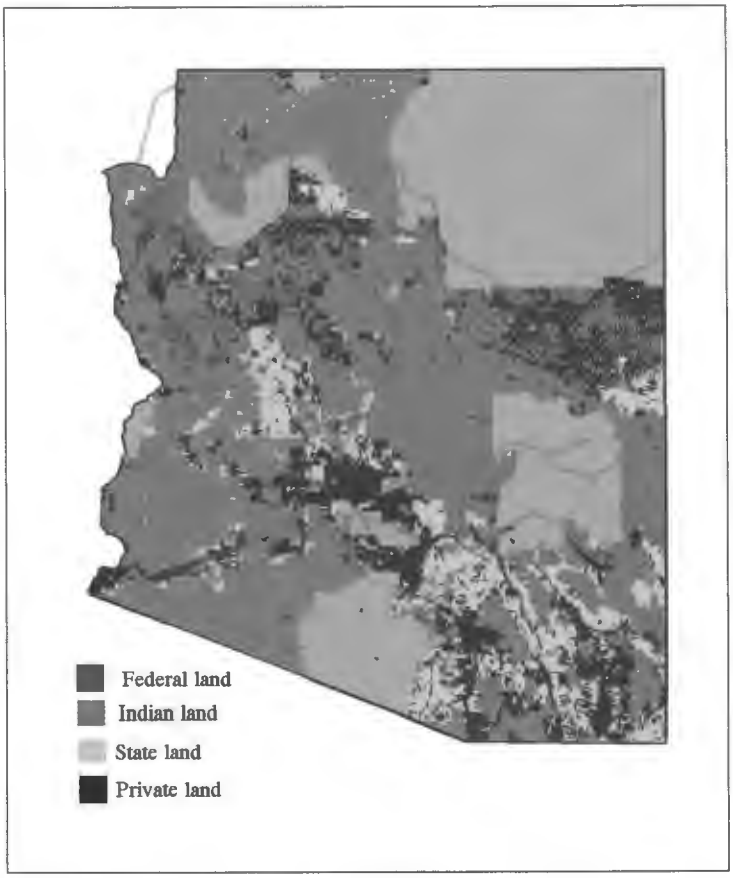
Major historic and modern mines.

Major agricultural areas.

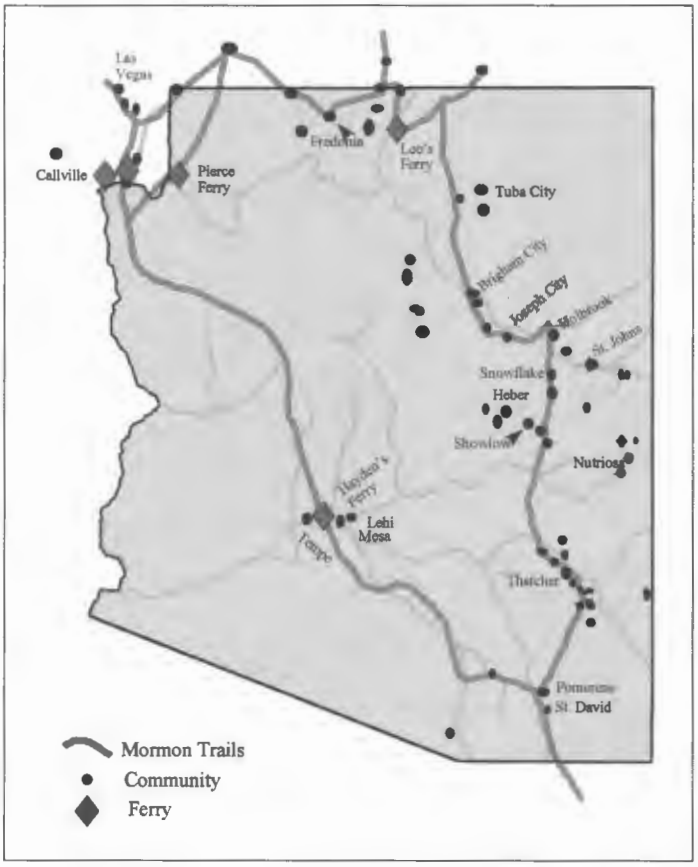


Major grazed areas.



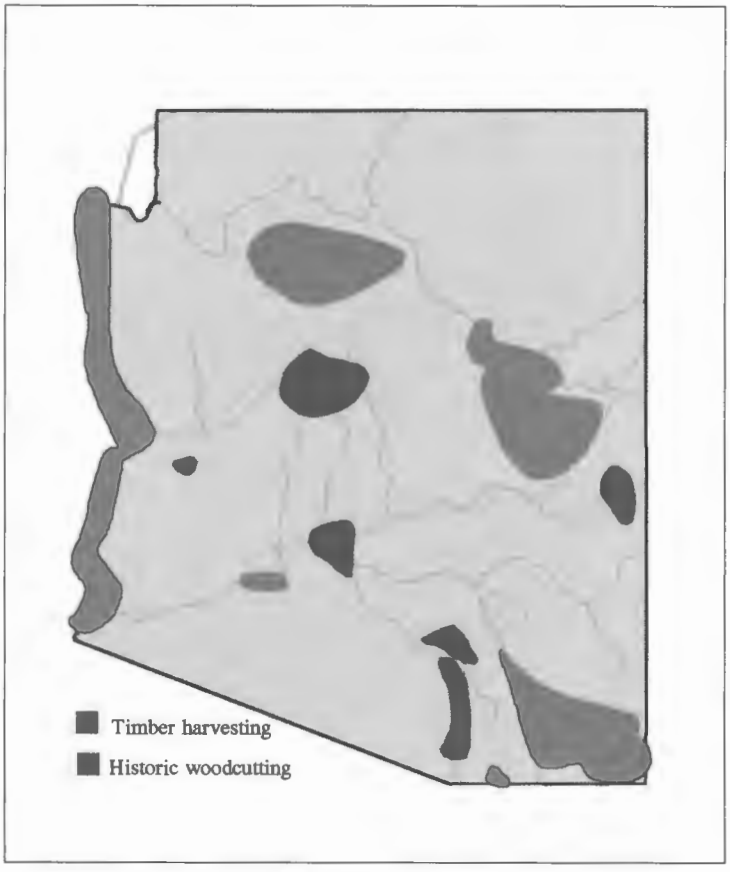


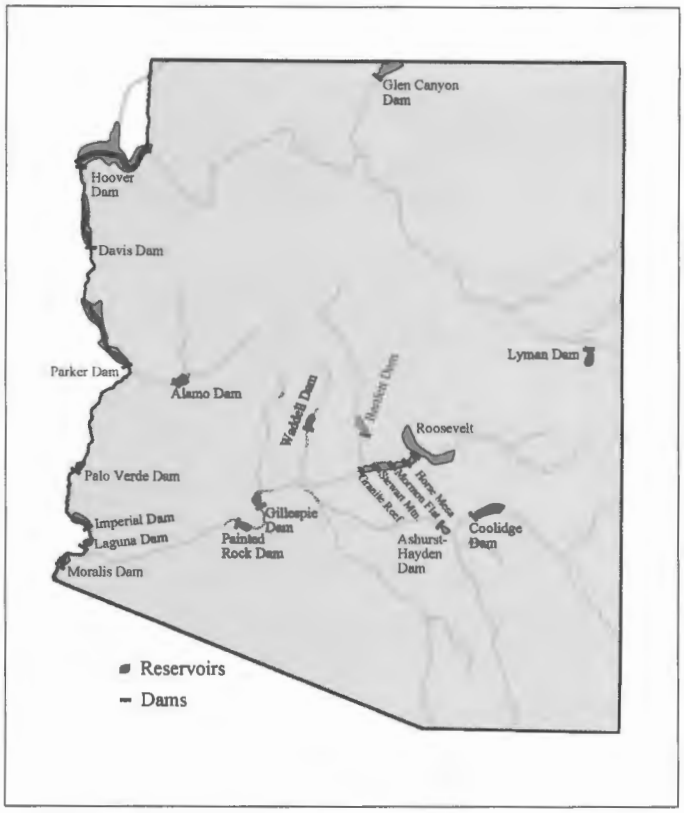
Land ownership.



