

Figure 2.4 (b)
 Profile of the aqueduct of Nimes. (Courtesy of Hauck, G., *The Aqueduct of Nemausus*, McFarland, Jefferson, NC, 1988)

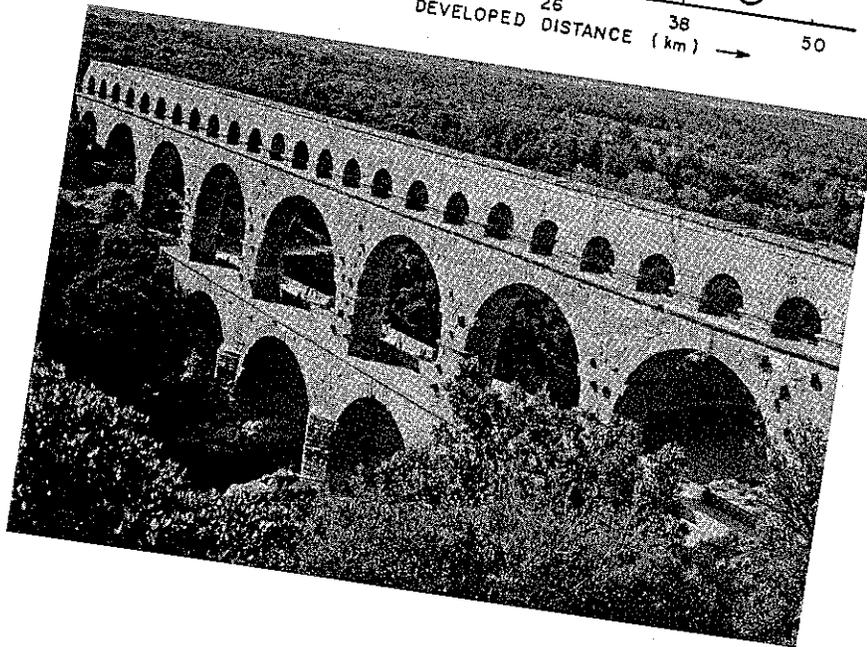


Figure 2.4 (c)
 Pont du Gard aqueduct bridge showing the three levels. (Photo copyright by L. W. Mays)

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Figure 2.4 (d)
 Views of the castellum divisorium at Nmes. Water enters the circular basin through the rectangular aqueduct opening. Refer to Fig. 2.4e for the plan view with dimensions. (Photos copyright by L. W. Mays)

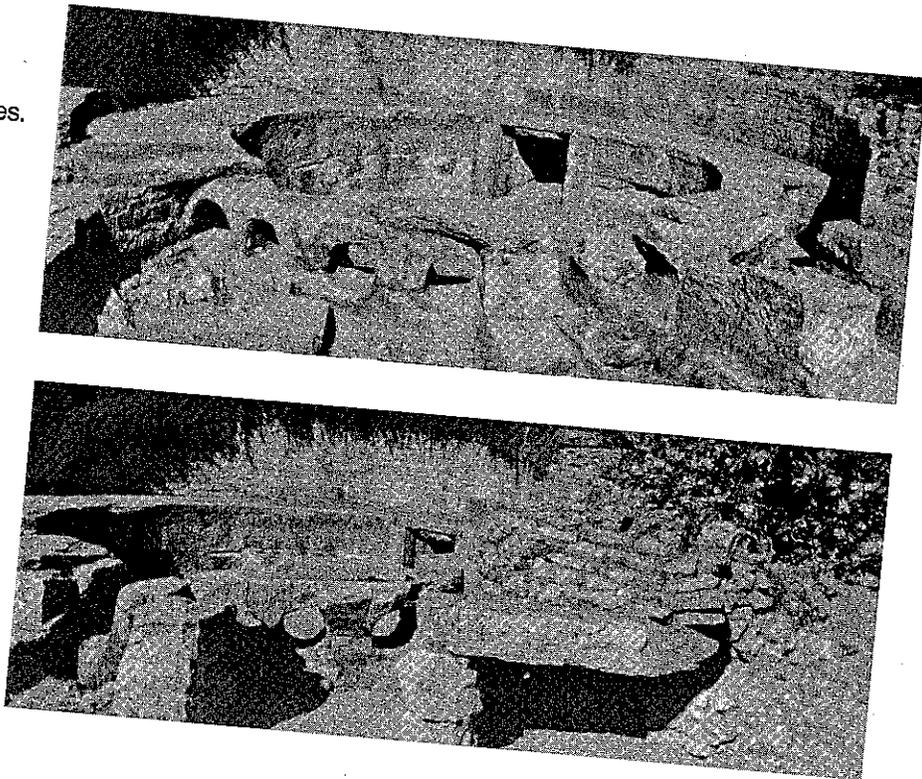
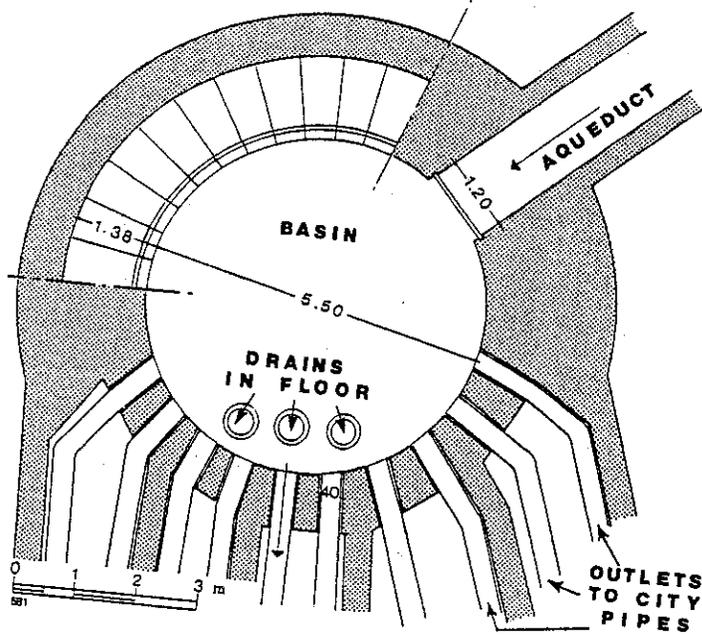


Figure 2.4 (e)
 Plan view of the Nimes castellum divisorium showing the 10 outlets and the 3 drains in the floor of the 1.5 m diameter basin. (Courtesy of J. P. Adam, La Construction Romaine, Paris (1984) as drawn in Hodge, 2002)



