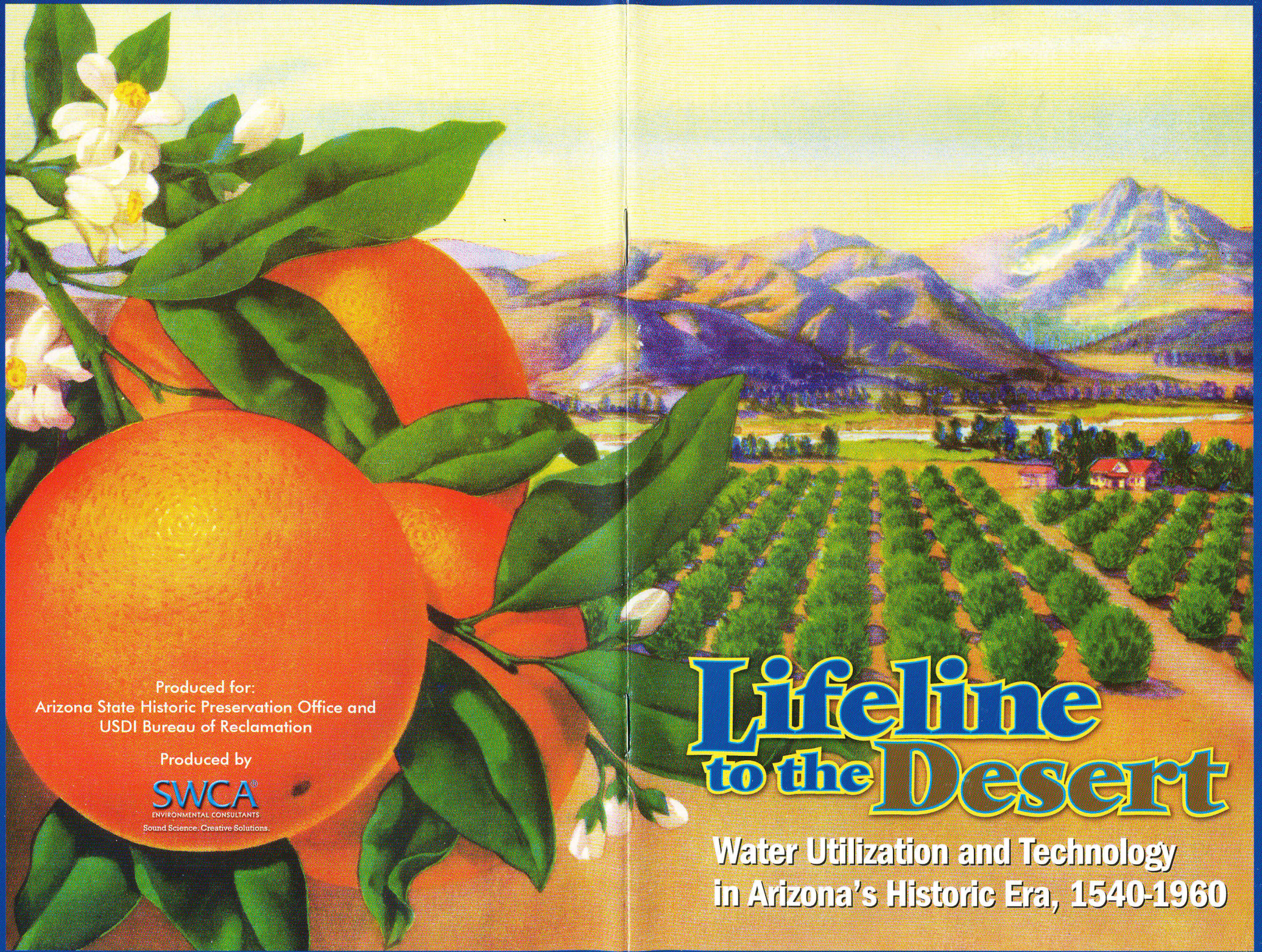

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Lifeline to the Desert

Water Utilization and Technology in Arizona's Historic Era, 1540-1960

LIFELINE TO THE DESERT
Water Utilization and Technology in Arizona's Historic Era, 1540–1960

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"TR," on 18 March 1911 prepares to press a button that will open the release gates of the great Salt River dam named in his honor. *Image courtesy Salt River Project Research Archives.*

"Great storage works are necessary to equalize the flow of streams and to save the flood waters. Far-reaching interstate problems are involved; and the resources of single states would often be inadequate. It is properly a national function, at least in some of its features...

"The object of the government is to dispose of the land to settlers who will build homes upon it. To accomplish this object water must be brought within their reach."
President Theodore Roosevelt to Congress, December 1901.

Theodore Roosevelt bounded into the U.S. presidency after the assassination in 1901 of his predecessor William McKinley. After only three months in office "TR" chose reliable water supplies for the desert West as one of his first major initiatives. Thus with his speech to Congress in support of the Federal Reclamation Act, he summarized the challenges for water in the West (storing scarce water and reducing flood damage), the reasons for federal assistance with water projects (interstate solutions and larger federal resources), and the ultimate goal (settling the land through irrigation) of the Washington, D.C., government.

LIFELINE TO THE DESERT

Water is the lifeline to the desert. Water law determines who has the right to use it. Technology diverts it to serve the most powerful interests of any moment...mining, agriculture, manufacturing, commercial and residential development, or tourism.
Arizona History Museum Exhibit, "The Desert Blooms: Agriculture in Arizona," 2003

Despite its desert reputation, Arizona has historically benefited from a relative abundance of water. As Hastings and Turner portray in their classic *The Changing Mile of 1965*, the state is not wholly a desert, but a *desert region*

"with a considerable variety of climate." Since the late nineteenth century, water in Arizona has been collected through careful management within extremes of that climate spectrum—in the mountains as winter snow and elsewhere as floodwaters. Water is then cleverly extended into the opposite extremes of both space and time upon arid lands throughout the balance of the year.

The very name Arizona and its region's well-known association with Spanish and Mexican history would appear in translation to warn of the absence of water in an arid land. On the contrary, scholars have agreed for the last century that this *nombre* that appears to transpose as *"La Zona árida"* is not the origin of "Arizona," that the name is decidedly not Spanish, and that it probably describes a place with a reliable source of water. James H. McClintock in his venerable *Arizona: Prehistoric – Aboriginal – Pioneer – Modern* of 1916 explained in detail that variations in the Tohono O'odham (Papago-Pima) language include *ari* meaning small, and *sonac* meaning flowing spring. Spanish explorers and mapmakers who first entered the region heard the place name *Arisonac* as early as 1736 describing a seasonally watered area in present-day Sonora, Mexico. References to *Real de Arizona* appeared in Spanish print as early as 1754 describing the same area and its rich silver deposits, eventually denoting a considerably larger landscape in western New Mexico and north of the Gila by the time the United States acquired the inclusive territory in 1848.