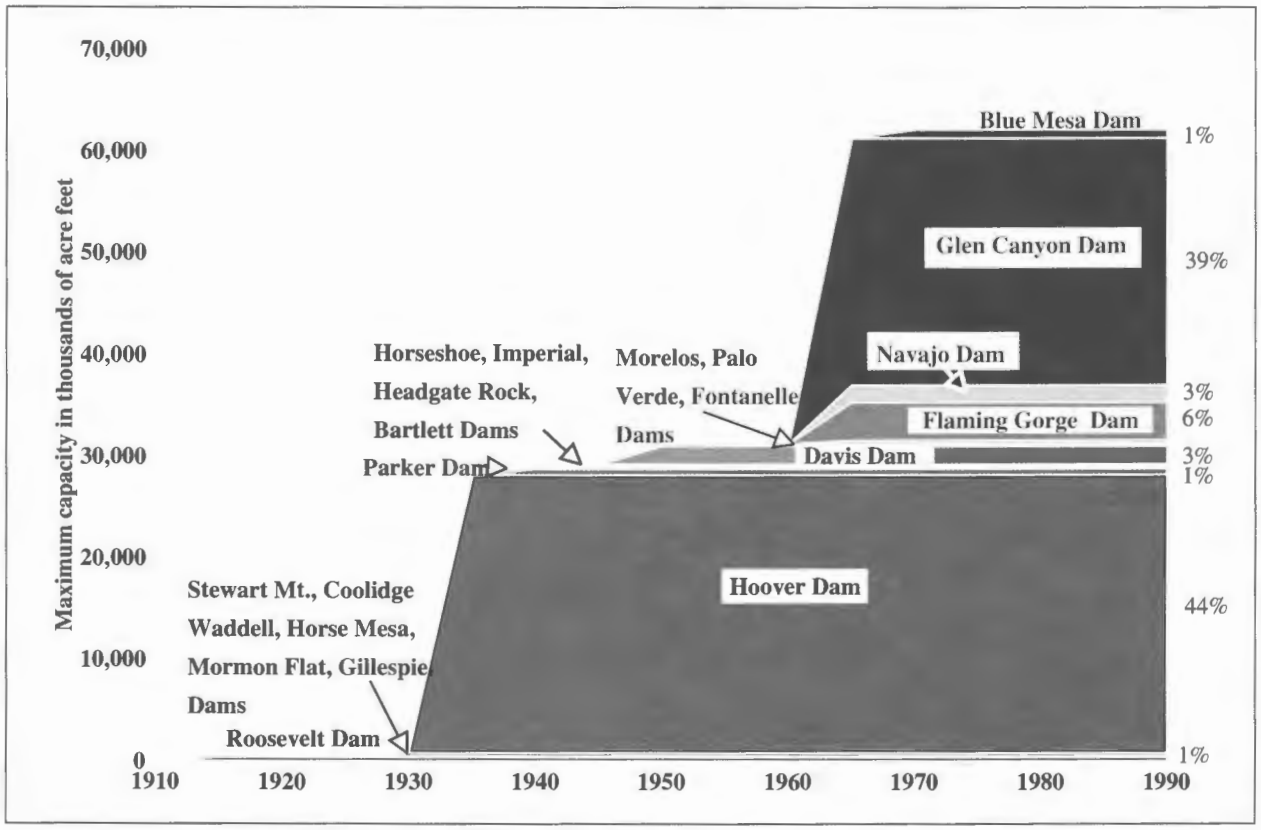
Mormon trails and settlements.

Woodcutting and timber harvesting.



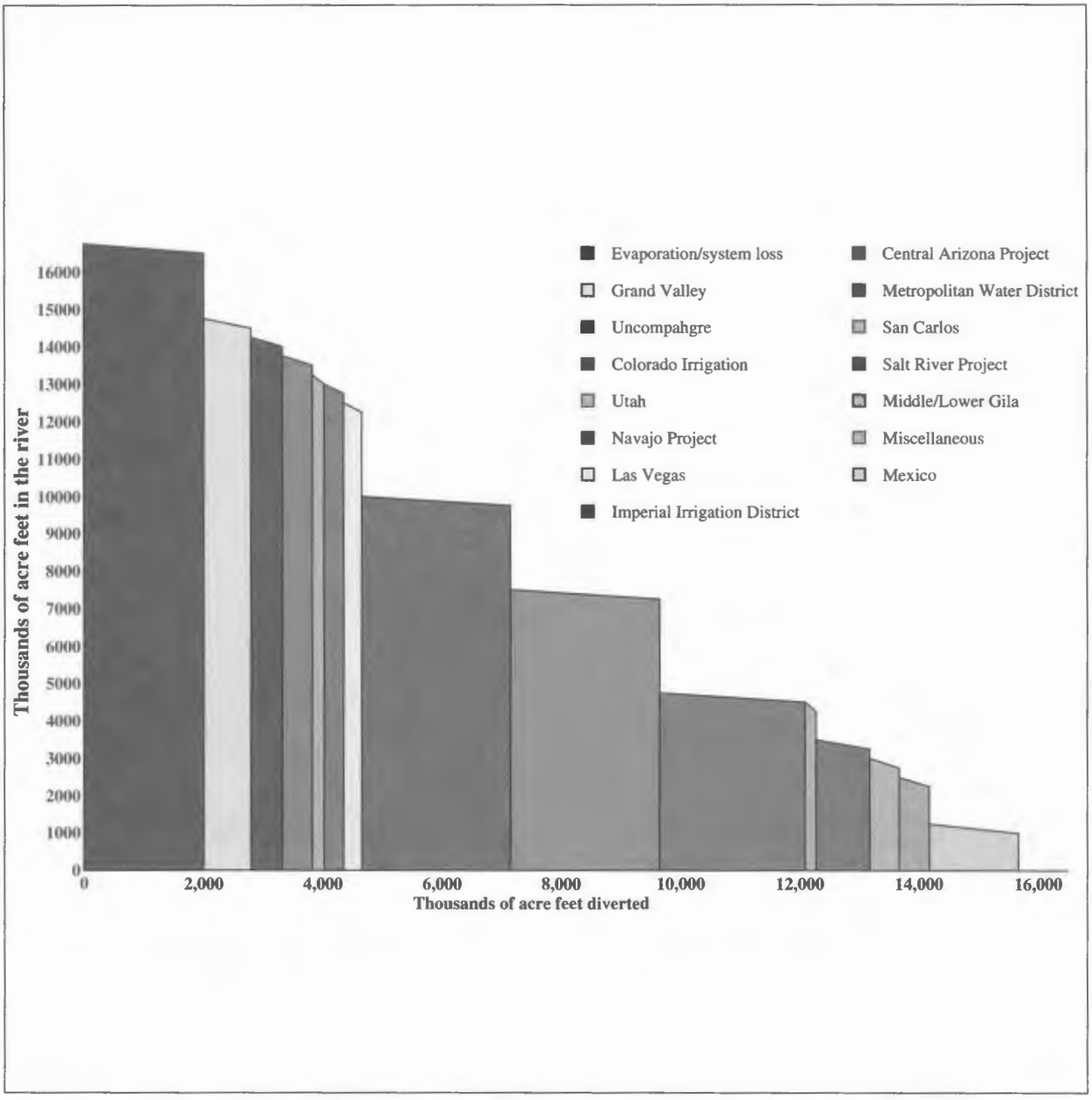


Major Arizona dams.



