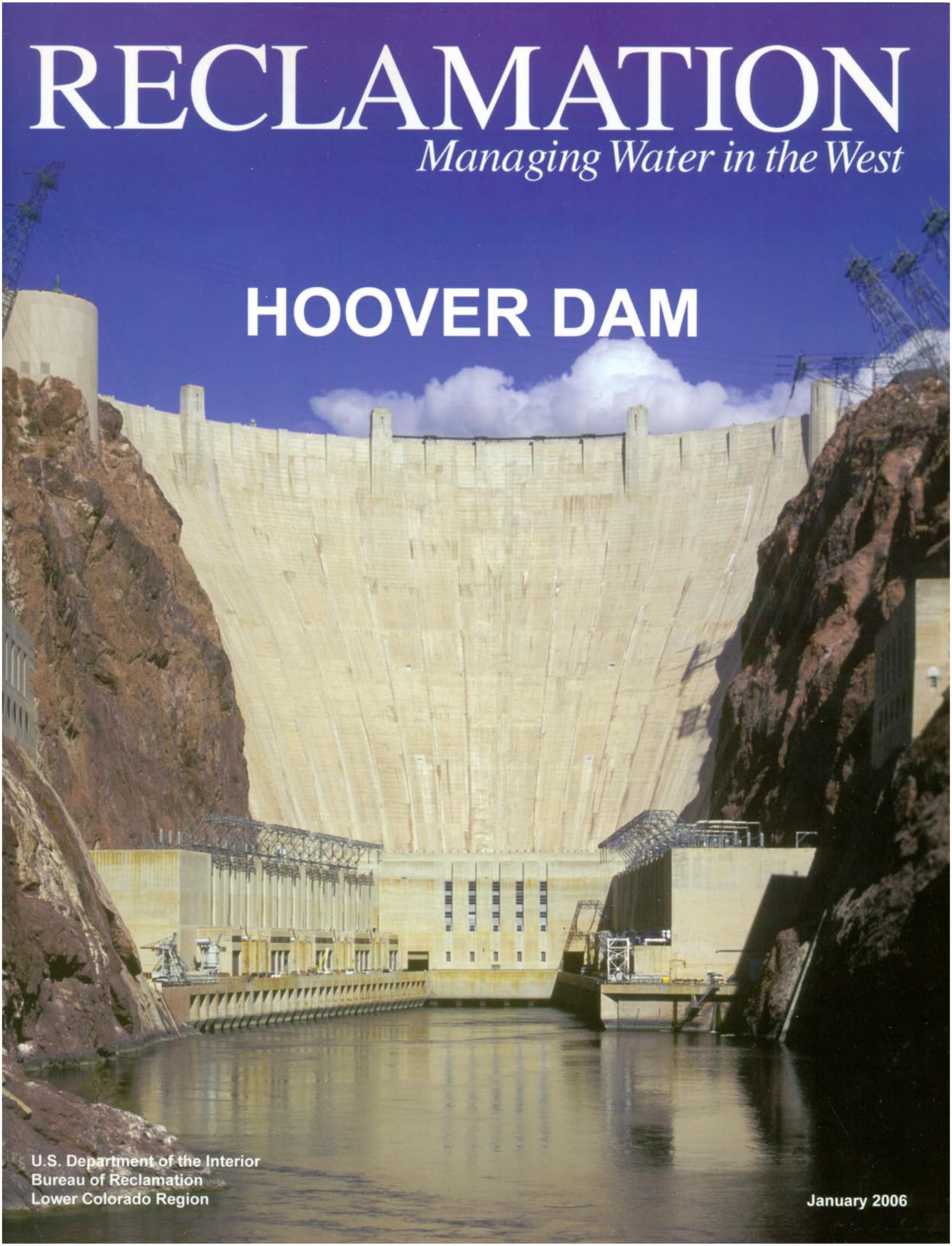
RECLAMATION

Managing Water in the West

HOOVER DAM



U.S. Department of the Interior
Bureau of Reclamation
Lower Colorado Region

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