At least one Spanish scribe, Padre Francisco de Escobar traveling with *conquistador* Juan de Oñate in 1604, suggested that logs could be floated down a certain desert river from the mountains to the sea. Ironically, Escobar described the Little Colorado River, unaware that the Grand Canyon and its perilous rapids lay downstream. Later explorers of Arizona considered a predominant lack of water to be the territory's greatest impediment to development. After passing through the Grand Canyon in 1858, Lieutenant Joseph Christmas Ives declared, "Ours has been the first, and will doubtless be the last, party of Whites to visit this profitless locality."

Recovering from this early confusion and pessimism, Arizona did prosper, and the universal element of that prosperity is water, collected in places of abundance then distributed to other places not so blessed. This brief history of Arizona water technology and utilization is rooted in the perception and reality that water is the historic lifeblood of the state and that it links every aspect of life and heritage in the desert region. Text and illustrations are condensed from the statewide historic context study *Water Utilization and Technology in Arizona's Historic Era, 1540–1960*, commissioned by the State Historic Preservation Office and the U.S. Bureau of Reclamation for the identification and evaluation of historic water systems throughout Arizona.

The study of water use and technology is best approached through three general periods in Arizona history: Spanish and Mexican influences, 1540–1847; United

States accession and territorial period, 1848–1901; and federal reclamation, 1902–present.

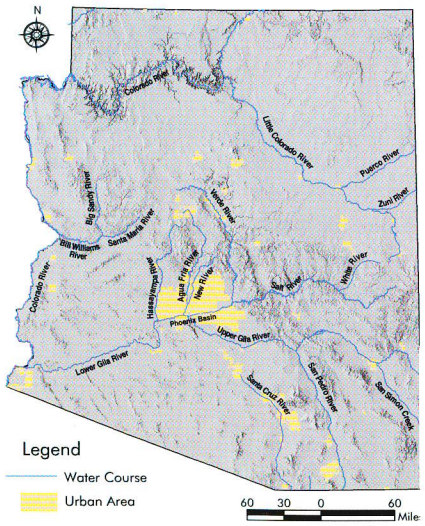
Spanish and Mexican Influences, 1540–1847

Although the prehistoric Hohokam had constructed elaborate irrigation canal systems in the Salt and Gila River valleys, they abandoned most of these systems in the late 1300s and early 1400s. Padre Eusebio Francisco Kino, one of the first to chronicle the Spanish *entrada*, in 1694 expressed amazement at the abandoned four-story Casa Grande near the Gila River, but the Spanish took no notice of remnant Hohokam canals throughout the basin.

Direct Spanish influences appeared in 1629, when missionaries from Mexico's interior far to the south established *misiones* and *visitas* among the Zuni and Hopi pueblos in present-day northeastern Arizona. Missionaries introduced new crops including peaches, and livestock with sheep and goats. Among the Hopi, woolen garments replaced cotton, and sheep dung replaced coal for firing clay pottery. Peaches became such an important food source that archaeologists at the Hopi's Awatovi have recently recovered peach pits from almost every room occupied during the mission period. Along with new crops, the Spaniards introduced control of virtually all Hopi and Zuni merchandise production and distribution, even as the conquerors dominated native politics and religions.

After the 1680 Pueblo revolts, Padre Kino founded missions in southern Arizona, and ultimately the Spaniards established a chain of colonies and presidios along the Santa Cruz and San Pedro rivers, supporting about 1,000 colonists. Their settlements needed culinary water for direct human consumption, and irrigation water for seasonal crops. Skilled missionaries directed construction of *acequias*, ditches from diverted natural streams, to bring water to irrigated fields and cisterns that stored culinary water. Such systems are well documented at Tubac and Tumacacori historic sites. The Spanish also introduced the *zanjero*, a skilled person who maintained irrigation ditches and regulated water distribution to fields along his *acequias*.

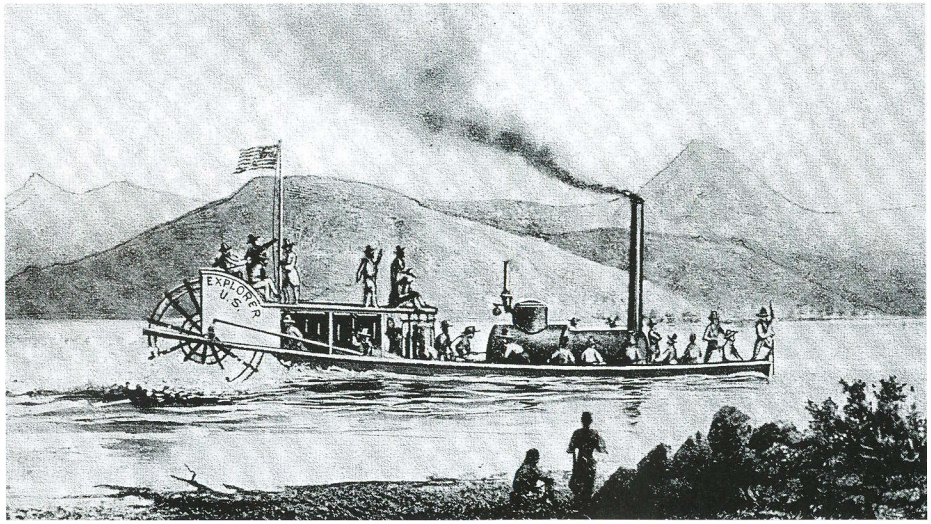
Arizona Water Basins



Mexico gained independence from Spain in 1821, and the new government expelled the Franciscans in 1827. Their far-flung mission system soon collapsed, and maintenance of essential water systems gradually declined.

United States Accession and Territorial Period, 1848–1901

The United States' own conquest of the Southwest began in 1846, when a U.S. Army battalion of Mormon recruits traveled across southern Arizona on its way to California seeking battle in the war with Mexico. Reaching Gila Bend west of Tucson, these trailblazers converted some of their wagons to rafts and attempted a more convenient float down the Gila River to California. The Mexican-American War ended with the Treaty of Guadalupe Hidalgo in 1848, and Arizona became part of the United States as the western half of New Mexico Territory.