Major Dams in the Colorado River Basin and Arizona.

This chart depicts the storage capacity of major dams in the Colorado River system, arranged by historical order of construction. The largest Arizona dams are included.



Major water diversions in the Colorado River Basin

This chart depicts the maximum allowable diversion capacity of major projects in the Colorado River Basin, as well a water loss due to evaporation and system losses. It does not show numerous smaller diversions throughout the system. The amount of water at the top of the Y-axis is the amount agreed to in the Colorado River Compact which does not include inflow from the Gila River. The actual long-term flow of the river, according to tree-ring studies is probably closer to 13.5 million acre feet (at Lee's Ferry). Very little water reaches the Gulf of Mexico, except in years of very high precipitation.

GLOSSARY

acre foot (a.f.)
The volume of water necessary to cover one acre to a depth of one foot. Equal to 43,560 cubic feet or 325,851 gallons or 1,233 cubic meters.

alluvium
Soil deposits left by floods. Alluvial soil contains a large amount of these deposits.

aquifer
One or more geologic formations containing sufficient saturated porous and permeable material to transmit water at a rate sufficient to feed a spring or for economic extraction by a well. Combination of two Latin words, *aqua* or water, and *ferre*, to bring; literally, something that brings water.

arroyo
A steep-sided gully which forms in valleys with fine consolidated soils.

artesian well or artesian spring
A well or spring that taps groundwater under pressure so that water rises without pumping. If the water rises above the surface, it is known as a flowing artesian well.

artificial recharge
The deliberate act of adding water to a groundwater aquifer by means of a recharge project; also the water that is recharged into an aquifer. Artificial recharge can be accomplished via injection wells, spreading basins or in-stream projects.

base flow
Streamflow derived from groundwater seepage into the stream.

bosque
A forest near a riparian area, usually of mesquite trees, getting its water from a high water table near the stream. Mesquites in a bosque grow to a much larger size than mesquites in drier areas.

Central Arizona Project (C.A.P.)
A canal system that delivers water from the Colorado River to central Arizona as far south as Tucson.

channelization
A flood control system that uses concrete or similar materials to stabilize (and often straighten) a stream to prevent erosion and move water quickly downstream.

cone of depression
A localized drop in the water table which may form around a well or group of wells. Such cones often reduce water available to streams.

constructed wetland
A wetland created artificially, often as part of a wastewater treatment facility.

cubic feet per second (c.f.s.)
A measure of the rate of flow of water.

consumptive use
A use that makes water unavailable for other uses, usually by permanently removing it from local surface or groundwater storage.

diversion
Physical removal of surface water from a channel.

drainage basin
A hydrologic unit consisting of a part of the surface of the earth covered by a drainage system consisting of a surface stream or body of impounded surface water plus all tributaries.

effluent
Treated wastewater discharged from sewage treatment plants.

endangered species
Plant or animal species that has been listed by the U.S. Fish and Wildlife Service as approaching extinction and therefore in need of protection.

entrenchment
A deepening of the channel of a river, in which steep sides form. Entrenchment usually moves upstream as more and more soil is eroded.

ephemeral stream
A stream in which water flows in a channel only in response to precipitation.

extirpated species
A species which is longer found in a particular area, though it is found elsewhere.

general stream adjudication
A judicial process to determine the extent and priority of the rights of all persons to use water in a river system.

groundwater
That portion of the water beneath the surface of the earth that can be collected with wells, tunnels, or drainage galleries, or that flows naturally to the earth's surface via seeps or springs.

groundwater mining
Pumping groundwater from a basin at a rate that exceeds safe yield, thereby extracting groundwater which had accumulated over a long period of time.

habitat
The surroundings which an animal needs for survival, including food supply and shelter.

intermittent stream
A stream in which surface water flows in some places but not others, usually because of the underlying geology.

listed species
Species of plants or animals listed by the federal or state government as threatened or endangered, or as candidates for threatened or endangered status because of their rarity.

natural recharge
Naturally occurring water added to an aquifer. Natural recharge generally comes from snowmelt and storm runoff.

non-consumptive use
A use that leaves the water available for other uses. Examples are power generation and wildlife and recreational uses.

overdraft
Groundwater pumped in excess of the amount of water returned to the aquifer by natural and artificial recharge.

perennial stream
A stream which flows all the time, usually because the water supply depends on a high water table.

phreatophyte
A plant with roots that generally extend downward to the water table. Phreatophytes are common in riparian habitats—literally "water-loving plants."

regulated flow
A surface flow downstream from a dam or other flow control structure.

riparian
Of, or pertaining to rivers, ponds, or lakes, and their banks, including vegetation dependent on the rivers. A riparian habitat includes the river, with its vegetation and wildlife.

runoff
Drainage or flood discharge that leaves an area as surface flow or as pipeline flow, having reached a channel or pipeline by either surface or sub-surface routes.

subsidence
Sinking of the ground surface usually because of groundwater pumping. Subsidence cracks may develop when the ground does not sink uniformly.

threatened species
Species of plants or animals the U.S. Fish and Wildlife Service considers in danger of extinction, but not in as precarious situation as endangered species.

tributary
A stream which flows into another larger stream.

water quality
The physical, chemical and biological characteristics of water and how they relate to its suitability for a particular use.

water table
The upper boundary of a free groundwater body, at atmospheric pressure.

watershed
That surface area which drains to a specified point on a water course, usually a confluence of streams or rivers.

wetland
Land with a wet, spongy soil, where the water table is at or above the land surface for at least part of the year. Also often called "cienega" in the Southwest.

Scientific and Common Names of Plant and Animals Mentioned in the Text

Plants

Common Names	Scientific Names	Native
Acacia	*Acacia spp.*	yes
Agave	*Agave spp.*	yes
Alfalfa	*Medicago sativa*	no
Amaranth	*Amaranthus spp.*	yes
Arrowweed	*Pluchea sericea*	yes
Ash	*Fraxinus velutina and pennsylvanica*	yes
Aspen	*Populus tremuloides*	yes
Barley	*Hordeum spp.*	no
Beargrass	*Xerophylum tenax*	yes
Bermuda grass	*Cynodon dactylon*	no
Buffelgrass	*Cenchrus ciliaris*	no
Bulrush	*Scirpus spp.*	yes
Camelthorn	*Alhagi camelorum*	no
Cattail	*Typha latifolia*	yes
Chili	*Chili capsicum*	yes
Corn	*Zea mais*	no
Cottonwood	*Populus freemontii and angustifolia*	yes
Desert willow	*Chilopsis linerea*	yes
English walnut	*Juglans major*	no
Eucalyptus	*Eucalyptus spp.*	no
Fig	*Ficus spp.*	no
Flax	*Linum spp.*	yes
Foxtail grass	*Alopecurus spp.*	no
Grama grass	*Bouteloua spp.*	yes
Grapevine	*Vitis spp.*	no
Hackberry	*Celtis reticulata*	yes
Johnsongrass	*Sorghum halepense*	no
Joshua tree	*Yucca brevifolia*	yes
Juniper	*Juniperus spp.*	yes
Lehmann's lovegrass	*Eragrostis lehmanniana*	no
Mesquite	*Prosopis veluntia, glandulosa, juliflora*	yes
Oak	*Quercus spp.*	yes
Paloverde	*Cercidium spp.*	yes
Peach tree	*Prunus persica*	no
Peanuts	*Arachis hypogaea*	no
Piñon (Mexican)	*Pinus cembroides*	yes
Plum	*Prunus spp.*	no
Ponderosa pine	*Pinus ponderosa*	yes
Red brome grass	*Bromus rubens*	no
Reed	*Phragmites communis*	yes
Saltcedar	*Tamarix pentandra, chinensis, ramosissima*	no
Sedge	*Carex spp.*	yes
Seep-willow	*Baccharis glutinosa*	yes
Squash	*Cucurbita spp.*	yes
Sugar cane	*Saccharum officinarum*	no
Sweet potato	*Ipomoea batatas*	no
Sycamore	*Platanus wrightti*	yes
Tepary beans	*Phaseolus acutifolius*	yes
Tobacco	*Nicotiana spp.*	yes
Tree of heaven	*Ailanthus altissima*	no
Tumbleweed (Russian thistle)	*Salsola iberica*	no
Walnut	*Juglans major*	yes
Watercress	*Nasturtium officinale*	no
Watermelon	*Citrullus vulgaris*	no
Wheat	*Triticum aestivum*	no
Willow	*Salix gooddingii,*	yes
Yucca	*Yucca spp.*	yes