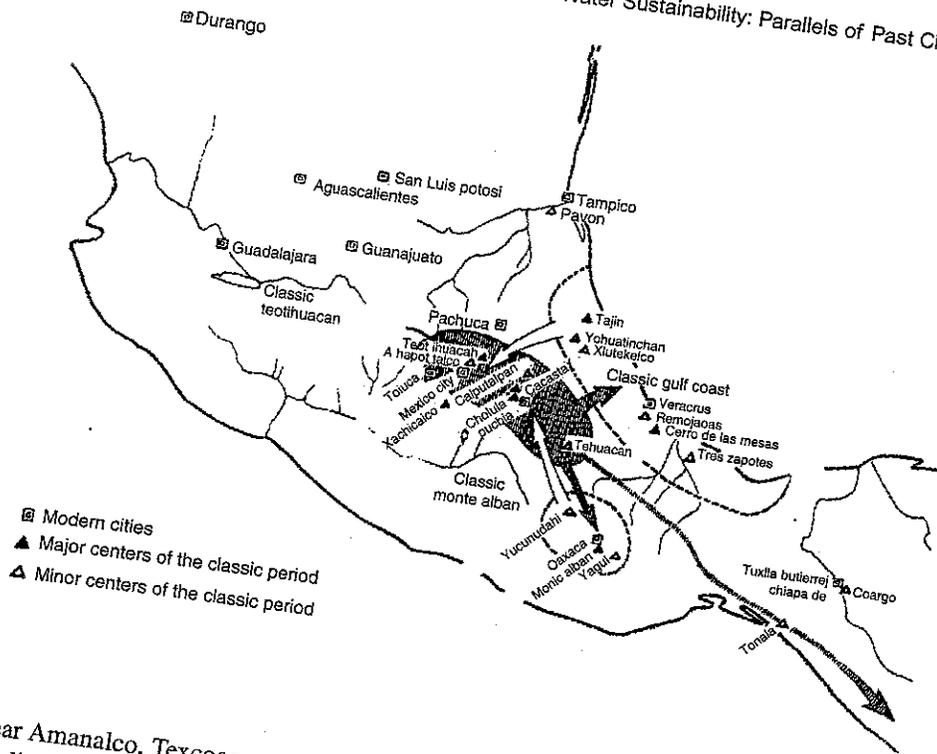


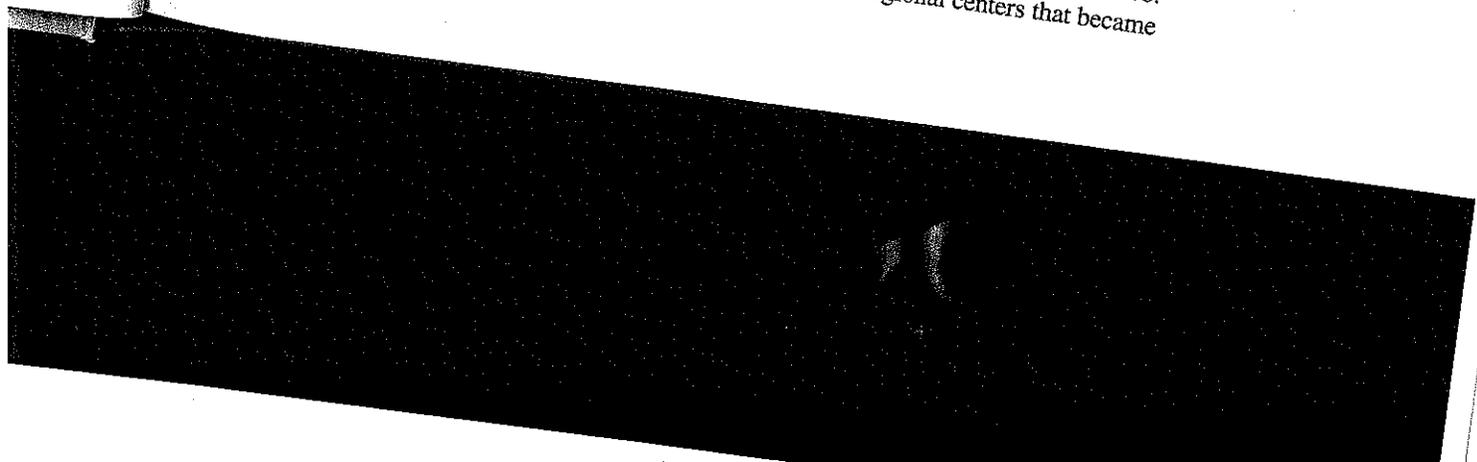
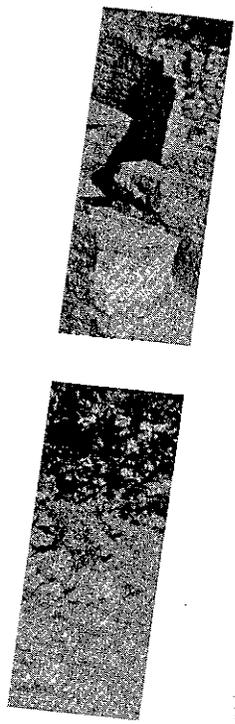
Figure 2.5
 Classic period in Mexico showing the area (shaded) covered by the Teotihuacan civilization and its extensions in Mexico. (Courtesy of Coe, M. M., Mexico: From the Olmecs to the Aztecs, 4th ed., Thames and Hudson, New York, 1994)

near Amanalco, Texcoco east of the Basin of Mexico, irrigation would have consisted of diverting water from shallow spring-fed streams into simple irrigation canals and then onto fields only a few meters away. Flood water systems also were used. Northeast of Teotihuacan, south of Otumba, a series of ancient irrigation canals (dating between 300 BC and 100 BC) were excavated. Other canals in the same area date to AD 900 to AD 1600. Evidence of canals that were built between AD 200 and AD 800 near Teotihuacan also exists. One of these was the first confirmed relocation of a natural stream. The reader can refer to Doolittle (1990) for further information on these canals.

The city of Teotihuacan was abandoned mysteriously around AD 600 to AD 700. During this time the collapse of civilized life occurred in most of central Mexico. One possible cause was the erosion and desiccation of the region resulting from the destruction of the surrounding forests that were used for the burning of the lime that went into the building of Teotihuacan. The increasing aridity of the climate in Mexico may have been a related factor. The entire edifice of the Teotihuacan state may have perished from the loss of agriculture. Even though the city had no outer defensive walls, Millon (1993) believes that it was not an open city easy for hostile outsiders to attack. The collapse of Teotihuacan opened civilized Mexico to nomadic tribes from the north. Human malnourishment has been indicated from skeletal remains.

After the disintegration of Teotihuacan's empire in the seventh century AD, foreigners from the Gulf Coast lowlands and the Yucatan Peninsula appeared in central Mexico. Cacaxtla and Xochicalco, both of Mayan influence, are two regional centers that became

Xochicalco



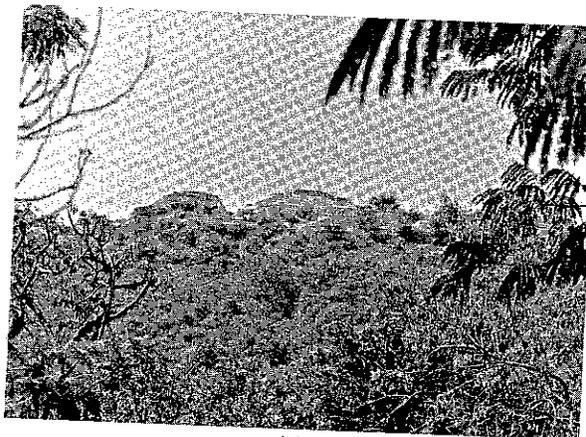
important with the disappearance of Teotihuacan. Xochicalco (in the place of the house of flowers), was located on hill top approximately 38 km from Cuernavaca, Mexico, and became one of the great Mesoamerican cities in the late classic period (AD 650 to AD 900). Figures 2.6a and 2.6b are photographs of the city, which was well thought out with terraces, streets, and plazas among the buildings. Despite the very Mayan influences, the predominant style and architecture is that of Teotihuacan.

There were no rivers or streams or wells to obtain water. Water was collected in the large plaza area and conveyed into cisterns such as the one shown in Fig. 2.6c. From the cisterns water was conveyed to other areas of the city using pipe as shown in Fig. 2.6d. The collapse/abandonment of Xochicalco, most likely, resulted from drought, warfare, and internal political struggles. The reliance upon collecting rainwater for water supply is very vulnerable and unsustainable through periods of low rainfall and even more important to drought conditions.

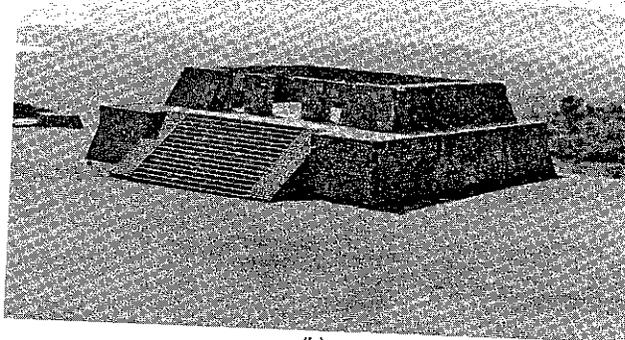
Crisis overtook all the classic civilizations of Mesoamerica (including the Mayans), forcing the abandonment of most of the cities. Some anthropologists believe the crisis may have been a lessening of the food supply caused by a drying out of the land and a

Figure 2.6

Photos of Xochicalco (a) View showing Xochicalco on hilltop (b) View from Xochicalco (c) Cistern (d) Water pipes. (Photos copyright by L. W. Mays)



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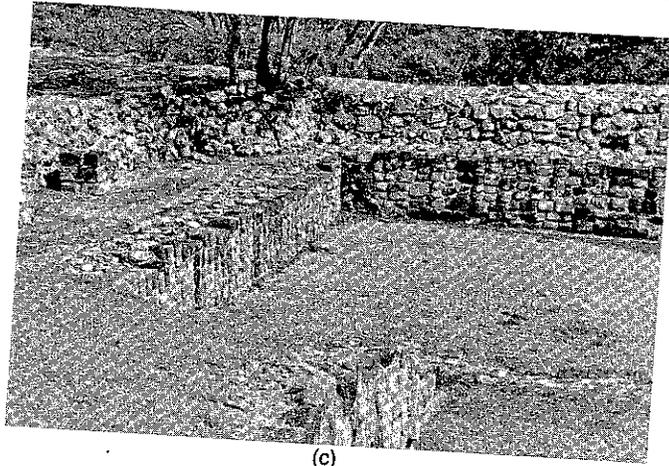


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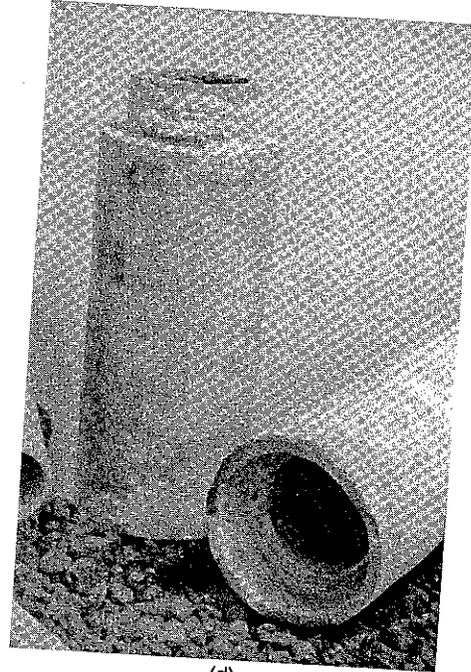
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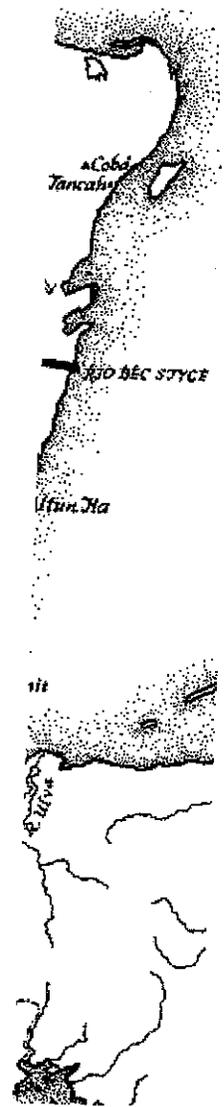
(d)

loss of water sources to the area. Speculation is that this might have been caused by a combination of a climatic shift toward aridness that appears to have happened all over Mexico during the classic period and the deforestation of the valley. Originally there were cedar, cypress, pine, and oak forests; today there are cactus, yucca, agave, and California pepper trees. Such a change in vegetation indicates a significant climate shift.