The Steamboat "Explorer" on the Colorado River in 1858, on an expedition beyond the mouth of Black Canyon, below present Hoover Dam and some 200 miles upstream from present Yuma. *Image from History of Arizona, Thomas Edwin Farish, 1915.*

Attracted by new lands in the region, American settlers first concentrated in the southern territory along the convenient Santa Cruz and San Pedro rivers, where irrigation agriculture continued as before through aging Spanish *acequias*. To protect its colonists, the U.S. government established forts that appropriated convenient water supplies for themselves and in turn deprived nomadic tribal bands of refreshment. Military mapping and exploration parties soon ranged across the landscape and established wagon roads that necessarily ran from water source to water source. The territory's first ferries extended these primitive roads across running waters, beginning with conveyance over the Colorado

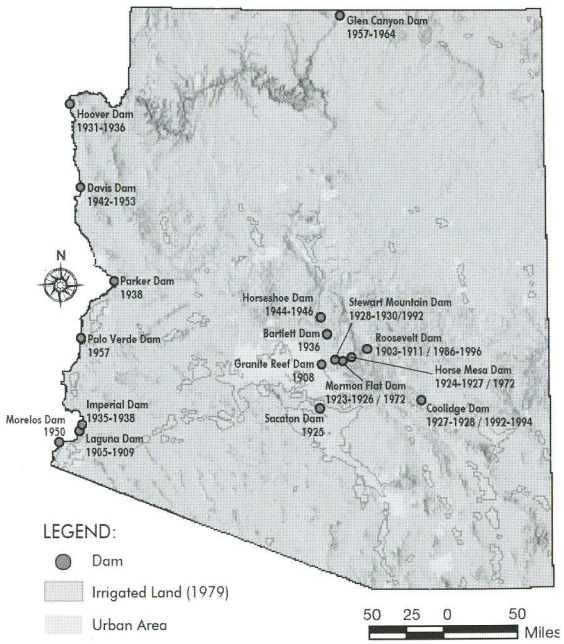
River at present-day Yuma. Entrepreneurs soon began commercial navigation through Yuma up the Colorado River, and steamboats plied the river as far north as the mouth of Grand Canyon, about 300 miles, well into the twentieth century.

With the establishment of Arizona Territory by Congress and President Abraham Lincoln in 1863, the federal government opened a new era for settlement of Arizona. The Spanish water-ownership system of "first in use, first in right"—conspicuously ignoring Native American claims—prevailed for settlers with the American takeover and eventually became the law of the land...and the water. One early contribution of the United States government to the region came through sponsorship of the mapping and geological explorations of John Wesley Powell, who first explored and explained Arizona water courses and their adjacent land formations.

The Homestead Act of 1862 and a succeeding act, the Desert Lands Act of 1877 that focused specifically on developing arid regions, encouraged settlement by farmers and ranchers. The standard homestead allotments of 160-acre farms, however, quickly proved much too small for arid regions, inspiring settlers—and their congressional representatives—to seek further assistance from the federal government (see Federal Reclamation on page 8).

The General Mining Law of 1872 encouraged mining by allowing individuals and corporations to prospect for minerals on public land and to claim any deposits they found. Railroads connecting the Midwest and California received large grants of public lands to pass through Arizona. By the 1880s the railroad industry brought further changes and innovations in water utilization and technology, for steam locomotion as well as for burgeoning railroad and mining towns. The typical relationship between mining camps and irrigated farming for miners' supplies resulted in an 1886 dam on the Hassayampa River at Walnut Grove, south of Prescott, for hydraulic mining

Irrigated Lands of 1979 and Dams



and irrigation farming. This poorly engineered project ended with disaster in 1890 when the dam burst and at least 70 settlers perished.

In all its various land incentives and other enticements, the federal government encouraged settlement and development of the new territory by individuals and corporations. Initial territorial growth followed age-old patterns, in that consistent water courses attracted and held only as many people and as much industry as available water could support in close proximity. Arizona's 12 reliable water basins reveal this growth to be severely limited initially by geography. The Santa Cruz and San Pedro, Upper Gila and Lower Gila, Colorado and Little Colorado, Phoenix Basin (including the Salt and Agua Fria), Verde, Hassayampa and Big Sandy Rivers, plus the Tonto Creek Basin and Kanab Creek all supported initial groups of settlers seeking homesteads and mining riches in Arizona Territory.

A tranquil boating scene on Arizona Canal near Ingleside Inn northwest of Scottsdale, circa 1915, represents the recreational utilization of water technology. *Image courtesy Salt River Project Research Archives.*

Recreation in Arizona began in the late nineteenth century with small gestures to offer leisure opportunities for residents, and to encourage tourism primarily from transcontinental trains passing through the territory. Among the few early facilities constructed specifically for recreation were a bathhouse at Silver Lake along the Santa Cruz at Tucson, the rustic facilities at Agua Caliente Ranch near Tucson, and spas and hotels such as Castle Hot Springs in 1897 and Indian Hot Springs Hotel about 1900. Lakes and canals constructed for other purposes doubled as recreation sites for swimming, boating, fishing, hunting,

and picnicking. In 1909, the Lyman Irrigation Company and the Lyman Land Company began construction near St. Johns on Lyman Dam, completed in 1912, rebuilt in 1915, and now part of Lyman Lake State Park.

Despite these early successes, the first advancements in water technology—metal tools, powerful draft animals pulling scraping machines and wagons, mortar, and eventually concrete for dams and other structures—could do little more than increase the efficiency of natural watercourses.

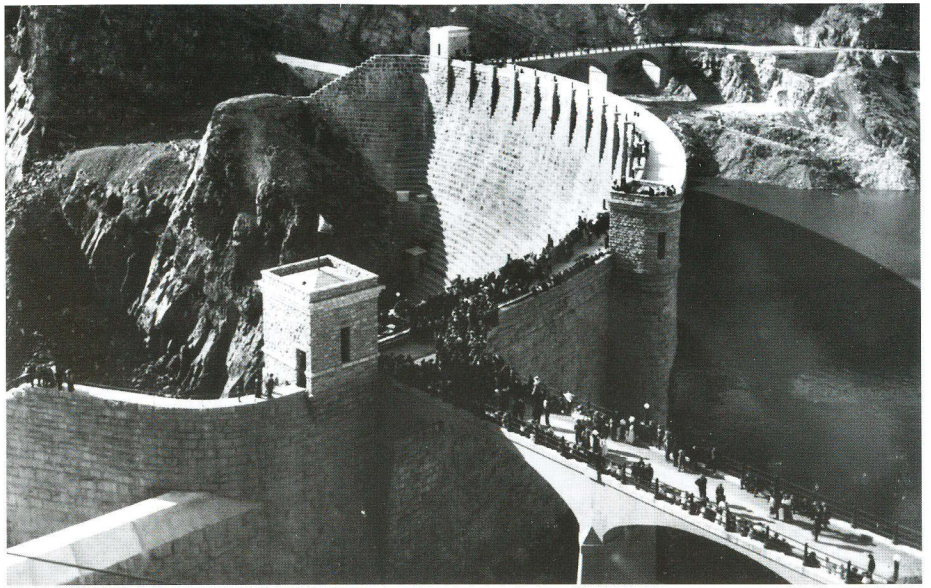
Federal Reclamation after 1902

Congress first granted private "Ditch and Canal Owners" right-of-way across public lands in 1866, and the Desert Lands Act of 1877 promoted irrigation as a solution for bringing water to fertile lands of desert regions in the West. A growing land "reclamation" political movement in the West demanded still greater federal assistance to cover the extensive irrigation engineering required, and to finance projects beyond any private, municipal, territorial, or state funding capabilities. By 1900 Nevada Congressman Francis Griffith Newlands emerged as the most articulate spokesman for the reclamation movement in the West. When Vice President Theodore Roosevelt unexpectedly became President in 1901, these two politicians combined their considerable influences into action, resulting in the Federal Reclamation Act of 1902.