Amphibians and Reptiles

Common Names	Scientific Names	Native
Mexican garter snake	*Thamnophis eques*	yes
Bullfrog	*Rana catesbeiana*	no
Leopard frog	*Rana*	
Lowland	*yavapaiensis*	yes
Relict	*onca*	yes
Chiricahua	*chiricahuensis*	yes
Tarahumara frog	*Rana tarahumarae*	yes
Colorado River toad	*Bufo americanus*	yes

Fish

Common Names	Scientific Names	Native
Apache Trout (Gila Trout)	*Oncorhynchus gilae*	yes
Bonytail chub	*Gila elegans*	yes
Carp	*Cyprinus carpio*	no
Colorado River squawfish (Salmon trout)	*Ptychocheilus lucius*	yes
Euryhaline striped mullet	*Mugil cephalus*	yes
Flannelmouth sucker	*Catostomus latipinnis*	yes
Humpback chub	*Gila cypha*	yes
Little Colorado spinedace	*Lepidomeda vittata*	yes
Machete	*Elops affinis*	yes
Pupfish	*Cyprinodon*	
Desert	*macularius*	yes
Monkey Springs	*macularius*	yes
Quitobaquito	*macularius eremus*	yes
Smallmouth bass	*Micropterus dolomieui dolomieui*	no
Topminnow	*Poeciliopsis*	
Sonoran	*occidentalis occidentalis*	yes
Gila	*occidentalis*	yes
Yaqui	*sonoriensis*	yes
Western mosquitofish	*Gambusia affinis*	no
Largemouth bass	*Micropterus salmoides*	no

Birds

Common Names	Scientific Names	Native
Abert's finch (Towhee)	*Pipilo aberti*	yes
Gambel's quail	*Lophortyx gambelii*	yes
Orange-crowned warbler	*Vermivora celata*	yes
Turkey (wild)	*Meleagris gallopavo*	yes
Yuma clapper rail	*Rallus longirostris yumanensis*	yes

Mammals

Common Names	Scientific Names	Native
Pronghorn antelope	*Antilocapra americana*	yes
Squirrel	*Sciurus*	
Apache fox	*apache*	yes
Abert's	*aberti*	yes
Arizona gray	*arizonensis*	yes
Beaver	*Castor canadensis*	yes
Bighorn sheep	*Ovis canadensis*	yes
Bear	*Ursus*	
black (Cinnamon bear)	*americanus*	yes
grizzly	*arctos*	yes
Black-tailed deer (Mule deer)	*Odocoileus hemionus*	yes
Bobcat (Lynx)	*Lynx rufus*	yes
Coyote	*Canis latrans*	yes
Gray wolf	*Canis lupus*	yes
Gray fox	*Urocyon cinereoargenteus*	yes
Hulapai Mexican vole	*Microtus mexicanus hualpaiensis*	yes
Jaguar	*Felis onca*	yes
Kit fox	*Vulpes macrotis*	yes
Mountain lion	*Felis concolor*	yes
Muskrat	*Ondatra zibethicus*	yes
Ocelot	*Felis pardalis*	yes
Peccary	*Dicotyles tajacu*	yes
Raccoon	*Procyon lotor*	yes
Red bat	*Lasiurus borealis*	yes
Ringtail cat	*Bassasriscus astutas*	yes
River otter	*Lutra canadensis*	yes
Water shrew	*Sorex palustris*	yes
White-tailed deer	*Odocoileus virginianus*	yes

FOR FURTHER READING

The most important sources of information for this publication are listed below. For a full list of references on many topics having to do with Arizona rivers, see **Where to Find Information about the History of Arizona Rivers** published by the Water Resources Research Center, University of Arizona in 1996, which contains over 1,800 entries about the history of Arizona rivers.

Changing Rivers

The pioneering study of environmental change in Arizona was written by James Hastings and Raymond Turner, **The Changing Mile: An Ecological Study of Vegetation Change with Time in the Lower Mile of an Arid and Semiarid Region** (Tucson: University of Arizona Press, 1980). The authors used historic and modern photos to document environmental changes brought about by humans.

Other studies of environmental change in Southern Arizona are: C. Bahre, **A Legacy of Change: Historic Human Impact on Vegetation in the Arizona Borderlands** (Tucson: University of Arizona Press, 1991) and H. Dobyns, **From Fire To Flood: Historic Human Destruction of Sonoran Desert Riverine Oases** (Socorro, New Mexico: Ballena Press, 1981).

Works that examine environmental change and develop techniques for evaluating change in specific areas are: Amadeo Rea, **Once a River: Bird Life and Habitat Changes on the Middle Gila** (Tucson: University of Arizona Press, 1983); D. Hadley and T. Sheridan, **Land Use History of the San Rafael Valley, Arizona (1540-1960)** (Fort Collins, CO: Rocky Mountain Forest and Range Experiment Station, 1995; USDA Forest Service General Technical Report RM-GTR-269); D. Hadley, P. Warshall, and D. Bufkin, **Environmental Change in Aravaipa, 1870-1970: An Ethnoecological Survey** (Phoenix: Arizona State Office of the Bureau of Land Management, 1991; G. Stumpf (ed.) Cultural Resource Series No. 7); D. Hadley, R. Ahlstrom and S. Mills, **El Rio Bonito: An Ethnoecological Study of the Bonita Creek Watershed, Southeastern Arizona** (Phoenix: Arizona State Office of the Bureau of Land Management, 1993; Cultural Resource Series No. 8); and Sierra Club, **The Impacts of Population Growth in Eastern Pima County** (San Francisco: Sierra Club, 1988).

Man and Wildlife in Arizona by Goode Davis (Phoenix: Arizona Game and Fish Department, 1986, D. Brown and N. Carmony, eds.) is an indispensable source of information about what mid-nineteenth century travelers observed about their surroundings, with emphasis on wildlife and habitat.

Arizona Historical Atlas by H. Walker and D. Bufkin (Norman: University of Oklahoma Press, 1986) has many maps illustrating important facts about Arizona history and was the source for many of the maps in this book.

Many histories of Arizona have been written over the years. A recent useful overview, which looks in part at environmental change, is Tom Sheridan's **Arizona—A History** (Tucson: University of Arizona Press, 1995).

Changing Landscape and People

Paul Martin was one of the first to suggest that ancient people had made major changes to Arizona's environment. He was also responsible for studies of climate change. One of his major works is **The Last 10,000 Years: A Fossil Pollen Record of the American Southwest** (Tucson: University of Arizona Press, 1963).