The ancient Maya lived in a vast area covering parts of present-day Guatemala, Mexico, Belize, and the western areas of Honduras and El Salvador as illustrated in Fig. 2.7. Mayans settled in the last millennium BC and their civilization flourished until around AD 870. The environment that the Mayans lived in was less fragile than that of the semiarid lands where the Anasazi and Hohokam lived.

The Maya

Because of this and the fact that few rivers or streams exist in the area, surface water is scarce. One important water supply source for the Maya, particularly in the north, was the underground caves (see Fig. 2.8) called *cenotes* (se-NO-tes), which also had religious significance (portals to the underworld where they journeyed after death to meet the gods and ancestors). In Yucatan there are over 2200 identified and mapped cenotes.



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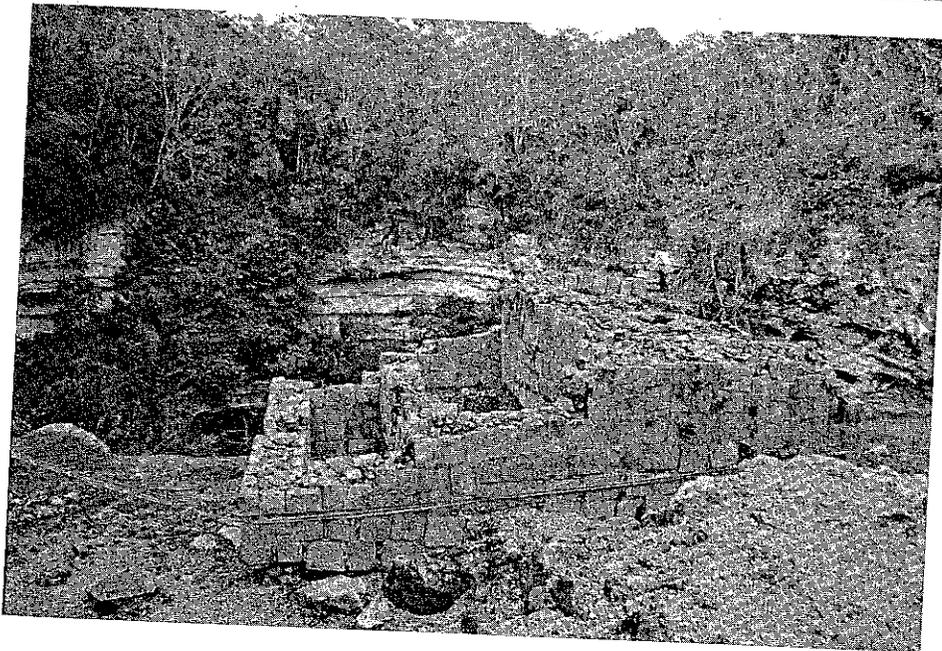
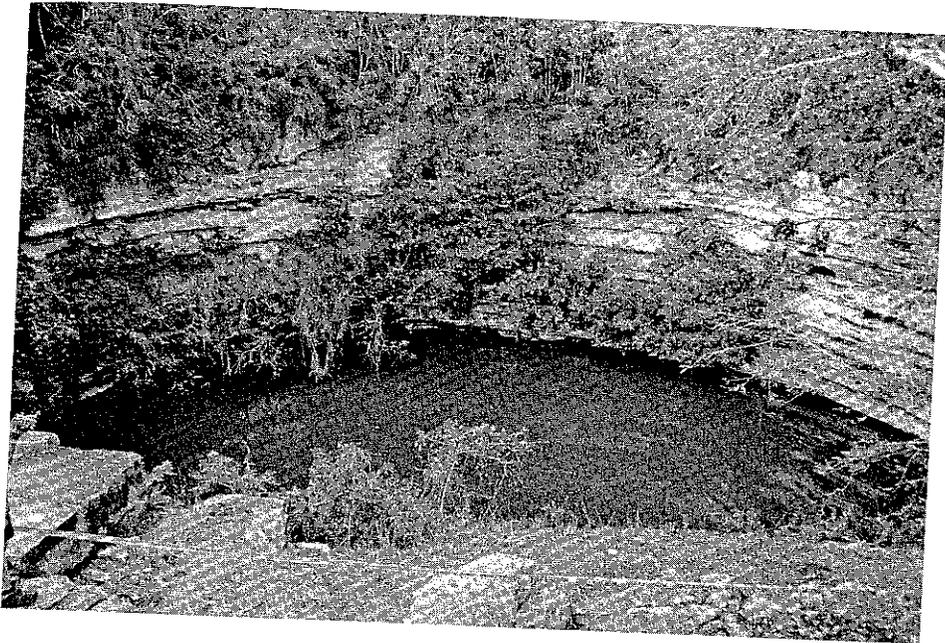


Figure 2.8

Sacred cenote at Chichen Itza (which means mouth of the well of the Itzas). The word *cenote* is derived from *tz'onot*, the Maya term for the natural sinkholes. (a) This cenote, which measures about 50 m from north to south and 60 m from east to west, was used for sacrifices of young men and women, warriors, and even children to keep alive the prophecy that all would live again. Shown at the left and in (b) is the remains of a building once used as a steam bath, or *temezcal*, to purify those who were to be sacrificed. Those sacrificed were tossed from a platform that jutted out over the edge of the cenote. (Photos copyright by L. W. Mays)

In the south the depths to the water table was too great for cenotes. Natural surface depressions were lined to reduce seepage losses and were used as reservoirs. Another source was water that collected when soil was removed for house construction in depressions called *aguados*. The Maya also constructed cisterns called *chultans* in limestone under buildings and ceremonial plazas. Drainage systems were developed from buildings and courtyards to divert surface runoff into the chultans. In the lowlands the Maya typically used one or more of these methods for obtaining and storing water supplies (Matheny, 1983).

Rainfall varies significantly from the north (18 in./year) to the south (100 in./year) of the Yucatan Peninsula. The soils are also deeper in the southern part, resulting in more productive agriculture; the area consequently supported more people. Rainfall was very unpredictable, resulting in droughts that destroyed crops. Ironically though, the water problems were more severe in the wetter southern part. Ground elevations increased from the north to the south, causing the depths down to the water table to be greater in the south.

Centuries before the Spanish arrived, the collapse of many other great Mayan cities occurred within a fairly short time period. Several reasons have emerged as to why these cities collapsed, including overpopulation and the consequent exhaustion of land resources possibly coupled with a prolonged drought. A drought from AD 125 until AD 250 caused the preclassic collapse at El Mirador and other locations. A drought around AD 600 caused a decline at Tikal and other locations. Around AD 760, a drought started that resulted in the Maya classic collapse in different locations from AD 760 to AD 910.

The soil of the rain forest is actually poor in nutrients so that crops could be grown for only two or three years, then to go fallow for up to 18 years. This required ever-increasing destruction of the rain forest (and animal habitat) to feed a growing population. Other secondary reasons for the collapse include increased warfare, a bloated ruling class requiring more and more support from the working classes, increased sacrifices extending to the lower classes, and possible epidemics. The Maya collapsed as a result of four of the five factors in Diamond's (2005) framework. Trade or cessation of trade with friendly societies was not a factor for the Maya. Water resources sustainability was certainly a factor in the collapse of the Maya.

American Southwest

Three major cultures—the Anasazi, the Hohokam, and the Mogollon—inhabited the American southwest during the late precontact period (see Fig. 2.9). The concept of prehistoric regional systems has been used to describe these cultures (Crown and Judge, 1991). The Hohokam and Chaco regional systems have received particular attention as two of the most important. The extent of the Hohokam regional system has been defined by ball courts and material culture, and the Chaco regional system has been defined by roads and other architectural criteria. Each of these occupied a distinctive ecological niche within the southwestern environment, and as a consequence, their infrastructures significantly differed. The American southwest is a difficult and fragile environment consisting of arid and semiarid lands, with minimal water resources.