The Reclamation Act fostered a revolution in the progress of water utilization and technology in Arizona with the establishment of the U.S. Reclamation Service. Dominant funding and engineering design now came from the Reclamation Service (renamed the Bureau of Reclamation in 1923), which in turn developed partnerships with irrigation districts or similar entities (see Cooperatives, discussed below), who distributed the precious commodity through their carefully managed systems. The Reclamation Service designated Arizona's Tonto Basin and Salt River Valley, east of the state capital of Phoenix, as collectors for the Salt River Project, one of its first five demonstration projects in arid Western states.

The Salt River Project's largest structure emerged as a massive cut-stone dam begun in 1905 on the Salt River about 80 miles east of Phoenix. The installation of water-powered electric generators during construction accelerated the project after 1907. This ingenious addition of electric dynamos as a cost-saving construction measure proved to be a prophetic leap for the U.S. Reclamation Service. Eventually, more generators and the sale of electricity from the dam covered its costs long before agricultural revenues could have, and the principal kilowatt customers of Phoenix and several copper mines found a second essential element for growth in addition to water.

Grateful water users named the dam upon completion in 1911 for reclamation



A **Retention and Storage** structure, represented by Roosevelt Dam, on dedication day, 18 March 1911 (view to the northwest). *Image courtesy Salt River Project Research Archives.*

champion Theodore Roosevelt. The ex-president journeyed to the dam's dedication from his train at Mesa by automobile via the 48-mile "Apache Trail." New-fangled motorcar owners soon commandeered Apache Trail—a treacherous but scenic wagon road supplying the Reclamation Service's remote dam site—as a premier recreation drive, which it remains today.

The first permanent Colorado River dam resulted from the Reclamation Service's Yuma Project begun in 1905. It featured a British silt-cleaning design borrowed from India and Egypt to construct the main Laguna Dam as a rock-fill, cut-stone, and concrete diversion dam (1905–1909). Years of working through a number of formidable material, transportation, flooding, and silting problems resulted in the Yuma Project's irrigation canals (1907–1915) on the Arizona side, and finally the amazing Colorado River Siphon (1909–1912) that moves water from the California diversion back under the river to Arizona at Yuma.

Cooperatives replaced the old ditch, canal, and irrigating companies that preceded federal water projects. Under the Reclamation Act, water users would repay the federal government for the construction and operation of the large federal irrigation projects. This cost recovery was accomplished through cooperatives of water-rights holders formed under the territory's Irrigation District Act of 1909; the Salt River Valley Water Users Association was the largest and promised the greatest impact. The federal Reclamation Service purchased several Phoenix-area private ditch companies, then arranged with the cooperative to manage the system as the Salt River Project, or SRP.

The Spanish colonial *zanjero*, assigned to control and maintain water systems, continued the timeless tradition into the 20th century somewhere on the Salt River Project. *Image courtesy Salt River Project Research*

Cooperative employees included the time-honored *zanjeros* of Spanish origin, who maintained the vast stretches of canals and ditches, and regulated water allowances to subscribing farmers in each cooperative. Cooperatives also agreed to a standard of measure for water allotments to members based on the "miner's inch," originally applied to flowing water by its depth and speed, for which 1 inch equals 11.22 gallons.

Abundant available water for agriculture and urban populations played an inestimable role in Arizona's achievement of statehood on February 14, 1912, after 20 years of frustrated attempts in Congress. With statehood, Arizona's incorporated cities could increase bond sales for better and larger municipal water systems; greater representation in Congress would bring more and larger federal reclamation projects to the state. Steady, and sometimes booming, growth of population and home-gown products followed this combination of factors.

Agriculture through farming expanded rapidly with these enormous new water supplies, particularly during the First World War. Phoenix Basin farmers planted thousands of acres in cotton for clothing and for tire manufacturing around the new Gila River community of Goodyear. In southern Arizona, Pima County cotton production grew dramatically from 150 acres in 1918 to 1,100 the next year and 4,000 in 1920, helping establish Arizona as one of the top cotton producers in the world.

Orchards experienced a tremendous boom beginning in 1930 around Phoenix and Yuma as the results of expanding water supplies and irrigation cooperatives. Orchards provided citrus fruits for demanding national markets, and at the same time attracted new Arizona residents to live on symbolically healthy landscapes of fruit trees. By 1935 the state boasted almost 1.2 million grapefruit trees and

An orange grove near Phoenix, irrigated by either Grand or Arizona Canal, 1908, represents the agricultural utilization of water technology. Walter Lubken photograph. *Image courtesy Salt River Project Research Archives.*

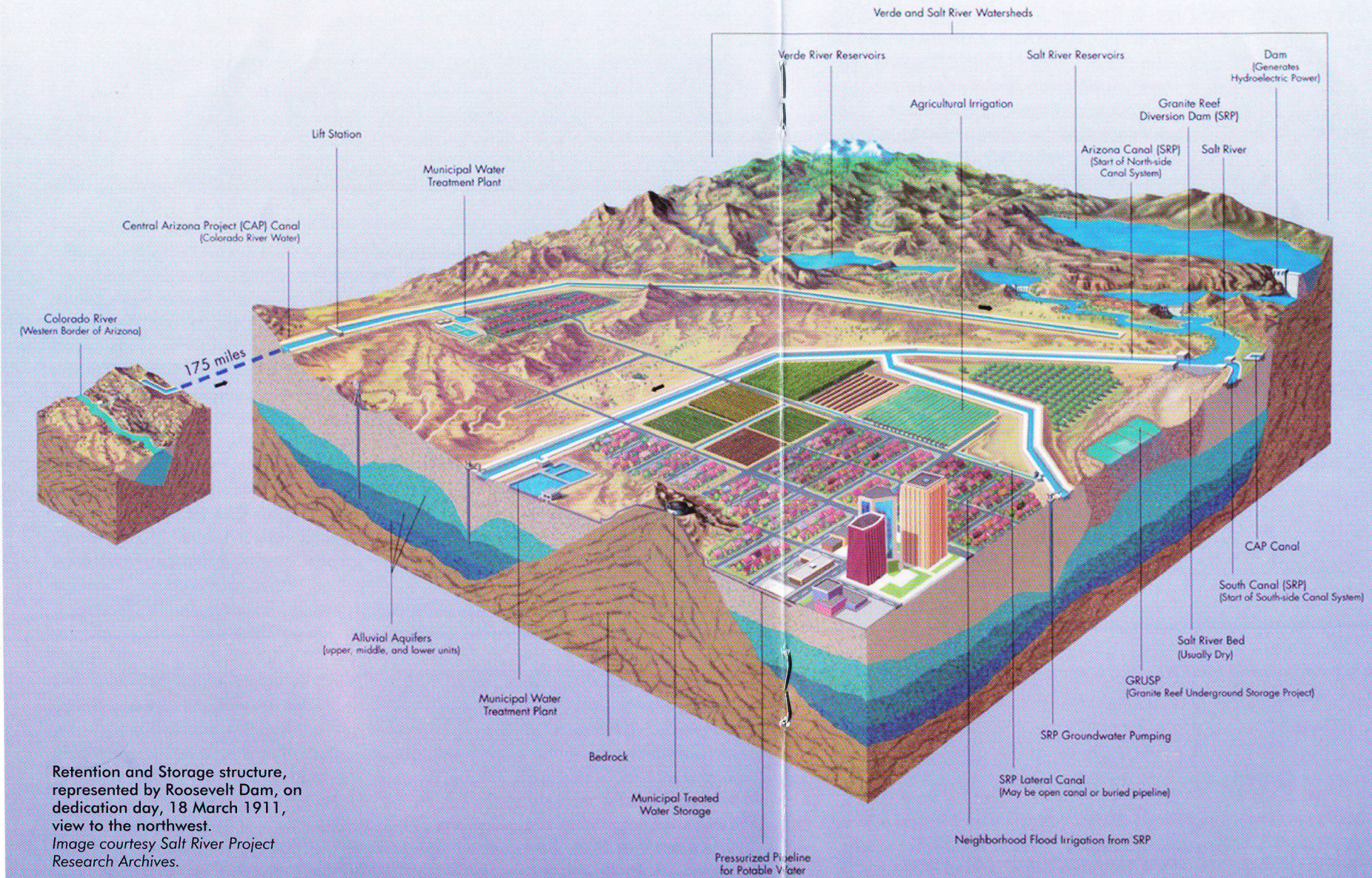
more than 625,000 orange trees, most watered by flood irrigation, and most of those ditches in the Yuma and Salt River Projects. With the dramatic residential growth of Phoenix before and after the Second World War, these level orchards offered attractive paths of little resistance for development radiating out from downtown Phoenix.