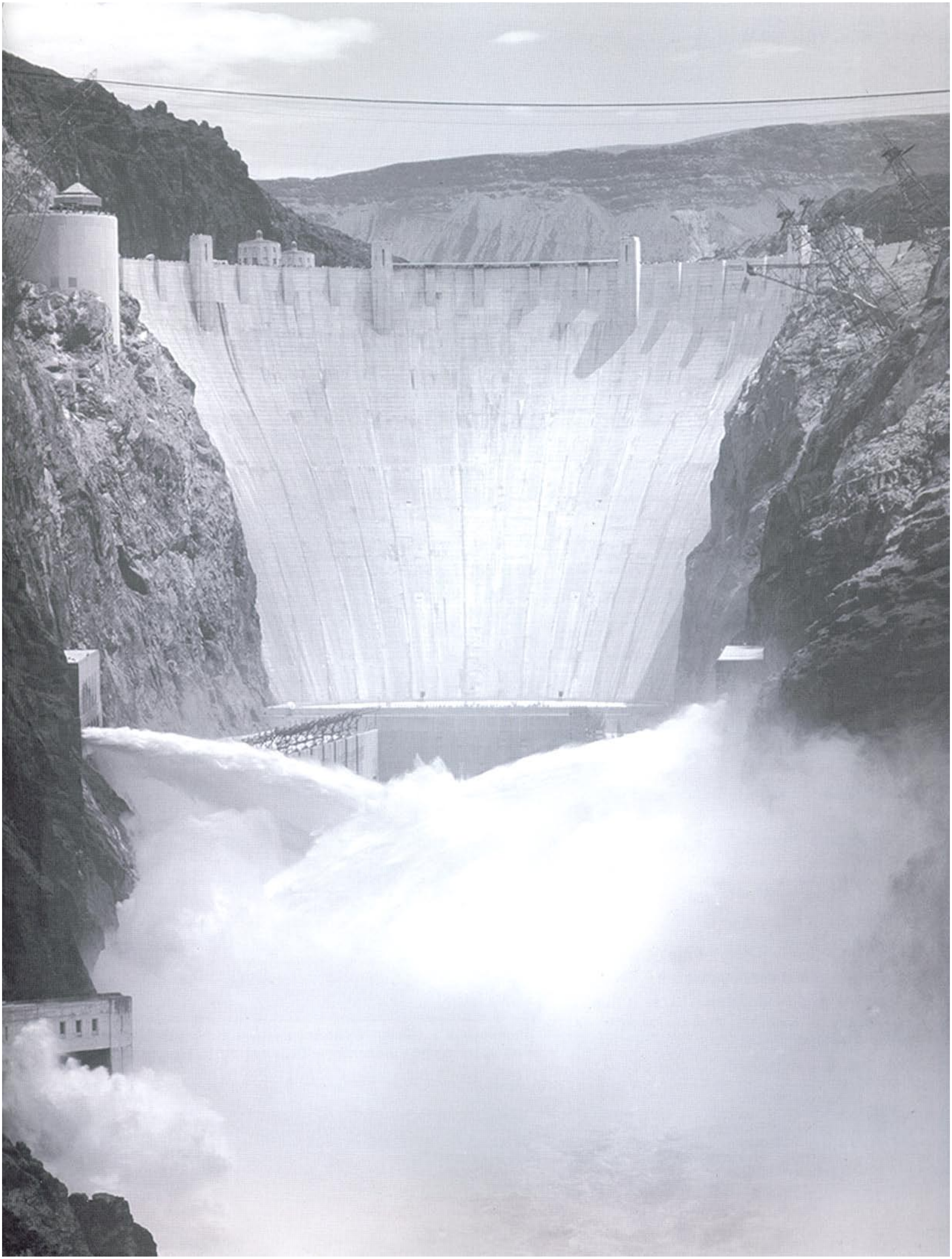


Foreword

Forging through the mostly arid southwestern United States, the Colorado River was once considered America's most dangerous waterway.