The Hohokam (300 BC to AD 1450)

Hohokam, translated as “the people who vanished,” is the name given to their prehistoric predecessors by the present-day Pima Indians. The Hohokam built a complex irrigation

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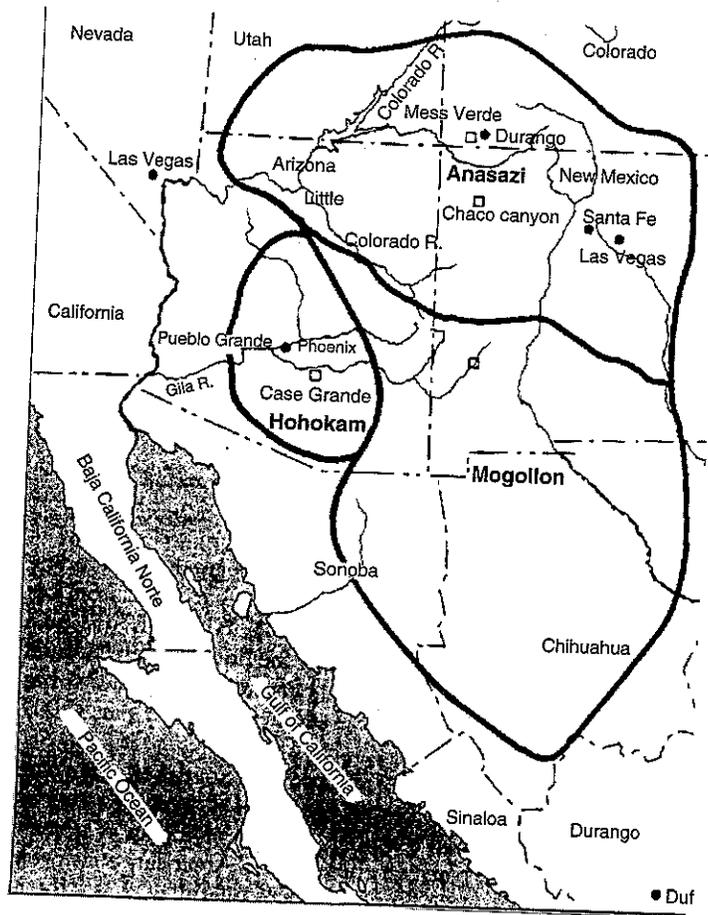


Figure 2.9
Three cultures in
the American
southwest.
(Courtesy of
Thomas, D. H.,
*Exploring Ancient
Native America:
An Archaeological
Guide*, Macmillan,
New York, 1994)

system in the desert lowlands of the Salt-Gila River Basin, Arizona, with no technology other than stone tools, sharpened sticks, and carrying baskets. They built more than 300 mi of major canals and over 700 mi of distribution canals in the Salt River Valley of present-day Phoenix, Arizona (see Fig. 2.10). The Hohokam civilization started in the Valley somewhere between 300 BC and AD 1 (see Crown and Judge, 1991) and extended to AD 1450 (Lister and Lister, 1983). Comparing Figs. 2.10 and 2.11, the similarities of the layout of the present-day canal systems with that of the Hohokams can be seen. A schematic representation of the major components of a Hohokam irrigation system is shown in Fig. 2.12.

In AD 899 a flood caused decentralization and widespread population movement of the Hohokams from the Salt-Gila River Basin to areas where they had to rely upon dry farming. The dry farming provided a more secure subsistence base. Eventual collapse of the Hohokam regional system resulted from a combination of several factors. These included flooding in the 1080s, hydrologic degradation in the early 1100s, and larger communities forcibly recruiting labor or levying tribute from surrounding populations (Crown and Judge, 1991). In 1358, a major flood ultimately destroyed the canal networks, resulting in the depopulation of the Hohokam area. Culturally drained, the Hohokam faced obliteration

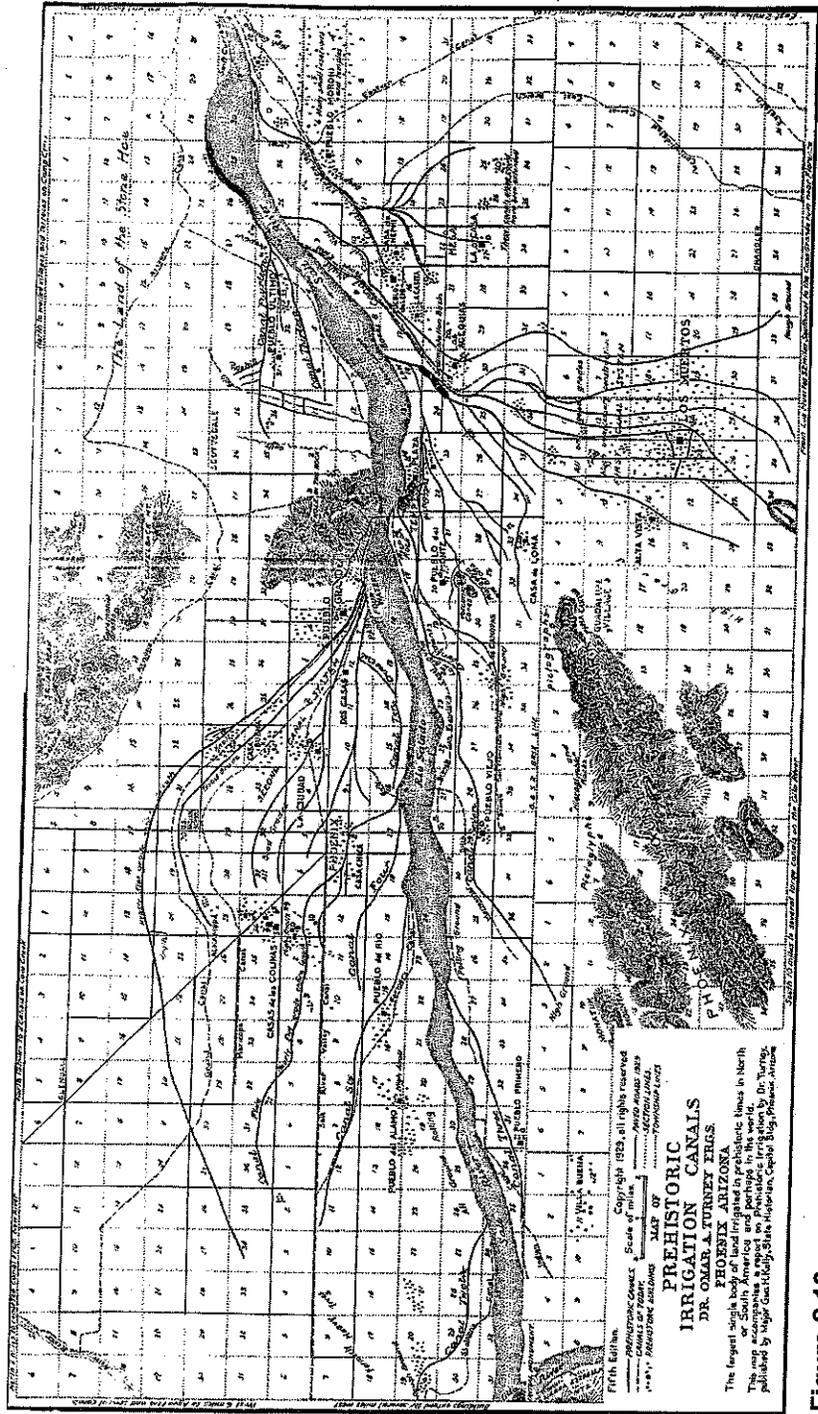


Figure 2.10
 Hohokam canal system in Salt River Valley. (Courtesy of Turney, O., "Prehistoric Irrigation in Arizona," Arizona Historical Review, Vol. 2, No. 5, Phoenix, 1929)

The map accompanying this article is the work of the Salt River Project, published by the Salt River Project, Phoenix, Arizona.

Figure 2.10

Hohokam canal system in Salt River Valley. (Courtesy of Turney, O., "Prehistoric Irrigation in Arizona," Arizona Historical Review, Vol. 2, No. 5, Phoenix, 1929)

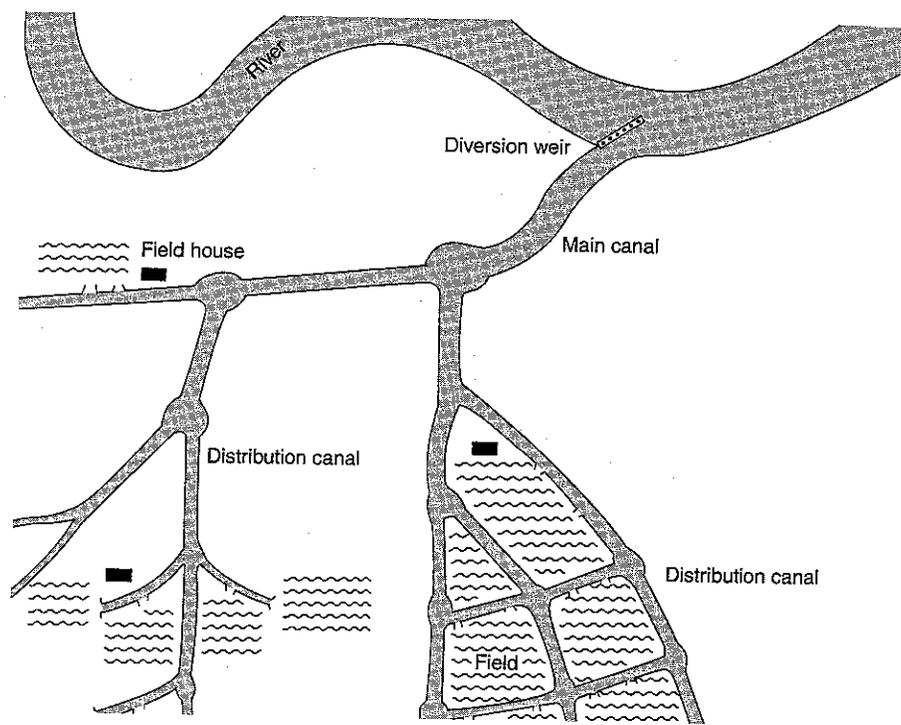


Figure 2.12
 Components of Hohokam irrigation system. (Courtesy of Masse, B., *The Quest for Subsistence Sufficiency and Civilization in the Sonora Desert, in Chaco & Hohokam: Prehistoric Regional Systems in the American Southwest*, in P.L. Crown and W.J. Judge (eds.), *School of American Research Press, Santa Fe, New Mexico, 1991*)