The Indian Irrigation Service of the Department of the Interior's Office (Bureau after 1947) of Indian Affairs sought to address some of the federal government's inconsistencies in Indian policies. Under the Reclamation Act and other legislation, the Indian Irrigation Service constructed many projects during the early twentieth century to improve living conditions on reservations. Extensive efforts improved water systems throughout the Navajo reservation in northeast Arizona, and small projects included an early Ak-Chin (Maricopa) reservation project of 160 acres south of Phoenix. This tribe now irrigates 15,000 acres with Central Arizona Project water. The largest Native American endeavor sponsored half of the huge San Carlos Irrigation Project centered on Coolidge and the Gila River Indian Community, authorized in 1916, funded in 1924, and operational after completion of Coolidge Dam in 1928.

During the 1930s, federal New Deal public works agencies led by the Works Progress Administration (WPA) and Civilian Conservation Corps (CCC) employed Arizonans to expand federal irrigation systems and soil and water conservation structures across the state. City water systems received considerable New Deal-facilitated increases in capacities through the early 1940s, including underground water and sewer pipes.

The National Park Service and the U.S. Department of Agriculture's Forest Service both developed sophisticated recreation programs in the 1930s and 1940s, including lakes and recreation water systems constructed by the CCC.

Water for the Salt River Valley



Retention and Storage structure, represented by Roosevelt Dam, on dedication day, 18 March 1911, view to the northwest.
Image courtesy Salt River Project Research Archives.

The greater Phoenix area draws its water from several sources. SRP is the largest supplier.

SRP manages water from the Salt and Verde Rivers; its dams store this water to even out seasonal and year-to-year fluctuations in river flows. Supplies from the river are supplemented with groundwater pumped from Valley wells.

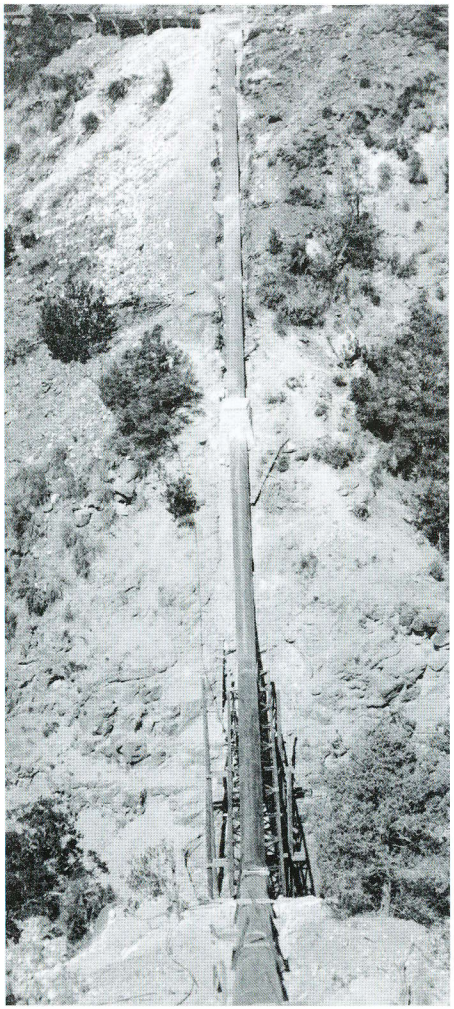
SRP delivers water through its historic canals to city facilities where it is treated and then delivered to homes and businesses for drinking water uses. SRP also delivers water directly to farms and urban irrigation users through an extensive distribution system of smaller open canals and underground pipes called "laterals."

Outside the SRP service territory, water demands are met by: imported Colorado River water from the CAP Canal; underground sources; water from the Agua Fria River; and reclaimed waste water.

SRP
Delivering More Than Power

The Bureau of Reclamation officially acknowledged a recreational assignment at its reservoirs in late 1930s, but assigned responsibility for most recreation facilities and their maintenance to other agencies. This pattern began in 1936 with an agreement between Reclamation and the National Park Service for Lake Mead's shoreline, behind Hoover Dam and bordering on the northwest corner of Arizona, to be developed as a national recreation area.

The Bureau of Reclamation intended for its Boulder Canyon Project (1931–1936, renamed Hoover Dam in 1947) to control flooding of the Colorado River and manage irrigation water downstream for Arizona and California. Congress for the first time funded this reclamation project without links to repayment through future user fees. But soon its power-generating capacity proved of greatest immediate benefit, and by 1987 the Bureau of Reclamation had fully "repaid" the dam's $165 million cost through sale of hydroelectric power.



A **Special Problem** structure, represented by the siphon across Sally May Wash along the Childs-Irving Hydroelectric Project. *Image courtesy of Arizona Public Service and HAER-AZ-65, Historic American Engineering Record Report.*

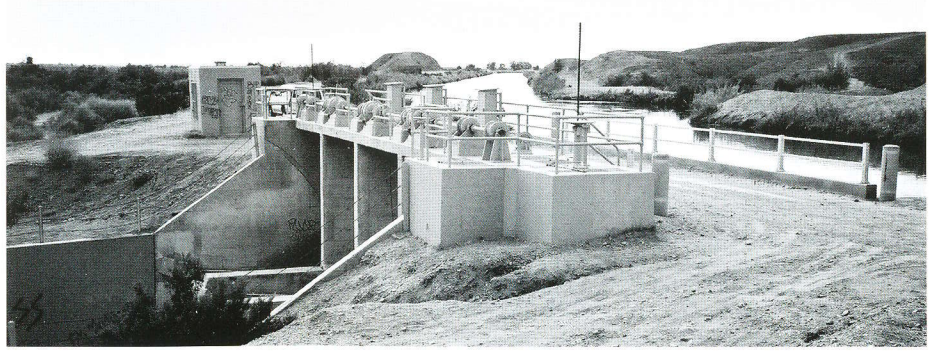
Colorado River planning and improvements to Yuma's 1930s Gila Project produced the Parker Dam and Powerplant (1938) and Davis Dam and Powerplant (1942–1953). Davis Dam, its Lake Mohave and their original construction town, Bullhead City, represented wartime planning and post-war realization of constant adjustments to the Colorado River system. The dam was named at its initiation for Arthur Powell Davis, USGS surveyor in the Salt River Valley in the 1890s, director of federal reclamation from 1914 to 1932, and an early proponent of harnessing the Colorado River for power and irrigation.