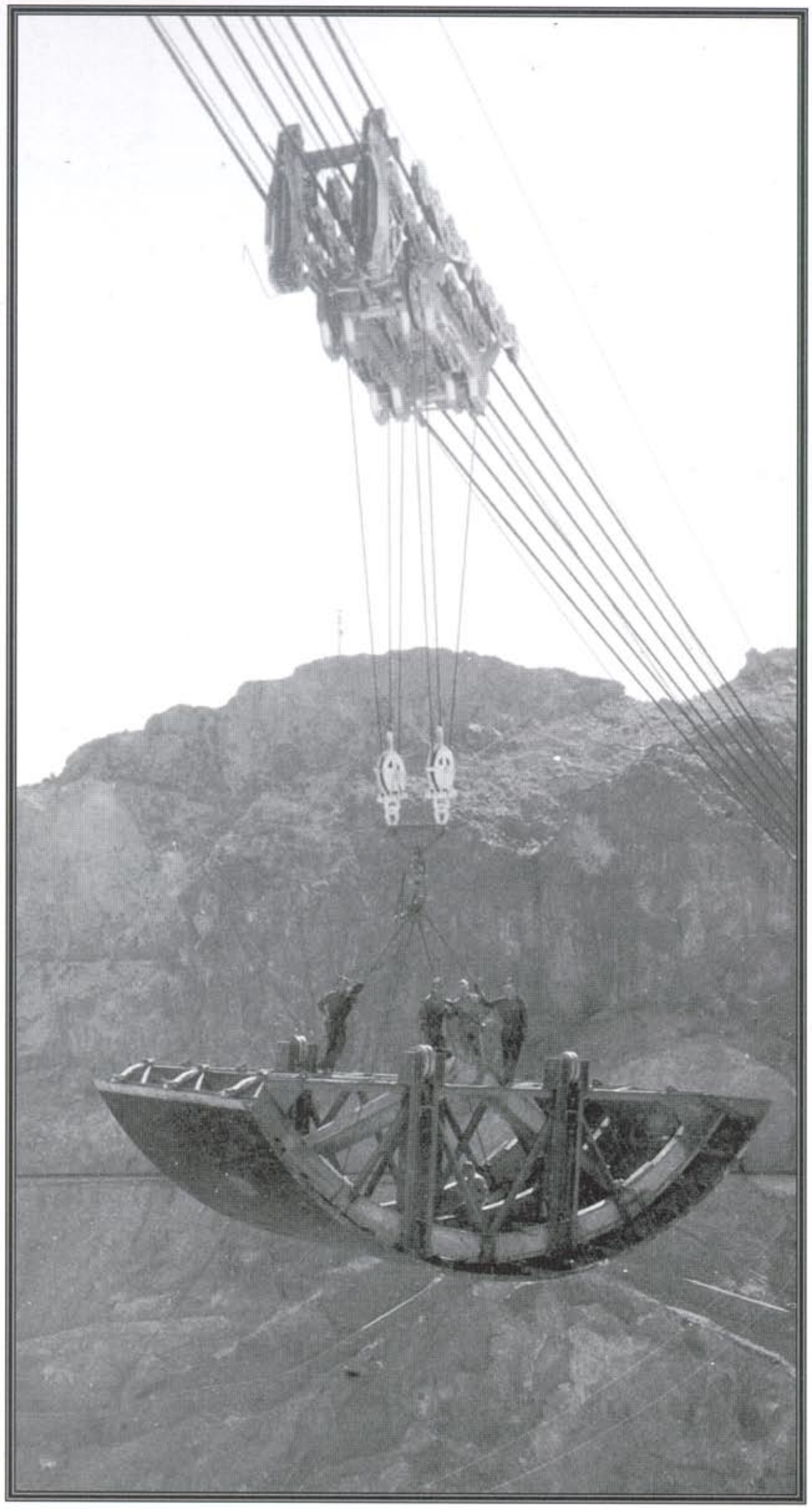
Today, the river is the region's most valuable resource. The change is the result of the essential need of the region's inhabitants for water, and their successful attempts to control the river.