Many studies of the Hohokam are available, including Emil Haury, **The Hohokam** (Tucson: University of Arizona Press, 1976). Detailed studies of specific Hohokam locations or agricultural techniques include: S. Fish and P. Fish, eds., **Prehistoric Agricultural**

Strategies in the Southwest (Tempe: Arizona State University, 1984; Anthropological Research Papers No. 33); H. Patrick, **The Ancient Canal Systems and Pueblos of the Salt River Valley, Arizona** (Phoenix: Phoenix Free Museum, 1903; Bulletin No. 1); L. Teague, **Prehistory and the Traditions of the O'odham and Hopi** (1993. *The Kiva*, 58(4):435-454); O. Turney, **Prehistoric Irrigation** (1929, *Arizona Historical Review*, 2(1-4); 4 parts in successive issues); R. Woodbury, **The Hohokam Canals at Pueblo Grande, Arizona** (1960, *American Antiquity*, 26(2):267-27); and P. Crown and W. Judge, **Chaco and Hohokam Prehistoric Regional Systems in the American Southwest (Santa Fe: School of American Research Press, 1991).**

Studies of the Anasazi include J. Schoenwetter, et al., **An Ecological Interpretation of Anasazi Settlement Patterns** (*In* Anthropological Archaeology in the Americas, Washington DC: Anthropological Society, 1968) and L. Agenbroad, **Before the Anasazi: Early Man on the Colorado Plateau** (1990, *Plateau* 61(2):1-32).

Information on the Sinagua can be found in H. Colton, The Sinagua: A Summary of the Archaeology of the Region of Flagstaff, Arizona (Flagstaff: Museum of Northern Arizona, 1946; Bulletin 22) and M. Tagg, A. Jones and L. Huckell, **The Tuzigoot Survey and Three Small Verde Valley Projects** (Tucson: Western Archaeological and Conservation Center, 1986; Publications in Anthropology).

The Mogollon culture is described in K. Lightfoot, R. Most, S. Fish and R. Jewett, **The Duncan Project: A Study of the Occupation, Duration, and Settlement Pattern of an Early Mogollon Pithouse Village** (Tempe: Arizona State University Archaeological Field Study #6, 1984) and the Northern Gila County Historical Society, **Rim Country History** (Payson, Arizona: Rim Country Printer, 1984).

Use of water by prehistoric people is described in **Surface Water Resources for Prehistoric Peoples in Western Papagueria of the North American Southwest** by Bill Broyles (1996, *Journal of Arid Environments* 33:483-495).

Climate and Geological Change

The most important long-term studies of climate have been done at the University of Arizona's Tree-Ring (Dendrochronology) Laboratory in Tucson by C. Stockton. One of his many works is **Long-Term Streamflow Records Reconstructed from Tree Rings** (Tucson: University of Arizona Press, 1975).

A discussion of the history of the climate based upon pollen and fossil analysis can be found in Owen Davis and David Shafer, **A Holocene Climatic Record for the Sonoran Desert from Pollen Analysis of Montezuma Well, Arizona** (1992, *Paleoecology* 92:107-119).

Fossil packrat middens provide information on historic vegetation and climate. One of T. Van Devender's many works on this topic, with F. Wiseman, is **A Preliminary Chronology of Bioenvironmental Changes During the Paleoindian Period of the Monsoonal Southwest** (pages 13-27 *In* E. M. Johnson ed., Lubbock, Texas: Paleoindian Lifeways West Texas Museum Association, 1977; Museum Journal Volume 17).

A brief, general overview of the geology of Arizona is found in Louis L. Jacob, **The Setting: Geology and Fossils** (*Plateau* 1982 53(1):1076).

Current and historic information on Arizona's climate can be found in W. Sellers, **Arizona Climate** (Tucson: University of Arizona Press, 1974) and **Major Storms and Floods in Arizona 1862-1983** (Phoenix: Laboratory of Climatology, Arizona State University, 1984).

A summary of recent flood events is contained in **Arizona Water Resources Assessment, Volume 1: Inventory and Analysis** (Phoenix: Arizona Department of Water Resources, August 1994). For specific information on the impact of the floods of 1983 in southeastern Arizona, see R.H. Roeske, J.M Garret and J.H Eychaner, **Floods of October 1983 in Southeastern Arizona** (Tucson: U.S. Geological Survey, 1989; Water-Resources Investigations Report 85-4225-C) and B. Tellman et al. **Flood and Erosion Hazards in Tucson** (Tucson: Southwest Environmental Service, 1980).

Information on the history of climate and potential mpacts of sustained droughts on the Colorado River basin is found in **Severe Sustained Drought Report: Managing the Colorado River System in Times of Water Shortage** (Tucson: Arizona Water Resources Research Center, University of Arizona, 1995; Issue No. One, Powell Consortium).

Santa Cruz River

The San Rafael Valley is thoroughly discussed by D. Hadley and T. Sheridan in **Land Use History of the San Rafael Valley, Arizona (1540-1960)** (Fort Collins, Colorado: Rocky Mountain Forest and Range Experiment Station, 1995). The most thorough study of the Santa Cruz River in the Tucson area is J. Betancourt and R. Turner, **Tucson's Santa Cruz River and the Arroyo Legacy** (manuscript at University of Arizona's Main Library; in press at University of Arizona Press, Tucson). A study of the Sky Island region of southern Arizona, John P.Wilson, **Islands in the Desert: A History of the Upland Areas of Southeast Arizona** (Las Cruces, NM: U.S. Forest Service, 1987), includes much material relevant to the Santa Cruz Valley.

The Spanish period is thoroughly discussed in Bolton, **Kino's Historical Memoir of Pimería Alta** (Cleveland: The Arthur H. Clark Company, 1919) and James Officer's**Hispanic Arizona 1536-1856** (Tucson: University of Arizona Press, 1987). John Spring, **John**

Spring's Arizona (Tucson: University of Arizona Press, 1966) describes circumstances existing during early American settlement. J. Wagoner, **History of the Cattle Industry in Southern Arizona, 1540-1940** (Tucson: University of Arizona Press, 1952) provides a good background on livestock and ranching. General information about water use across Arizona can be found in S. Eden and M. Wallace, **Arizona Water: Information and Issues** (Tucson: Water Resources Research Center, 1992; Issue Paper No. 11).

Other useful sources of information at the Arizona Historical Society or Special Collections at the University of Arizona are Wheeler's manuscript on the **History and Facts Concerning Warner and Silver Lake and the Santa Cruz River** (Tucson: Arizona Historical Society; MS 853) and Hugh Holub and Donald Bufkin, **The Santa Cruz River in Pima County** (Tucson: Arizona Historical Society files, 1987).

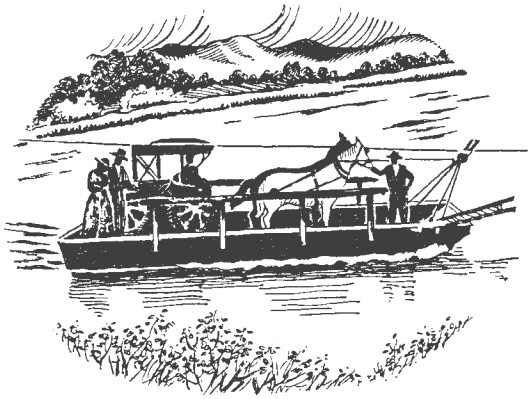
Changes in wildlife and vegetation are described by Robert Ohmart, **Past and Present Biotic Communities of the Lower Colorado River Mainstem and Selected Tributaries: Volume Five—the Gila, San Pedro and Santa Cruz Rivers** (Boulder City, Nevada, Bureau of Reclamation, 1986) and D.A. Hendrickson and W.L. Minckley, **Cienegas—Vanishing Climax Communities of the American Southwest**, *(Desert Plants*, 6:130-175).

A Time of Change

Studies of the Spanish period include: J. Officer, **Hispanic Arizona, 1536-1856** (Tucson: University of Arizona Press, 1987) and E. Spicer, **Cycles of Conquest: The Impact of Spain, Mexico, and the United States on the Indians of the Southwest 1533-1960** (Tucson: University of Arizona Press, 1962).