Water Utilization and Technology

Arizona school children are taught that their modern economy historically depends on the "Five C's: cattle, citrus, climate, copper, and cotton." Put another way, the foundations of Arizona's modern economy are agriculture (cotton and citrus), mining (copper), ranching (cattle), and recreation/tourism (climate).

Without water, none of the "Five C's" would be possible, much less the state's tremendous urban growth following the Second World War. One cow consumes 5,000 gallons of water per year; one ton of oranges requires 15,000 gallons of water throughout a year; one ton of copper requires 25,000 gallons of water for processing; one residential swimming pool (a modern measure of recreation) holds 50,000 gallons of water; and one ton of cotton consumes an incredible 1,650,000 gallons of water prior to harvest. An adult human being, in addition, ingests about 2 liters of water per day, or a life-sustaining 193 gallons per year. Thus water not only made agriculture, mining, and urban populations achievable in the state; water, controlled through innovation and technology, made the state possible.

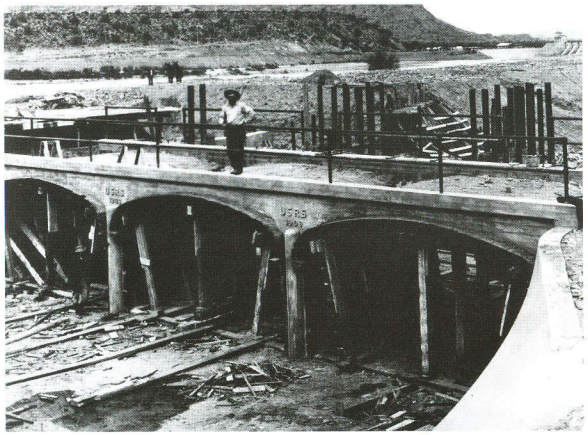
Farming through irrigation on Native American lands, observed in the 1860s at Navajo and Hopi communities, utilized age-old practices adapted to their arid landscapes. By mounding and cutting the earth downstream of limited water sources, Navajo crops received regulated amounts of water. By diverting spring waters onto leveled plots in hilly terrain, the Hopi created terraced gardens. The Spanish brought refined irrigation systems of earthen dams and ditches dug with improved hand tools, along with orchards of fruit trees, primarily to the Santa Cruz and San Pedro Valleys. In Territorial years, ranchers, or "stockraisers," irrigated their forage fields, especially along the lower Gila, Verde, Hassayampa, Big Sandy, and San Francisco Rivers, by tapping "improved" springs, digging wells, and pumping groundwater with windmills.



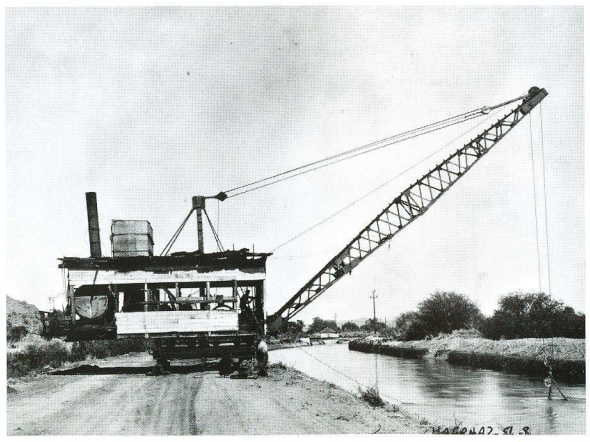
A **Special Problem** structure, represented by "wasteway" relief gates built in 1938 along the Bureau of Reclamation's Gila Gravity Main Canal near Yuma. This structure allows excess storm runoff from high ground (right) to drain into the Gila River basin (left). *Photograph by James Steely, SWCA.*

These most basic irrigation technologies remained largely unchanged even with the dramatic introduction after 1900 of federal dams and their vast reservoirs to charge irrigation systems continually throughout annual seasons. In a study of Southwestern irrigation systems similar to those in Arizona, archeologist Neal W. Ackerly provided a classification of water technology, recognizing five types of structures based on function:

1. **retention and storage** (dams and reservoirs)
2. **diversion** (including diversion dams that partially block natural water courses)
3. **conveyance** (canals, ditches, "laterals" and "sub-laterals")
4. **control and distribution** (gates, drops, checks, tapboxes)
5. **special problem** (tunnels, flumes, overchutes, siphons)

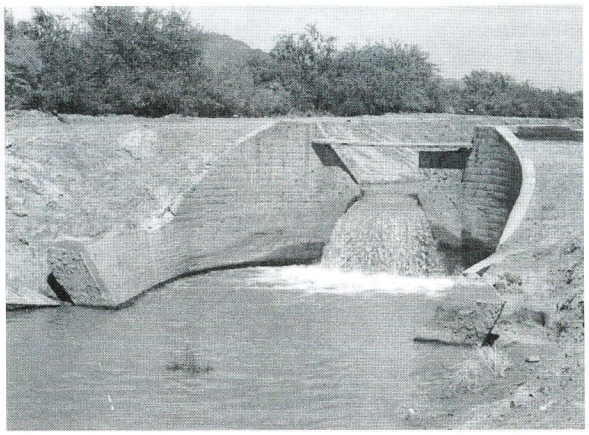


A **Diversion** structure, represented by Granite Reef Diversion Dam, in background, supplying Salt River water to South Canal, under construction in foreground, near Mesa in 1909. *Image courtesy Salt River Project Research Archives.*



A **Conveyance** structure, represented by Eastern Canal and dredging maintenance through a ponderous steam-powered dragline near Gilbert, 1925. *Image courtesy Salt River Project Research Archives.*

Gates, and even the shape of canals ranging in cross section from U to V, control the volume and velocity of water. Drops control the flow of water across steep terrain and protect irrigation ditches from rapid erosion. Checks halt or



A **Control and Distribution** structure, represented by a distribution ditch "drop" to lower the elevation of flowing water on the San Carlos Irrigation Project near Sacaton. *Image from San Carlos Irrigation Project, HAER-AZ-50, Historic American Engineering Record Report.*

slow water running through a canal to raise levels enough for diversion through open ditches or underground pipes into fields and lawns through tapboxes. Tapboxes control the flow of water from ditches into fields by opening and closing almost-watertight doors, usually by turning wheels and screws connected to the doors. Many small irrigation systems did not make use of tapboxes, as irrigators simply breached the earthen ditch wall and allowed water to flow into adjacent fields. More elaborate irrigation systems contained wooden or concrete tapboxes, or even commercially manufactured tapboxes from faraway suppliers. Another tapping technique, utilized since the mid-twentieth century, siphons water through short sections of flexible hose from the ditch directly into furrowed rows of agricultural fields.