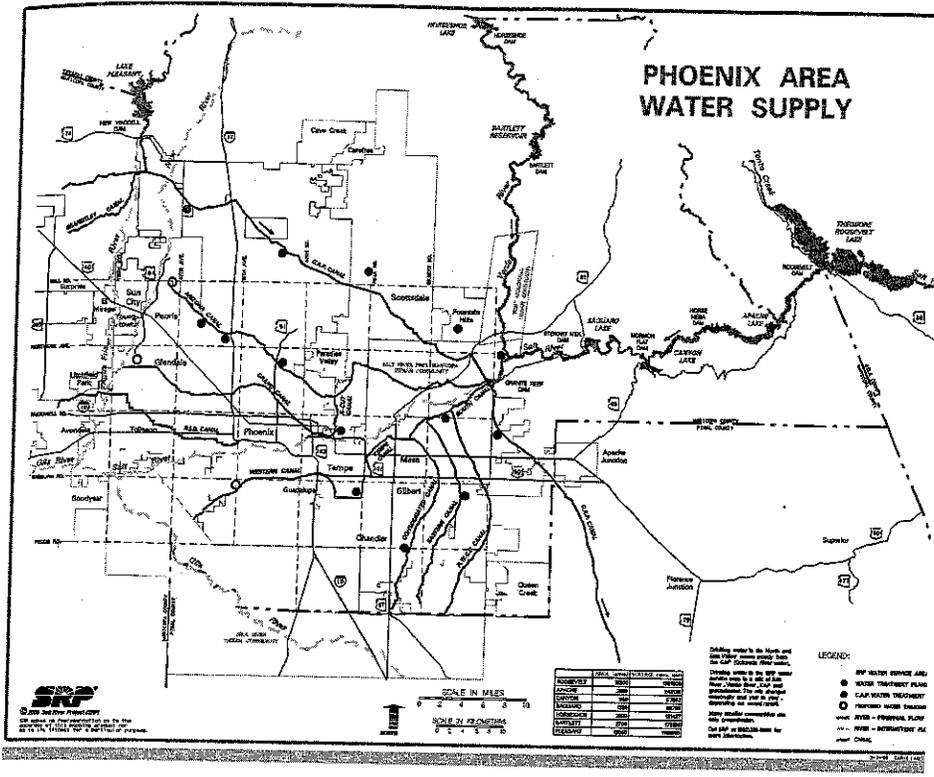


Figure 2.11
 Present day canal system in Salt River Valley. (Courtesy of Salt River Project)

in about 1450. Parts of the irrigation system had been in service for almost 1500 years, which may have fallen into disrepair, canals silted in need of extensive maintenance, and problems with salt. See Haury (1978), Masse (1981), and Woodbury (1960) for further information.

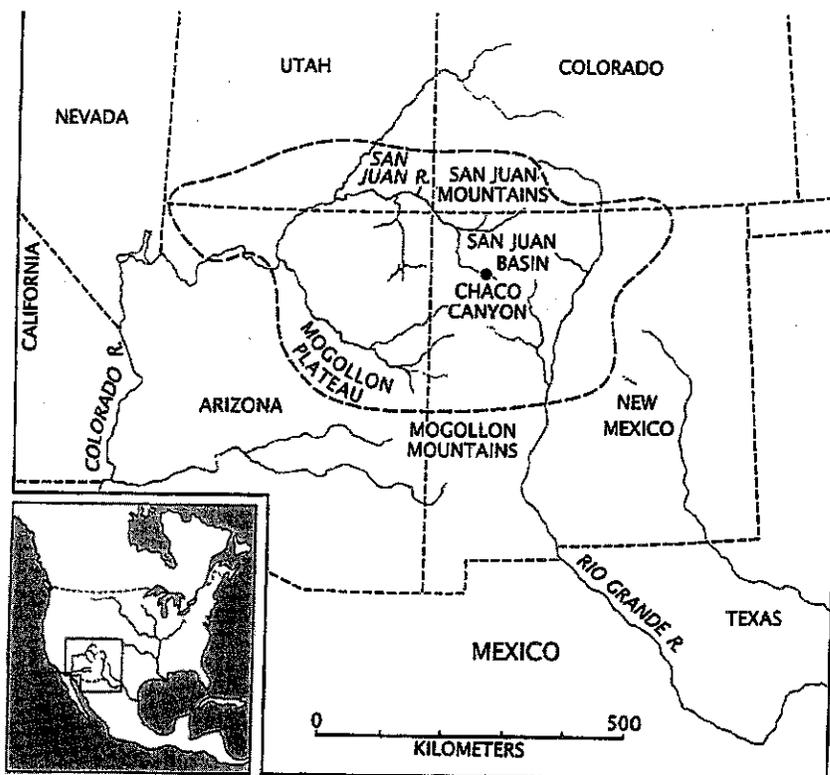
The Chaco Anasazi (AD 600 to AD 1200)

In the high deserts of the Colorado Plateau (see Fig. 2.13), the Anasazi (a Dine' (Navajo) word meaning "enemy ancestors"), also called the "ancient ones," had their homeland. When the first people arrived in Chaco Canyon, there were abundant trees, a high groundwater table, and level floodplains without arroyos. This was most likely an ideal environment (conditions) for agriculture in this area. Chaco is beautiful, with four distant mountain ranges: the San Juan Mountains to the north, the Jemez Mountains to the east, the Chuska Mountains to the west, and the Zuni Mountains to the south.

The first Anasazi settlers, also called "basket makers," arrived in Mesa Verde (southwestern Colorado) around AD 600. They entered the early Pueblo phase (AD 700 to AD 900), which was the time they transitioned from pit houses to surface dwellings, evidenced by their dramatic adobe dwellings, or pueblos. Chaco Canyon was the center of Anasazi civilization, with many large pueblos probably serving as administrative and ceremonial centers for a widespread population of the Chaco regional system. Also of particular note is the extensive road system, built by a people who did not rely on either wheeled vehicles

Figure 2.13

Anasazi region showing Chaco Canyon. (Courtesy of Lekson, S. H., T. C. Windes, J. R. Stein, and W. J. Judge, "The Chaco Canyon Community," *Scientific American*, Vol. 259, No. 1, pp. 100-109, July 1988)



most 1500 years, maintenance, and (1960) for further

(a Dine' (Navajo) and their homeland. abundant trees, a high altitude likely an ideal environment, with four distinct mountain ranges to the north and south.

Trade (southwestern) from 700 to AD 900), and ruins, evidenced by the presence of Anasazi ceremonial centers. A particular note is the use of wheeled vehicles

or draft animals. The longest and best-defined roads (constructed between AD 1075 and AD 1140) extended over 50 mi in length. The rise and fall of the Chacoan civilization was from AD 600 to AD 1200, with the peak decade being AD 1110 to AD 1120.

Chaco Canyon is situated in the San Juan Basin in northwestern New Mexico as shown in Fig. 2.13. The basin has limited surface water, most of which is discharged from ephemeral washes and arroyos. Figure 2.14 illustrates the method of collecting and diverting runoff throughout Chaco Canyon. The water, collected from the side canyon that drained from the top of the upper mesa, was diverted into canals by either an earthen or a masonry dam near the mouth of the side canyon. These canals averaged 4.5 m in width and 1.4 m in depth (Vivian, 1990); some were lined with stone slabs and others were bordered by masonry walls. The canals ended at a masonry head gate, where water was then diverted to the fields in small ditches or to overflow ponds and small reservoirs.