Father Kino's travels and impacts can be studied in H. Bolton, ed., **Kino's Historical Memoir of Pimeria Alta** (Cleveland: The Arthur H. Clark Company, 1919) or in E. Kino, **A Contemporary Account of the Beginnings of California, Sonora, and Arizona, by Father Eusebio Francisco Kino, S.J., Pioneer Missionary, Explorer, Cartographer, and Ranchman, 1683-1711**. J. Manje's journals, **Unknown Arizona and Sonora, 1693-1721** (Tucson: Arizona Silhouettes, 1954; from the Francisco Fernandez del Castillo version of Luz de Tierra Incognita, Harry J. Karns and Associates) describes his travels in the Southwest.

For histories of the Apaches and Navajos, see W. Buskirk, **The Western Apache: Living With the Land Before 1950** (Norman: University of Oklahoma Press, 1986) and G. Bailey and R. Bailey, **A History of the Navajos**, (Santa Fe, NM: School of American Research Press, 1986).



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Information on early Spanish and Mexican settlement along the San Pedro River is found in George Hammond, **Narratives of the Coronado Expedition, 1540-1542** (Albuquerque: University of New Mexico Press, 1940); James Officer, **Hispanic Arizona 1536-1856** (Tucson: University of Arizona Press, 1987); Edward H. Spicer, **Cycles of Conquest: The Impact of Spain, Mexico, and the United States on the Indians of the Southwest** (Tucson: University of Arizona Press, 1972); Reba B. Well, **The San Bernadino Ranch** (1985, *The Cochise Quarterly*, 15(4)); and John

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A detailed study of the hydrology of the San Pedro as well as its riparian vegetation is by the Arizona Department of Water Resources, **Hydrographic Survey Report for the San Pedro River Watershed, Vol. 1, General Assessment** (Phoenix: Arizona Department of Water Resources, August 1990) and in Laurel Lacher, **Hydrologic and Legal Issues of the Upper San Pedro River Basin, Arizona** (Tucson: Department of Hydrology and Water Resources, University of Arizona).

For information about the San Pedro Riparian National Conservation Area, see William Jackson, **Assessment of Water Condition and Management Opportunities in Support of Riparian Values: BLM San Pedro River Properties, Arizona** (Denver: Bureau of Land Management. 1993).

Anglo-Americans Arrive

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The era of trapping in Arizona is described by Frank C. Lockwood in **American Hunters and Trappers in Arizona** (1929, *Arizona Historical Review*, 2(2 July). For a lively (if not always accurate) journal of the trapping period, see James O. Pattie, **The Personal Narrative of James Ohio Pattie** (Philadelphia: Lippincott, 1962).

Surveyors and early explorers are discussed in M. Gordon, ed., **Through Indian Country to California: John P. Sherburne's Diary of the Whipple Expedition, 1853-1854** (Stanford: Stanford University Press, 1988). The reports of surveyors, Sitgreaves, Gray, Emory, Ives, Powell, Whipple and Beale are basic to understanding this period. Full references are available on **Where to Find Information about the History of Arizona Rivers** (Tucson: Water Resources Research Center, University of Arizona, 1995). An interesting study of the role of women in the Mormom Batallion is Norma B. Ricketts, Melissa's Journey with the Mormon Batallion (Salt Lake City: International Society of Daughters of Utah Pioneers, 1994).

Works about specific types of travel are: R. Lingenfelter, **Steamboats on the Colorado River 1852-1916** (Tucson: University of Arizona Press, 1978); R. Conkling and M. Conkling, **The Butterfield Overland Mail 1857-1869** (Glendale, CA: The Arthur H. Clark Co., 1947); D. Myrick, **Railroads of Arizona** (Berkeley, California: Howell-North Books, 1975); K. Bryant, **History of the Atchison, Topeka and Santa Fe Railway** (New York: MacMilllan Publishing Co., 1974); J. Sayre, **A Journey Through Yesteryear: Ghost Railroads of Central Arizona** (Phoenix: Red Rock Publishing Co., 1985); and, R. Carlock, **The Hashknife: The Early Days of the Aztec Land and Cattle Company, Limited** (Tucson: Westernlore Press, 1994) discusses the role of the railroad through Northern Arizona.

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The story of mining along the Verde is described in C. Dunning, **Rock to Riches** (Phoenix: Southwest Publishing Company, Inc., 1959).

A thorough study of Bartlett Dam and its history is D. Introcaso, **Bartlett Dam, Maricopa County, Arizona: Photographs, Written Historical & Descriptive Data, Reduced Copies of Drawings** (San Francisco: National Park Service, Historic American Building Survey, 1990).

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Miners, Ranchers and Farmers Settle Arizona

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Recent statistics on mining, agriculture and other topics are found in **Arizona Statistical Abstract** (Tucson: Economic and Business Research Program, Office of Community Affairs, Karl Eller Graduate School of Management, College of Business and Public Administration, University of Arizona) for the years in question.

Arroyos

Many people have looked at the causes of arroyo cutting. The major works are: James Hastings and Raymond Turner, **The Changing Mile: An Ecological Study of Vegetation Change with Time in the Lower Mile of an Arid and Semiarid Region** (Tucson: University of Arizona Press, 1980); R. Cooke and R. Reeves, **Arroyos and Environmental Change in the American Southwest** (Oxford: Clarendon Press, Oxford Research Studies in Geography, 1976); C. Bahre, **A Legacy of Change: Historic Human Impact on Vegetation in the Arizona Borderlands** (Tucson: University of Arizona Press, 1991); E. Antevs, **Arroyo-Cutting and Filling** (1952, *Journal of Geology* 60:375-385); C. Bahre and M. Shelton, **Historic Vegetation Change, Mesquite Increases, and Climate in Southeastern Arizona** (1993, *Journal of Biogeography* 20:209-224); J. Betancourt and R. Turner, **Tucson's Santa Cruz River and the Arroyo Legacy** (Forthcoming from University of Arizona Press, Tucson); H. Calkins, **Man and Gullies** (1941, *The New Mexico Quarterly Review* 11:69-78); H. Dobyns, **From Fire To Flood: Historic Human Destruction of Sonoran Desert Riverine Oases** (Socorro, NM: Ballena Press, 1981); J. Duce, **The Effect of Cattle on the Erosion of Canyon Bottoms** (1918, *Science* 47(1219):450-452); and F. Winn, **The West Fork of the Gila River** (1926, *Science* 64(1644):16-17).

Salt River

Information about the prehistory of the Salt River area can be found in the Hohokam studies referenced in the "The Early Landscape and People" chapter and in C. Hayden, **A History of the Pima Indians and the San Carlos Irrigation Project** (Washington DC: Government Printing Office, 1965); F. Hodge, **Prehistoric Irrigation in Arizona** (1893, *American Anthropologist* 6(July):323-330); J. Myers and R. Gryda, **The Salt River Pima Maricopa Indians: Legends, Reflections, History and Future** (Phoenix: Life's Reflections,1988); H. Patrick, **The Ancient Canal Systems and Pueblos of the Salt River Valley, Arizona** (Phoenix: Phoenix Free Museum, Bulletin No. 1, 1903); and O. Turney, **Prehistoric Irrigation** (1929, *Arizona Historical Review* 2(1-4): four parts in successive issues).