Ackerly's "special problem structures" describe a number of irrigation ditches in Arizona that are routed in tunnels through mountains. Flumes of wood, metal or concrete carry irrigation water over arroyos, other irrigation ditches, or drops in terrain. Overchutes, usually concrete structures, carry adjacent drainage water over open canals to prevent mixing with irrigation water. Siphons move water under obstacles through bent piping, harnessing atmospheric pressure to maintain flow.

Water utilization for mining in Arizona was accomplished in three ways through the use of water: placer mining and hydraulic mining—both used primarily for gold—and hardrock mining, used primarily for copper. Each method had its own set of historic water technologies. One government study recorded 246 historic mining districts throughout the state of Arizona, and within these districts were hundreds of individual mines and countless mining features.

Placer mining was the typical gold-rush technique of washing riverbed materials to expose dense gold. Hydraulic mining pressurized water to wash away soil layers and expose gold, a destructive technique common in California but practiced on an extremely limited scale in Arizona from 1868 to the early

1890s. Hardrock mining from the Territorial era to the present resulted in water-use technology typically consisting of water diversions and conveyances plus arrastras, ore crushers sometimes powered by water wheels; cradles or rockers to separate the precious metals; headboxes to pressurize nozzles; and whims, or capstans, for raising or lowering ore or water. Water, ironically, can be overabundant in Arizona mines, as underground formations seep or spill water into operations that continue only with the technology of pumps. The most efficient systems recycle groundwater for ore processing.

Domestic water-supply systems emerged from virtually every concentration of settlers during the Territorial period. The earliest, most elaborate works appeared at military forts to box-in springs, dam-up streams, dig wells, and funnel runoff into cisterns. Railroads had a tremendous need for water in the Arizona desert, to serve their remote communities of employees and their steam locomotives that consumed 100 to 110 gallons of water per mile. To quench these thirsts, railroad companies invested vast sums to dam streams, sink wells, construct reservoirs—of stone, concrete, and even steel—and distribute the commodity through water towers and pressurized pipes. Water technology and utilization remained an important function of Arizona railroads until their shift from steam to diesel locomotives beginning in the late 1930s. The largest Arizona rail systems, Southern Pacific in the south and Santa Fe in the north, completely eliminated steam locomotives, and their need for enormous water supplies, from mainline service by the late 1950s. Water towers, urban reservoirs, pipelines, and treatment plants are typical structures that reveal historic railroad water systems throughout the state.

Some cities grew to maintain the old fort and railroad systems, inheriting their technology when the original purposes vanished. Phoenix, struggling to develop beyond its agricultural economy, boldly pumped municipal water in 1918 from the Verde River through miles of pipe assembled of redwood staves. Eventually 139 municipalities organized to define present-day urban Arizona, each with its own historic struggle to secure and enhance a consistent source of water. Combined with the Bureau of Reclamation dams and irrigation systems, Arizona's domestic water resources positioned the state for a major defense-establishment role during the Second World War, and forecasted the population, housing, and industrial boom that followed the war.

Phoenix turned again to its Verde River water source in 1949 for a new treatment plant, and in 1950 for the rebuilding of Horseshoe Dam for additional flood-storage capacity. But the next summer the city triggered a crisis by far exceeding its water allotments from the Salt River Project. Soon the two parties worked out new agreements for SRP agricultural waters coursing through rapidly urbanizing fields and orchards, effectively converting these farming distributions to municipal supplies. The majority of SRP water allotments for the city now become tap water, but SRP still maintains much of its urban irrigation system in Phoenix.

Large open canals feed ditches and underground pipes that periodically flood-irrigate residential lawns. SRP zanjeros still carry on the Spanish tradition of system maintenance and distribution.

In the early 1950s Tucson bought existing private systems, acquired aquifer-water rights in the Avra Valley, and drilled wells in the Santa Cruz River floodplain. In 1954 Tucson built tanks of 20-million-gallon capacity to store its combined well waters. In the early 1950s Flagstaff attempted to raise Lower Lake Mary's dam, inherited from the Santa Fe Railway, but soon turned to a series of wells drilled at Woody Mountain between 1954 and 1956. Those sources pumped enough water into Lake Mary to accommodate the city's growth through the early 2000s.

The most interesting of Arizona's recreational water technology is at Grand Canyon National Park. Following its arrival at the national monument's dramatic scenic rim in 1901, the Santa Fe Railway pumped water up from Indian Springs, 3,000 feet below the canyon rim, for its tourism facilities, including the then-new El Tovar Hotel. The railroad also imported huge amounts of water some 100 miles by rail from the Chino Valley, storing and pressurizing the resulting supply for Grand Canyon Village in steel water tanks of one-million-gallon capacity. Because of Indian Garden's substantial but limited spring output below the South Rim, early national park management in 1926 invested in an "engineering marvel," an activated sludge disposal plant that recycled 99 percent of the park's brown water, in turn supplying 120,000 gallons per day for non-potable needs.

In 1965 Union Pacific Railroad management at the Grand Canyon's North Rim donated its high-capacity Roaring Springs water system to the National Park Service. Park managers then built a 12.5-mile pipeline, finished in 1970, across the canyon via a series of bridges to its South Rim distribution system beginning at Indian Garden.

The Recent Past

A series of congressional debates and actions launched the 336-mile Central Arizona Project (CAP) in 1968, fulfilling a concept proposed in the 1920s to move Colorado River water deep into central Arizona. The resulting incredibly complex system of aqueducts, tunnels, pumping stations, underground storage, aquifer-recharge, and related infrastructure—matched by an equally complex series of water-rights agreements and lawsuits—transformed a significant part of the Arizona landscape with its construction between 1973 and 1985. The 173.6-mile-long Hayden-Rhodes Aqueduct alone is the dominant manmade object across huge areas of the state's undeveloped terrain, dwarfing railroads and interstate highways when viewed from airliners high above the desert

region. CAP construction continues into the 2000s with distribution system improvements primarily on Native American reservations.

In the 1980s Phoenix and Tucson aggressively implemented water recycling for a number of uses, including "engineered wetlands" for environmental agreements. Recycled water also cools power plants, including the Arizona (Palo Verde) Nuclear Power Project west of Phoenix at Tonopah, first operational in 1986. Lawsuits associated with this sale of cooling water from effluent brought an Arizona Supreme Court decision that declared treated wastewater neither ground- nor surface water, and approved its sale by the city to supplement traditional but limited supplies of potable water.