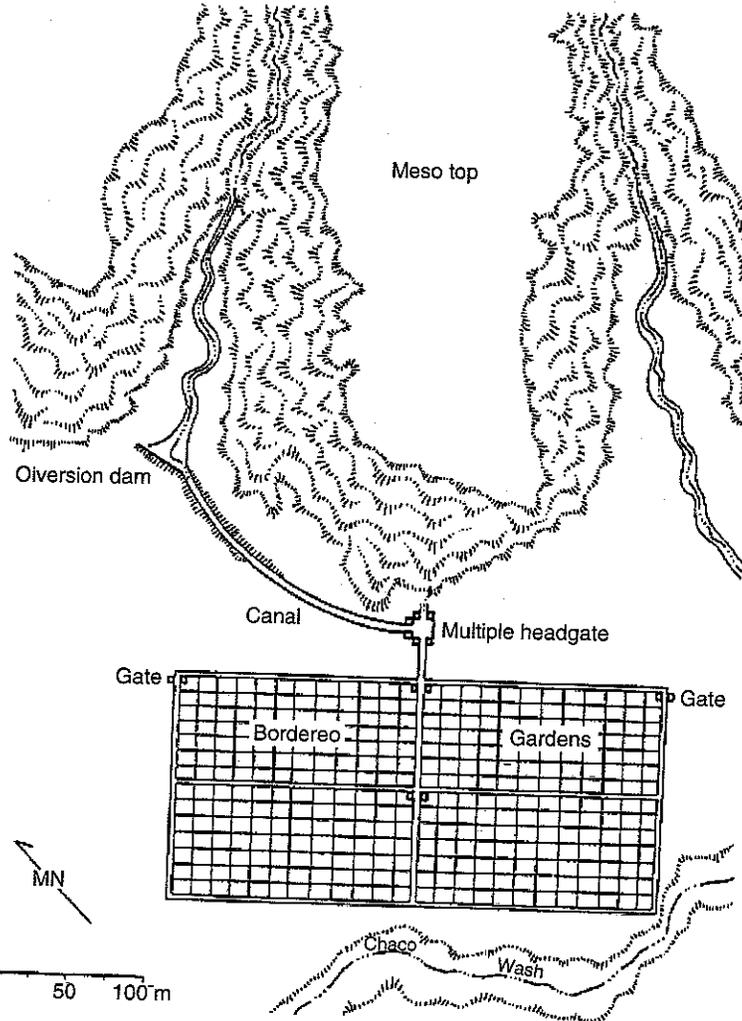


Figure 2.14
Water-control system in Chaco Canyon. (Courtesy of Vivian, R. G., "Conservation and Diversion: Water Control Systems in the Anasazi Southwest," in T. Downing and M. Gibson (eds.), *Irrigation Impact on Society, Anthropological papers of the University of Arizona*, No. 25, pp. 95-112, University of Arizona, Tucson, 1974)

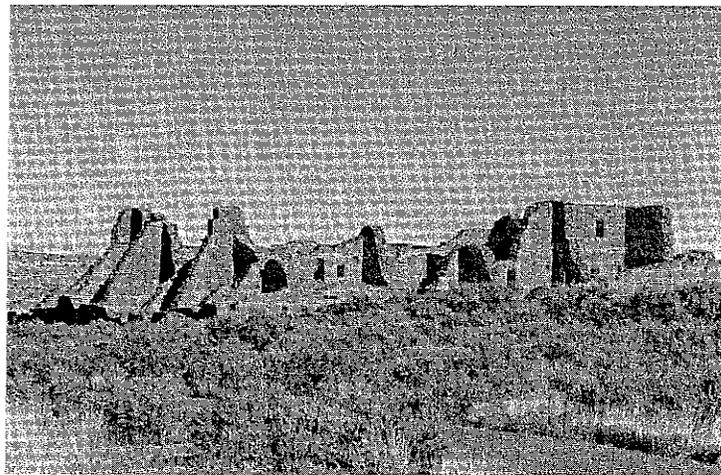
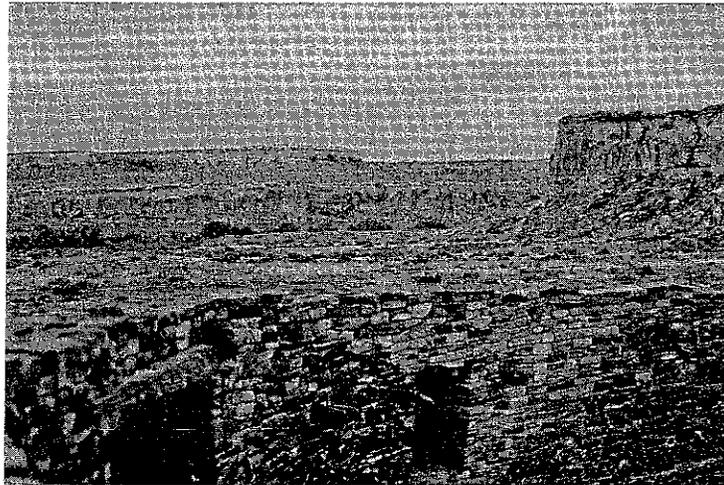


The diversion of water into the canals combined with the clearing of vegetation resulted in the eroding (cutting) of deep arroyos to depths below the fields being irrigated. By AD 1000 the forests of pinyon and juniper trees had been deforested completely to build roofs, and even today the area remains deforested as shown in Fig. 2.15.

Between AD 1125 and 1180, very little rain fell in the region. After 1180, rainfall briefly returned to normal. Another drought occurred from 1270 to 1274, followed by a period of normal rainfall. In 1275, yet another drought began which lasted 14 years.

Of the five-factor framework for social collapse suggested by Diamond (2005), the only factor that did not play a role in the collapse of the Anasazi was hostile neighbors. Water sustainability was affected by the deforestation, the erosion (cutting) of the arroyos from the diversion of water resulting in lowering the groundwater levels and the supply source to the irrigated fields, and finally, the repeated periods of drought caused the final collapse.

Figure 2.15
Chaco Canyon.
(Photos copyright
by L. W. Mays)



THE BEGINNING OF THE WATERING OF THE WEST

The Colorado River blocked the exploration of sections in the west for several centuries. After the end of the Mexican War in 1848, the United States acquired Arizona, New Mexico, and California. In 1857, Lt. J.C. Ives explored the Colorado River from the Gulf of California to over 400 mi upstream near the present day Hoover Dam. Twelve years later Major John Wesley Powell, a one-armed veteran of the Civil War, explored the Colorado River from the Green River in Wyoming to the Virgin River in Nevada. His party was the first known to have traveled through the Grand Canyon and lived to tell about it. Powell was founder of the *United States Geological Survey* (USGS) and is considered as "the father of reclamation" in the United States (Espeland, 1998).

On the basis of Powell's studies and explorations, he created a comprehensive plan for developing the West, most of which was ignored. He was the first to argue the idea that large-scale irrigation was necessary to settle the West and that government, not private industry, would need to develop irrigation on the scale needed to sustain agriculture in the West. He recognized that the resources, technology, and coordination required were far beyond the means of individuals or private industry (Espeland, 1998). His *Report on the Lands of the Arid Region*, in 1878, was the first important stimulus to the national irrigation movement.

Approximately one-third of the United States, including most of the West, requires irrigation to sustain tilled agriculture. During the 1870s and early 1880s many private irrigation companies were created to meet the demand for irrigation, relying on eastern capital to make fast money. Most of the companies went bankrupt within 10 years, causing the irrigation boom to bust. After years of drought (1888–1897), farms failed, people left, and some began pressuring the federal government to invest in irrigation in the West.

President Theodore Roosevelt, being a strong backer of the federal development of irrigation and reclamation, maneuvered the Reclamation Act of 1902, creating the Reclamation Service or a new branch of the USGS. The Reclamation Service was moved from the USGS in 1907 to the Department of the Interior and renamed the Bureau of Reclamation in 1923. It is interesting to note that the Reclamation Act was conceived and sold as a regional home-building program, a political strategy to appease legislators who were concerned that subsidized water for large farms would cause unfair competition for eastern farmers.

Once the Reclamation Service was created, it was flooded with project requests. The Salt River Project in Arizona was one of the first projects authorized in 1903, illustrating what became a prominent pattern in the *United States Bureau of Reclamation* (USBR) development.

Water management decisions are most often underlain by water laws. In the United States, water law has two basic functions:

1. The creation of supplemental private property rights in scarce resources
2. The imposition of public interest limitation on private use

**Water Law and
Policy in the
Southwest**

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For our purposes, water law is divided into surface water law and groundwater law. Surface water law is further categorized into riparian law and appropriation law. Riparian law is based on the riparian doctrine, which states that the right to use water is considered real property, but the water itself is not property of the landowner (Wehmhoefer, 1989). Appropriation law states that the allocation of water rests on the proposition that the beneficial use of water is the basis, measure, and limit of the appropriative right, the first in time is prior in right. In the western United States, surface water policy generally follows this doctrine of "first in time, first in right." In order to appropriate water, the user need only demonstrate availability of water in the source of supply, show an intent to put the water to beneficial use, and give priority to more senior permit holders during times of shortage. Beneficial use of water under the law includes domestic consumption, livestock watering, irrigation, mining, power generation, municipal use, and others. The states of Arizona and New Mexico follow the appropriation law of surface water, and in California and Texas both the appropriation doctrine and the riparian doctrine coexist.

Groundwater allocation is handled quite differently and is typically divided into common law or statutory law. Common law doctrines include the overlaying rights doctrines of absolute ownership, reasonable use, and correlative rights. These doctrines give equal rights to all landowners overlying an aquifer. Arizona, California, and Texas have adopted these principles for groundwater allocation.

The above surface and groundwater laws serve as the basis for individual state water policies. The burden of developing water policies lies upon each state. This is often achieved by the state proposing a water project and securing federal funds for the construction. It is also up to the states to agree on apportionment in interstate waters; if the states cannot agree, then the courts will intervene and settle the dispute by decree. The federal government only gets involved in such disputes where federal lands and Indian reservations are concerned.