Information about settlement of the Salt River Valley can be found in J. Barney, **Looking Back [John Swilling]** (1952, *Phoenix Gazette*, April 16:16); J. Barney, **Agricultural Conditions in the Salt River Valley In the Early 1870's** (1955, *The Sheriff Magazine* (April-May):37-40); F. Barrios, **A History of the Taming of the Salt River** (Paper presented at the Arizona Historical Society Convention, on file at Arizona Historical Society, Tucson, 1988); G. Carlin, **Life on the St. Johns Ditch** (1981, *Journal of Arizona History* (Summer):159-176); A. Davis, **Mormon Settlement in Arizona** (Phoenix: State of Arizona, 1897); W. Merrill, **One Hundred Steps Down Mesa's Past** (Mesa, AZ: Lofgreen Printing Co., 1970); W. Merrill, **One Hundred Yesterdays** (Mesa, AZ: Lofgreen Printing, 1972); W. Merrill, **One Hundred Echoes From Mesa's Past** (Mesa, AZ: Lofgreen Printing, 1975); and W. Merrill, **One Hundred Footprints on Forgotten Trails** (Mesa, AZ: Lofgreen Printing Company, 1977).

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There are several histories of Phoenix. One useful work is B. Luckingham, **Phoenix: The History of a Southwestern Metropolis** (Tucson: University of Arizona Press, 1989). The history of Tempe is found in M. Weisiger, **This History of Tempe, Arizona, 1871-1930: A Preliminary Report** (Manuscript on file at Tempe Historical Museum, 1978).

The Rio Salado Project is described in B. Davis, **Rio Salado: A River Runs Through It** (1993, *Tempe Daily News Tribune*, 25-26, April).

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An important source of information about historic woodcutting and its impacts is C. Bahre, **A Legacy of Change: Historic Human Impact on Vegetation in the Arizona Borderlands** (Tucson: University of Arizona Press, 1991); C. Bahre and C. Hutchinson, **The Impact of Historic Fuelwood Cutting on the Semidesert Woodlands of Southeastern Arizona** (1985, *Journal of Forest History 29(4):175-186); and, G. Nabhan, et al.,* **Papago Influences on Habitat and Biotic Diversity:** Quitovac Oasis Ethnoecology (1982, *Journal of Ethnobiology* 2: 124-143).

Changes to forests as a result of fire suppression are discussed in W. Covington and M. Moore, **Postsettlement Changes in Natural Fire Regimes and Forest Structure: Ecological Restoration of Old-Growth Ponderosa Pine Forests** (p. 153-181 *In* R. N. Sampson and D. L. Adams, eds., Assessing Forest Ecosystem Health in the Inland West, Papers from the American Forests Workshop November 14-20, 1993 in Sun Valley, Idaho. Food Products Press, New York).

For general information on the history of the timber industry, see T. Sheridan, **Arizona: A History** (Tucson: University of Arizona Press, 1995). The Arizona Historical Society has many articles on Arizona's early woodcutting and timber industry.

Five Tributaries

Agua Fria

Prehistoric occupation of the area is found in S. Fish and P. Fish ed., **Prehistoric Agricultural Strategies in the Southwest** (Tempe: Arizona State University, Anthropological Research Papers, No. 33, 1984). Waddell Dam is discussed in D. Introcaso, **Waddell Dam Maricopa County, Arizona: Photographs, Written Historical & Descriptive Data, Reduced Copies of Drawings** (San Francisco: National Park Service, Historic American Building Survey, 1988). Mining along the Agua Fria is discussed in C. Dunning, **Rock to Riches** (Phoenix: Southwest Publishing Company, Inc., 1959).

Hassayampa River

An overview of the Hassayampa River is **Arizona Stream Navigability Study for the Hassayampa River:** Gila River confluence to Headwaters (Phoenix: Prepared by CH2M Hill for the Arizona State Land Department, 1993). For a general history of the Wickenburg area, see H. Hawkins, **A History of Wickenburg to 1875** (Wickenburg: Maricopa County Historical Society, 1971). Edwin Corle discusses the Vulture Mine in **The Gila, River of the Southwest** (Lincoln: University of Nebraska Press, 1951).

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Bonita Creek

The only comprehensive study of Rio Bonito is D. Hadley, R. Ahlstrom and S. Mills, **El Rio Bonito: An Ethnoecological Study of the Bonita Creek Watershed, Southeastern Arizona** (Phoenix: Arizona State Office of the U.S. Bureau of Land Management, Cultural Resource Series No. 8, 1993).

San Simon River

A History of the San Simon River is available in G. Jordan and M. Maynard, **The San Simon Watershed: Historical Review** (1970, *Progressive Agriculture in Arizona* 22:10-13). Grazing in the valley is discussed in W. Barnes, **Herds in the San Simon Valley** (1936, *American Forests* 42:456-457).

Growth of Arizona's Towns

Statistics on the growth of towns and counties are found in **Arizona Statistical Abstract** for various years (Tucson: Economic and Business Research Program, Office of Community Affairs, Karl Eller Graduate School of Management, College of Business and Public Administration, University of Arizona). H. Walker and D. Bufkin show growth of towns through annotated maps in **Historical Atlas of Arizona** (Norman: University of Oklahoma Press, 1986). Statistics on population growth are available from the Arizona Department of Economic Security, most notably in **A Demographic Guide to Arizona 1985** (Phoenix: Population Statistics Unit Report #14, 1985).

The history of Mormon settlement is described in James H. McClintock, **Mormon Settlement in Arizona,** (Tucson: University of Arizona Press, 1985 - originally published in 1921). Also see references in the "Little Colorado River" and "Salt River" chapters.

Gila River

For general history of the Gila River, see Edwin Corle, **The Gila: River of the Southwest** (Lincoln: University of Nebraska Press, 1951).

Information on early Spanish, Mexican and Anglo settlement along the Gila River is found in George Hammond, **Narratives of the Coronado Expedition, 1540-1542** (Albuquerque: University of New Mexico Press, 1940); James Officer, **Hispanic Arizona, 1536-1856** (Tucson: University of Arizona Press, 1987); Edward H. Spicer, **Cycles of Conquest: The Impact of Spain, Mexico, and the United States on the Indians of the Southwest** (Tucson: University of Arizona Press, 1972); and Donald Dove, **Early White Settlements Along the Gila River, Arizona, 1850-1980** (Manuscript on File at the Arizona Collection, Arizona State University).

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The history of Florence is told in A. Baldwin, **The History of Florence, Arizona, 1866-1940** (Tucson: University of Arizona, Ph.D. Dissertation, 1941).

Dams on the Gila are discussed in B. Thum, **Coolidge Dam and the San Carlos Project** (1930, *The Great Southwest* 5(4):19-22). For information on the impacts of water diversions on the Pima and Maricopa Indians, see George Webb, **A Pima Remembers** (Tucson: University of Arizona Press, 1992); Paul H. Ezell, **Plants Without Water-The Pima-Maricopa Experience** (1994, *Journal of the Southwest* 36:315-392); Robert Hackenberg, **A Brief History of the Gila River Indian Reservation** (Tucson: Manuscript at the University of Arizona Library, 1955); and C. Hayden, **A History of the Pima Indians and the San Carlos Irrigation Project** (Washington DC: U.S. Government Printing Office, 1965).

An important study of changes in the river is Amadeo Rea's, **Once a River: Bird Life and Habitat Changes Along the Middle Gila** (Tucson: University of Arizona Press, 1983). The impact of water diversions and dams on the Gila River can be found in Henry Dobyns, **Who Killed the Gila?** (1978, *Journal of Arizona History* 19:17-30). Descriptions of changes in vegetation and wildlife can be found in Robert Ohmart, **Past and Present Biotic Communities of the Lower Colorado River Mainstem and Selected Tributaries: Volume Five—the Gila, San Pedro and Santa Cruz Rivers** (Boulder City, NV: Bureau of Reclamation, 1986); Raymond Turner, **Quantitative and Historical Evidence of Vegetation Changes Along the Upper Gila River, Arizona** (Washington DC: U.S. Government Printing Office, 1974); and W. Minckley and T. Clark, **Formation and Destruction of a Gila River Mesquite Bosque Community** (1984, *Desert Plants* 6(1):23-27).