Building upon a 1960s initiative through Arizona State University to "restore" water to the "Rio Salado," the City of Tempe in 1999 finished two remarkable inflatable dams in the Salt River bed for a new "town lake." The city dressed the two miles of shorelines between and filled its new recreation lake with 220 acre-feet of CAP water delivered through the SRP system. Tempe Town Lake dams are deflatable to allow Salt River floodwater to pass through its traditional channel. Phoenix also is fulfilling part of the Rio Salado plan through wetland developments fed by recycled water.

A **Special Problem** structure, represented by Lift Station No. 2 built in 1952 on the Bureau of Reclamation's Wellton-Mohawk Project near Ligurta in Yuma County, lifts Colorado River water more than 50 feet to irrigated lands of the lower Gila River valley. *Photograph by James Steely, SWCA.*

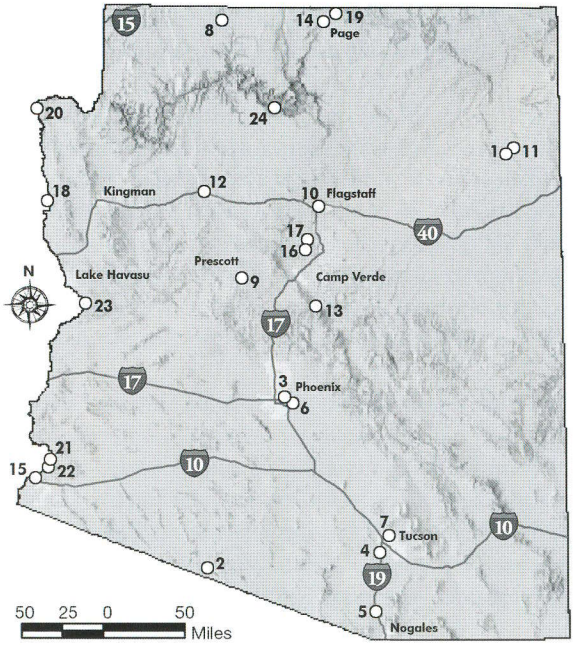
The rippling dynamics of CAP and heavy floods in the early 1980s inspired the federal Safety of Dams Act with major modifications to several historic-age dams in Arizona. The most dramatic alterations included work on Roosevelt

Dam between 1986 and 1996 that covered the 1903–1911 stone structure with concrete and raised it 76 feet for additional flood-control capacity.

At $4.4 billion in cost CAP is, and likely will remain, the most expensive Bureau of Reclamation project ever built. Its sweeping legal influences established Arizona's rights to Colorado River water following decades of that river's dominance by California. Water claims of Native American tribes in Arizona add to the many legal battles CAP inspired and might solve through sheer volume of Colorado River water inflow. Olympian municipal struggles for CAP water confirm a definite shift from the state's onetime security in agricultural water to supplies that are fundamental for urban survival and growth.

Many Arizona water systems and their components have gained historic significance over time. The Bureau of Reclamation and the Salt River Project celebrated their 100th anniversaries in 2002 and 2003, respectively, and both organizations still rely upon considerable infrastructure over half a century in age. The tasks of maintaining historic water systems are largely carried out by such government agencies and cooperatives, not only to utilize their invaluable investments but also to preserve remarkable landmarks of the state's extraordinary water history.

Few topics in Arizona history remain as newsworthy and as controversial as water utilization and technology, particularly in the new century's struggle with persistently drier seasons. Water rights, drought, environmental impacts, maintenance of water systems, and water's links to sustained urban growth inspire daily headlines in Arizona. Even the most contemporary debates on the future of Arizona water must defer to the history of Arizona water, and its role in the development of American democracy in the West. "Water is more precious than gold," Dean Mann warned in *The Politics of Water in Arizona*, "and more explosive than dynamite."



Sites to Visit, Major Highways, and Principal Cities

(consult a current travel guide for further information)

LEGEND:

- Point of Interest
- Interstate
- Urban Area

Native American:

1. Ganado Irrigation System, Hubbell Trading Post National Historical Park
2. Quitobaquito Springs, Organ Pipe National Monument
3. Park of Four Waters, Pueblo Grande Museum, Phoenix

Spanish and Mexican Influence:

4. San Xavier del Bac National Historic Landmark
5. Tumacacori National Historic Park United States Accession and Territorial Period:

U.S. Accession and Territorial Period

6. Arizona Historical Society Museum, Tempe
7. Agua Caliente Ranch, Pima County Park, Tucson
8. Pipe Spring National Monument
9. Iron Turbine Windmill, Sharlot Hall Museum, Prescott
10. Flagstaff Old Town Spring and City Park Pond (Francis Short Pond)
11. Kintiel Well, Hubbell Trading Post National Historical Park
12. Ash Fork Steel Dam
13. Childs-Irving Hydroelectric Project near Strawberry on Fossil Creek
14. Lees Ferry, near Marble Canyon
15. Yuma Crossing State Historic Park

Federal Reclamation Period

16. Crescent Moon and Red Cliffs ranches, Coconino National Forest
17. Jordan Historical Park, Sedona
18. Davis Dam and Powerplant (http://www.lc.usbr.gov/pao/davis.html)
19. Glen Canyon Dam (http://www.usbr.gov/power/new/new.htm)
20. Hoover Dam (http://www.usbr.gov/lc/hooverdam/service/)
21. Imperial Dam (http://www.usbr.gov/lc/yuma/river/imperial.htm)
22. Laguna Dam (http://www.usbr.gov/lc/yuma/river/laguna.htm)
23. Parker Dam and Powerplant (http://www.lc.usbr.gov/pao/parker.html)
24. Grand Canyon National Park Water Reclamation Plant

Further Reading

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Arizona Historic Contexts

See http://www.pr.state.az.us/partnerships/shpo/context_sum.html for ordering any completed historic context in 2004, except the out-of-print New Deal study.

1. Homesteading in Arizona, 1870–1942
2. Commerce in Phoenix, 1870–1942
3. Gold and Silver Mining in Arizona, 1848–1945
4. The Chinese in Arizona, 1870–1950
5. The United States Military in Arizona, 1846–1945
6. Transcontinental Railroading in Arizona, 1878–1940
7. Prehistoric Rock Art in Arizona
8. Historic Trails in Arizona from Coronado to 1940
9. Prehistoric to Historic Transition Period [Proto-Historic] in Arizona, circa AD 1519 to 1692
10. Paleoindian and Archaic Sites in Arizona
11. The New Deal in Arizona
12. Prehistoric Water Utilization and Technology in Arizona
13. Water Utilization and Technology in Arizona's Historic Era, 1540–1960

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Cover design and layout by Michelle Weigman.

Cover image: Tasty citrus products from Arizona's irrigated desert once found their way across the United States inside ventilated wooden crates bearing bright and bold printed labels. The 1940s unlettered stock label providing background for this publication's titles and credits was printed by the Stecher-Traung Lithography Company of San Francisco probably as a salesman's sample. Label from the vintage label collection of R. John Medley, Jr., Oracle, Arizona, rjkamedley@yahoo.com.