Arizona

It is no secret that throughout Arizona's history, water policy has been directed at supporting the unconstrained growth of its population and major revenue-producing activities. Starting with mining, ranching, and farming, with the gradual shift to municipal and industrial uses, the water policy of the state has been directed at obtaining imported supplies. This has been an effort to augment what has appeared to be an insufficient and indigenous resource. Waterstone (1992) points out that the "state's water policies have led to the protracted exercise to capture and secure the *Central Arizona Project* (CAP), the ongoing infatuation with weather and water shed manipulation, the current experimentation with groundwater recharge and effluent use, and the recent spate of purchases of remote water farms." In Arizona, the state's water policy and management focused more on surface water than groundwater prior to 1980, when the Groundwater Management Code was developed; thereafter, the emphasis has been on groundwater. In regards to surface water, Arizona law defines surface water as "the waters of all sources, flowing in streams, canyons, ravines or other natural channels, or in definite underground channels, whether perennial or intermittent, flood, waste, or surplus water, and of lakes, ponds and springs on the surface." These surface waters are subject to the "doctrine of prior appropriation"

(ADWR, 1998). In Arizona, surface water rights are obtained by filing an application with the Department of Water Resources for a permit to appropriate surface water. Once the permit is issued and the water is actually put to beneficial use, proof of that use is made to the department and a certificate of water right is issued to the applicant. Once a certificate is issued, the use of the water is subject to all prior appropriations.

Because water law in the state of Arizona has changed substantially over the years, Arizona is now conducting a general adjudication of water rights in certain parts of the state. Adjudications are court determinations of the status of all state law rights to surface water and all claims based upon federal law within the river systems. These adjudications will provide a comprehensive way to identify and rank the rights to the use of water in some areas. The adjudications will also quantify the water rights of the federal government and the Indian reservations within Arizona.

In Arizona, groundwater problems arise from the overdrafting of water from the aquifers. Groundwater overdrafts cause many problems, such as increased well pumping costs and water quality issues. In areas of severe groundwater depletion, the earth's surface may also subside, causing cracks or fissures that can damage roads or building foundations. In order to manage groundwater pumping in Arizona, the Arizona groundwater management code was developed in 1980 as state legislation. The Arizona groundwater management code was named as one of the nation's 10 most innovative programs in state and local government by the Ford Foundation in 1986. This achievement came from the cooperation of Arizonans working together and compromising when necessary in order to protect the future of the state's water supply.

The Groundwater Management Code has three primary goals (ADWR, 1998):

1. Control the severe overdraft currently occurring in many parts of the state
2. Provide a means to allocate the state's limited groundwater resources to most effectively meet the changing needs of the state
3. Augment Arizona's groundwater through water supply development

In order to achieve these goals, the code set up a comprehensive management environment and established the Arizona Department of Water Resources.

The code outlines three levels of water management. Each level is based on different groundwater conditions. The lowest level applies statewide, and includes general groundwater provisions. The next level applies to *irrigation nonexpansion areas* (INAs), and the highest level applies to *active management areas* (AMAs) where groundwater depletion is the highest. The boundaries that divide the INAs and AMAs are determined by groundwater basins and not by political jurisdiction. The main purpose of groundwater management is to determine who may pump groundwater and how much may be pumped. This includes identifying existing water rights and providing new ways for nonirrigation water users to initiate new withdrawals. In an AMA or INA new irrigation users are not allowed. Even with the original publicity and enthusiasm, many people now feel that the efforts under the groundwater management code have been very costly with very little savings in water, making the success questionable.

Colorado River Basin and the Central Arizona Project (CAP)

Of the many river basins in the southwest, the Colorado River Basin has been the center of many controversies. The Colorado River Basin is divided into two sections, the upper and lower basins. The upper Colorado River Basin consists of the states of Arizona, Colorado, New Mexico, Utah, and Wyoming; the lower Colorado River Basin consists of Arizona, California, New Mexico, and Utah. Due to the doctrine of prior appropriation, the states in the upper Colorado River Basin became worried that the rapidly developing California would obtain a large portion of the appropriated water, leaving them with a shortage in the future. As an attempt to settle the issues, the upper basin states agreed to support California on the Hoover Dam proposal that it needed to obtain Colorado River water for its growing development. In return, the states requested a guaranteed amount of water from the river for their own future development. This agreement between the states resulted in the Colorado River Compact in 1922, which Arizona did not ratify until 1944. Table 2.1 lists the U.S. Federal laws of the Colorado River.

Under the Colorado River Compact, it was agreed that the upper Colorado River Basin would receive 7.5 maf, and the lower Colorado River Basin would receive 7.5 maf. It was also agreed that the lower basin would have the right to increase its beneficial consumptive use by 1 maf annually. All of the states supported the compact except Arizona, which opposed the compact and refused to sign it. The dispute over the water continued as the Boulder Canyon Project Act was passed. The Boulder Canyon Project Act was passed on December 21, 1928 by Congress, which authorized the construction of Boulder Dam (now Hoover Dam). However, the one stipulation was California must agree to limit its use of Colorado River water to an amount of 4.4 maf. Arizona and California fought over both the Colorado River Compact and the Boulder Canyon Act. Arizona was against the act and

Table 2.1
Federal Laws of
the Colorado River

Year	Action
1922	Colorado River Compact apportions 7.5 MAF to lower basin states of California, Arizona, and Nevada
1928	Boulder Canyon Project Act authorizes Hoover Dam and All American Canal. Apportions lower Colorado River water, CA-4.4 MAF; AZ-2.8 MAF; NV-0.3 MAF
1945	Mexican Water Treaty apportions 1.5 MAF to Mexico
1948	Upper Colorado River Basin Compact. Arizona is apportioned 50,000 AF of water for territory in upper Colorado River Basin drainage
1964	Arizona vs. California. U.S. Supreme Court Decree. Ratification of 1928 apportionment of the Colorado River water supply
1968	Colorado River Basin Project Act. Authorizes construction of the Central Arizona Project. Sets forth law governing the distribution and use of the CAP water
1974	Colorado River Basin Salinity Control Act. Authorizes works to control salinity of Colorado River water below Imperial Dam as part of Mexican Treaty obligation.

Source: Hermes and Mays, 2002.

did not want California to have any of their water. In order to help in settling the dispute, the U.S. Congress made it clear to Arizona that until they could settle the dispute of water allocation in the lower basin, the state would not receive any support for their water canal system, the CAP, which would later become a controversy in itself. Arizona finally agreed to share its water with California in order to receive funding for the CAP. As a result of the case *Arizona v. California*, which took place in 1964, the Supreme Court decreed that California would receive 4.4 maf of Colorado River water, Arizona would receive 2.8 maf, and Nevada would receive 300,000 maf.

CAP and the Users The CAP was the largest, most expensive, and most politically volatile water-development project in the U.S. history; it was also the most ambitious basin project that the Bureau of Reclamation attempted (Espeland, 1998). Even early on in 1947, the strategy of CAP supporters was to paint CAP as a "rescue" operation. This was the project necessary to replace the "exhausted" groundwater supply in order to save the local economy. By 1963, the CAP was still justified as a "rescue" project; a doubling of the population over the previous 10 years supposedly made the project even more urgent. Economic development was assumed to be driven by agricultural development. The thought was that without more irrigated farmland, urban growth (which reduces irrigated farmland) would be stymied. How did the population grow so fast despite the previous prediction that water supply would limit economic growth?

In 1968, Congress authorized the construction of the CAP under the Colorado River Basin Project Act. The main purpose for the authorization was to assist Arizona in reducing its water deficiencies. By 1971, the first *environmental impact statement* (EIS) on the CAP was written and then finalized in 1972. The 1976 EIS was devoted solely to the Orme Dam, to become the beginning of a series of EISs in the major features of the CAP. In 1971, the *Central Arizona Water Conservation District* (CAWCD) was created to provide a means for Arizona to repay the federal government for the reimbursable costs of construction and to manage and operate the CAP once complete. The construction began in 1973 at Lake Havasu and was completed in 1993. The entire cost of the project was more than \$4 billion. Under the Colorado River Basin Project Act, the CAP would be the first to take shortages in the lower Colorado River Basin.

The CAP is a 336 mi long system of aqueducts, tunnels, pumping plants, and pipelines. As shown in Fig. 2.16a, the CAP carries water from the Colorado River at Lake Havasu, through Phoenix, to the San Xavier Indian reservation southwest of Tucson. The main purpose of the CAP was to help Arizona conserve its groundwater supplies by importing surface water from the Colorado River.