General studies that include important information on changes in the Gila River are C. Bowden, **Killing the Hidden Waters** (Austin: University of Texas Press, 1977); Phillip Fradkin, **A River No More: The Colorado River and the West** (New York: Knopf, 1981); Mark Reisner, **Cadillac Desert: The American West and Its Disappearing Waters** (New York: Penguin Books, 1993); and Henry Dobyns, **From Fire to Flood: Historic Human Destruction of Sonoran Desert Riverine Oases** (Socorro, NM: Ballena Press, 1981).

Competition for Water

There is no complete history of water law in Arizona. An overview of Arizona surface and groundwater law as well as federal water rights can be found in B. Tellman, **My Well vs. Your Surface Water Rights: How Western States Manage Interconnected Groundwater and Surface Water** (Tucson: Water Resources Research Center, University of Arizona, 1994).

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Information on current water demand and water supply is found in **Arizona Water Resources Assessment, Volume I: Inventory and Analysis** (Phoenix: Arizona Department of Water Resources, 1994) and many other publications of the Arizona Department of Water Resources, especially the five-year plans of the Active Management Areas. Statistics on water use are found in annual issues of **Arizona Statistical Abstract** (Tucson: Economic and Business Research Program, Office of Community Affairs, Karl Eller Graduate School of Management, College of Business and Public Administration, University of Arizona).

Little Colorado River

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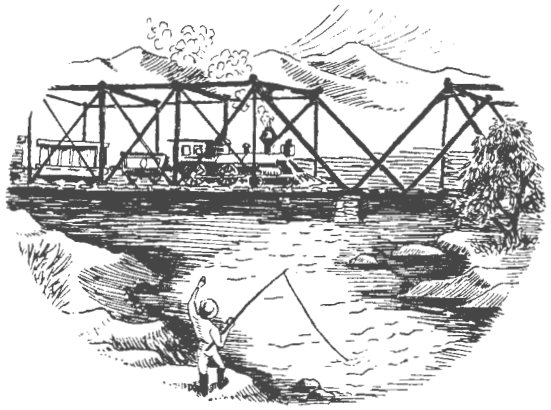

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An overview of park resources and recreational demand is found in the five-year plans of the Arizona State Parks Department, the "Statewide Comprehensive Outdoor Recreation Plan." The latest was published in 1994. Arizona State Parks' guidebooks **Arizona's Rivers and Streams** and **Arizona's Other Lakes** have a great deal of information about the recreational value of streams and lakes as does Arizona Game and Fish Department's **Wildlife Viewing Guide**.

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Photo: The pumps were installed after the collapse of Gillespie Dam to provide water for agriculture.

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130) Quote: Dean A. Hendrickson and W.L. Minckley. 1984. *Cienegas—Vanishing Climax Communities of the American Southwest.* "Desert Plants" 6(3):130-175.
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131) Drawing: W. Emory. 1848. *Notes of a Military Reconnaissance, from Fort Leavenworth, in Missouri, to San Diego, in California, Including Part of the Arkansas, Del Norte, and Gila Rivers.* Wendell and Van Benthuysen. Washington D.C.

135) Photo caption says "Clair Haught, Col. Ellison, Jess Ellison; Big grizzly cut a gash in Colonel's horse's rump and nearly got the colonel in a thicket."

137) Toad drawing by S.F. Baird and fish *(Acomus latispinus)* drawing by C. Girard from W.H. Emory. 1859. *Report on the United States and Mexican Boundary Survey.* Department of Interior. Washington, D.C.

139-140) Quote: Cyril Forde. 1931. *Ethnography of the Yuma Indians*. University of California publications in American Archaeology and Ethnography V. 28 #4. Berkeley, California. (also p. 40)

140) Map adapted from *Severe Sustained Drought Report: Managing the Colorado River System in Times of Water Shortage* (Tucson: Arizona Water Resources Research Center, University of Arizona. 1995; Issue 1, Powell Consortium).
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142) Drawing: J. Young from a sketch by Balduin Mollhausen in Quote: Joseph Ives. 1861. *Report Upon the Colorado River of the West explored in 1857 and 1858 by Lt. Joseph C. Ives*. USGPO. Washington D.C.
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143) Quote: May Sarton. 1948. *The Lion and the Rose*. Rinehart. New York City.
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147) Quote: Glenton Sykes. 1944. *A Westerly Trend*. Arizona Pioneers' Historical Society. Tucson, Arizona.

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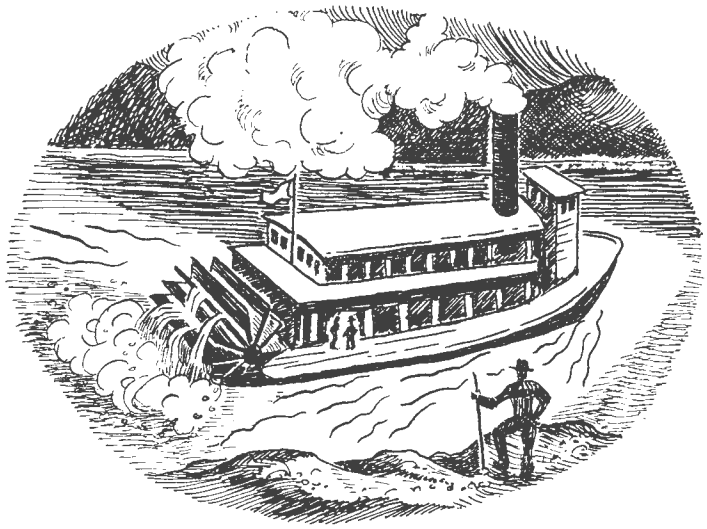
156) Drawing: J.W. Powell. 1869. *Exploration of the Colorado River of the West.*

158) Map adapted from Hendrickson and Minckley. 1984. *Cienegas—Vanishing Climax Communities of the American Southwest*. "Desert Plants" 6(3):130-175.

164) Quote: Conrad J. Bahre. 1985. *A Legacy of Change: Historic Human Impact on Vegetation in the Arizona Borderlands*. University of Arizona Press. Tucson, Arizona.



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Drawings

Drawings on the covers, Table of Contents and on pages 175-193 are by Pat Oogjen, Tempe artist. The drawings on pages 5 and 27 are by William Hartmann, Tucson artist.

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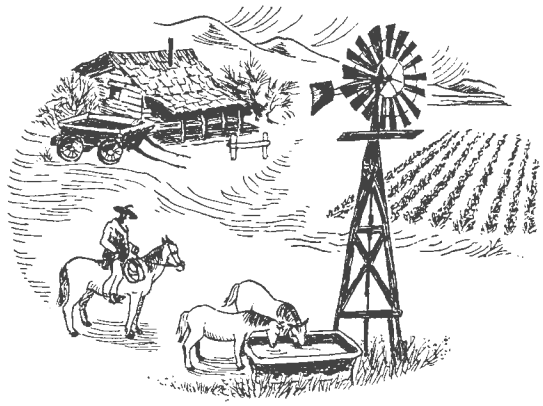

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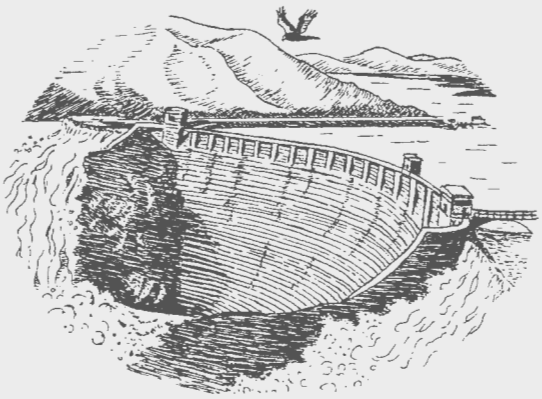

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