The users of the CAP water fall into three categories. The first category is municipal and industrial. These customers include cities and water utilities which are responsible for treating drinking water and delivering it to residences, commercial buildings, and industries. The next water use category is agricultural. These agricultural users are primarily irrigation districts. The last category is the Indian community. These communities receive water from the CAP under contracts with the federal government. Agriculture has been the main water user in the past; however, due to the increasing development of Arizona, cities will soon become the largest customer for the CAP. The three priorities

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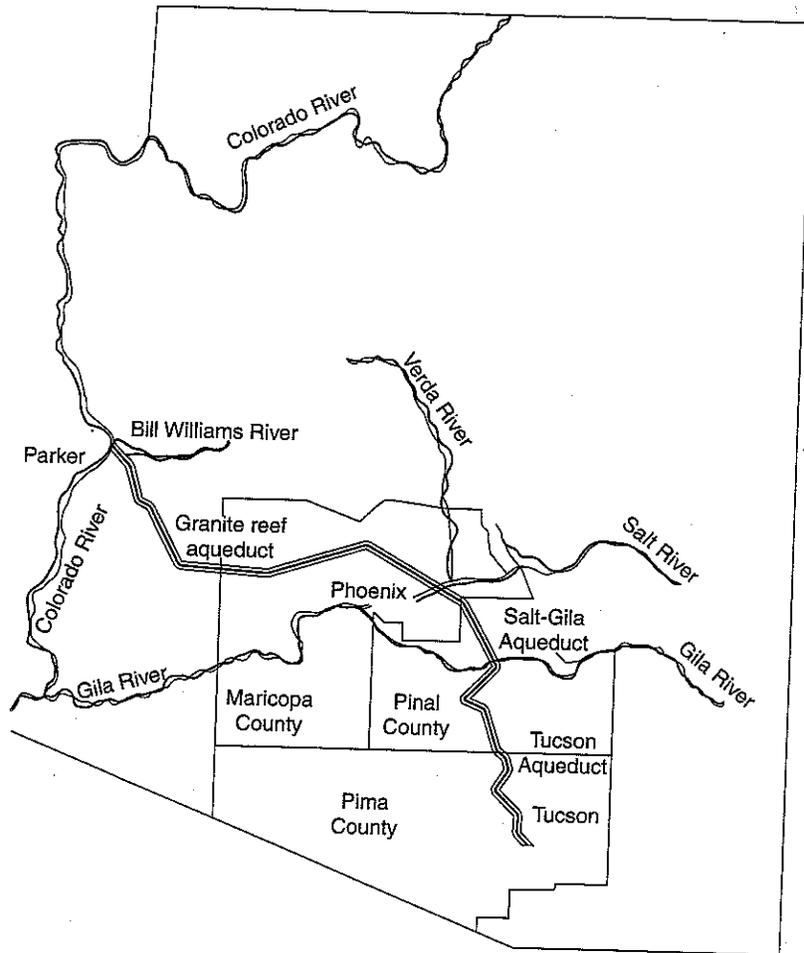
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Figure 2.16 (a)
 The Central
 Arizona project.
 (Courtesy of CAP)



for water are (1) the municipal and industry of the Indians (2) agriculture (3) miscellaneous. Under shortages the order of issuing water would be the miscellaneous, agriculture, and then municipal and industry of the Indians.

One of the main criticisms of the CAP is the cost of the water and how the revenue is obtained. The price of the CAP water is determined annually by the CAWCD board of directors, and is based on projections of energy and operation, maintenance, and replacement costs. The payment shares for the municipal and industrial category, as well as the Indian agriculture, are based on their full annual CAP entitlement. The non-Indian agriculture user has the "take or pay" payment option. "Take or pay" means that the charge for the water is based on the amount available for delivery, not what is requested. The users essentially must pay for the water even if they do not use it all. This type of payment scenario was based on the assumption that non-Indian agriculture subcontractors would seek to purchase the remaining CAP water entitlement. Non-Indian agriculture obtains irrigation water from other less-expensive sources such as groundwater. This chain of events becomes very important to the future of the CAP, because if Arizona does not use its full entitlement of Colorado River water it could

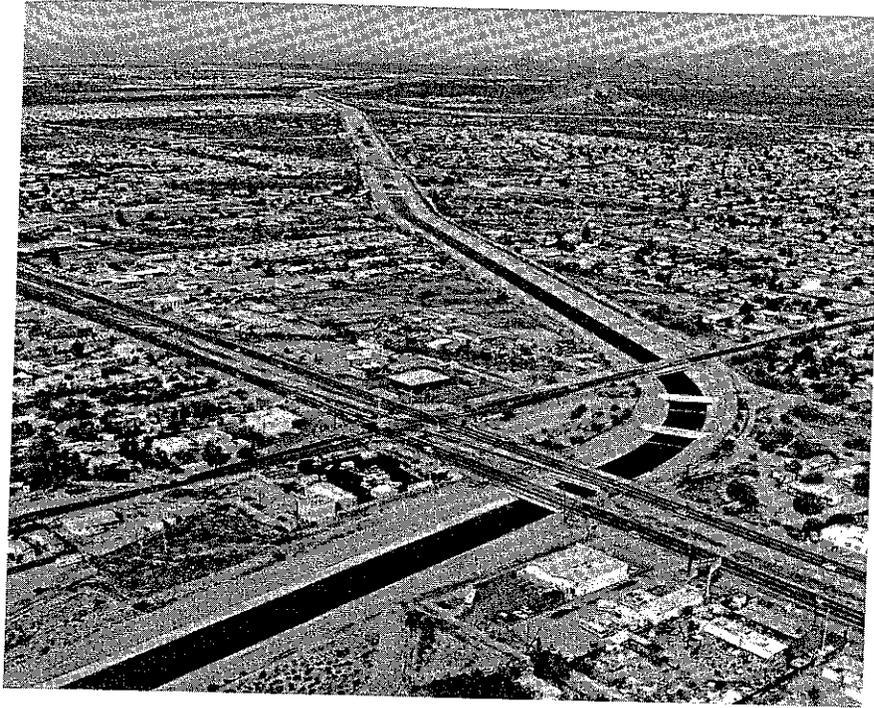


Figure 2.16 (b)
Central Arizona
project (CAP)
aqueduct through
a residential area in
Scottsdale,
Arizona. (Courtesy
of CAP)

possibly lose it. However, the protection of Arizona's Colorado River water entitlement is protected by law but can be changed by Congress.

THE PAST AND THE FUTURE

What relevance does the collapse of ancient civilizations have upon modern societies? When I look at the rapid development and population increases in the southwestern United States, a region with limited water resources, I continue to hope that our society will awaken. So many areas are being developed without regard to the future availability of water. We have developed the southwest with limited knowledge (short records) of historical rainfall and streamflow data. In many cases *paper water* (water created on paper that really does not exist) is being used to justify these projects. In recent decades we have not been exposed to the repeated extremely severe droughts that historically have occurred. Neither have we been faced with the realities of what a global climate change might bring rather rapidly. Simply stated, we have developed water policies under the assumptions that the past decades are typical of the future—and they may not be.

One might argue that if the ancient societies had our present-day technologies, they would not have failed. However in my opinion, presently we have the technologies to prevent future collapse of areas such as the southwestern United States, but there is still a good chance we will fail. I don't think that even newer (undeveloped) technologies are the answer for our present-day problems. The technologies exist to have prevented

Relevance of the Ancients

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many of the problems associated with the water sustainability of Mexico City. The technologies have been available to have prevented much of the flood damage in New Orleans resulting from Hurricane Katrina. What we need is for society to have the political and institutional will to fund and to apply the available technology/solutions.

Quoting Falkenmach and Lindh (1993), "Water's fundamental importance in sustaining life and a culture makes any threat to an area's water supply a threat to its economic life as well."

The Unsustainable American Southwest

The American southwest is an excellent example of a highly developed region that is heading toward an unsustainable water base for the future. I have chosen to discuss the American southwest for several reasons. First it is where I live and it is a region I deeply love. I share my time between the "Valley of the Sun" in Arizona (the desert) and Pagosa Springs, Colorado (the mountains), two vastly different areas. Phoenix, Arizona is in a region with a semiarid climate that has attracted a large and rapidly growing population. More importantly this is an area that is growing rapidly and so far, very successfully, but may have severe problems in the future if we do not establish limits on its growth. Unfortunately the people of this region have relied on expensive supply-side projects such as the CAP (Fig. 2.16) to import water from the Colorado River.

Through the importation of water to southern California cities via aqueducts from northern California and the Colorado River, we have diverted nearly the entire flow of the Colorado River to supply water to Southern California and Arizona to irrigate crops and lawns in the desert and to fill swimming pools. Because of these diversions, today the Colorado River delta in northern Mexico is "a desiccated place of mud-cracked earth, salt flats, and murky pools," as noted by Postel (1997). The Coca Indians, "the people of the river," who have fished and farmed in the region for hundreds of years, are now a culture at the risk of extinction. After a canoeing trip of the Colorado River delta in 1922, Aldo Leopold, in his book *A Sand County Almanac*, referred to the delta as "a milk and honey wilderness."

Many barriers exist to the efficient management of the region's water resources, including a legal system from the gold and silver mining in the nineteenth century, "first in time, first in right" or "use it or lose it." Many areas rely on water pumped from groundwater aquifers that have been overdrafted for years and others are being allowed to develop without adequate water supplies for the future. Many areas have severe irrigation problems that are similar to what many ancient civilizations faced, with the irrigated soil becoming increasingly salty. California's San Joaquin Valley is an example where without irrigation, abundant crop yields are impossible. With irrigation, the land will very likely become impossible to farm. Modern methods do not seem to be helping the San Joaquin Valley avoid this fate. Farmers have tried to cleanse the salts from the soil by flushing it with water and draining it into the sea.

Simply stated, the water situation in the southwestern United States, as in many other parts of the world, is unsustainable as it is presently used and operated. Diamond (2005) states, "Just think today of the dry U.S. West and its urban and rural policies that profligate water use, after drawn up in wet decades on the tacit assumption that they were typical." We certainly are a much more advanced society than those of ancient societies, but will be able to overcome the obstacles to survival before us? Remember, the Ancients have warned us!

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