American and European immigrant farmers in the area tapped the river to irrigate the desert soil. But the river's destructive spring floods too often destroyed their crops and property and, in most years, its flow dwindled away in summer's heat until all living things were faced with water shortages.

As settlement of the river's southern reaches began to increase in the late 1800s, so too did the demand for control and conservation of its waters.

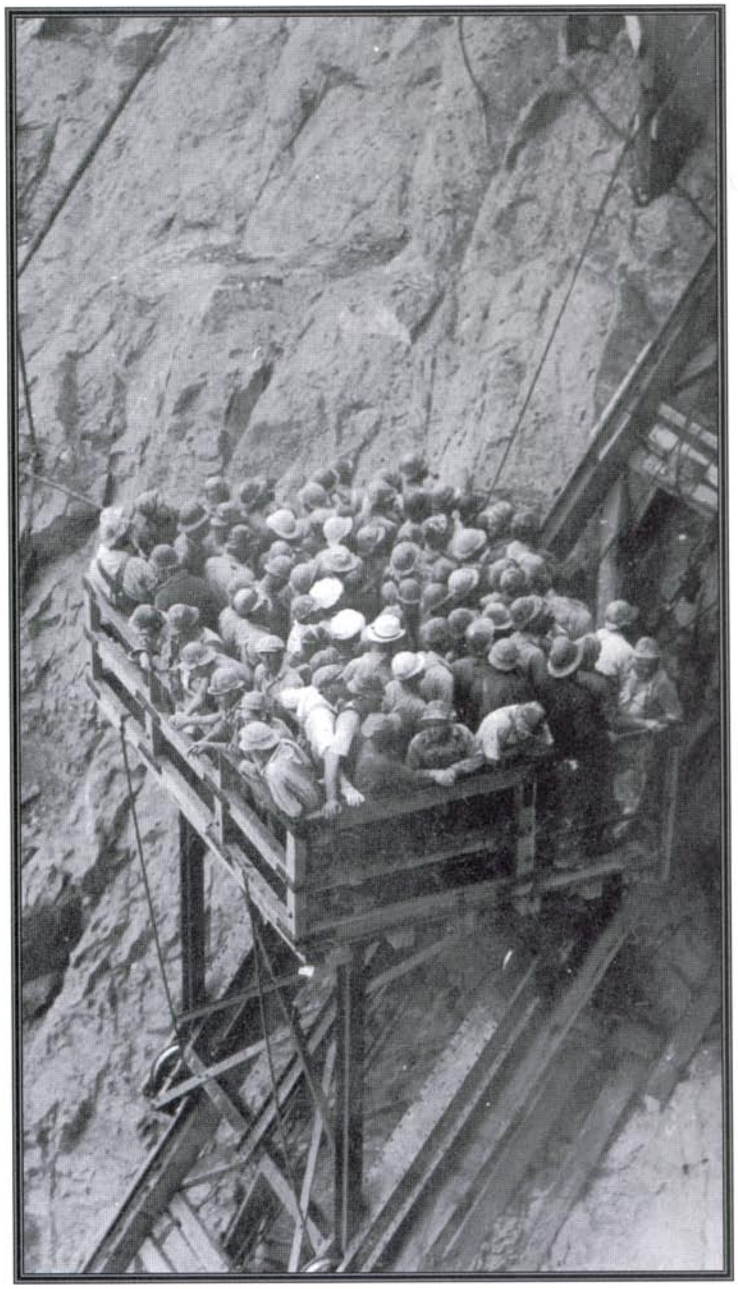
In the early 1900s, the Bureau of Reclamation was tasked to find a way to control and manage the Colorado. In response, after numerous investigations, Reclamation engineers set out to design and construct one of the most significant engineering achievements of all time, Hoover Dam.

The fascinating story of the dam's construction and the benefits it has brought are of worldwide interest. This is that story.



Hoover Dam's 150-ton capacity cableway, still in use today, lowers a penstock header tunnel lining form into the canyon in 1933.

Contents



Workmen ride an inclined rail skip from the Nevada rim of Black Canyon to the top of the dam in 1934.

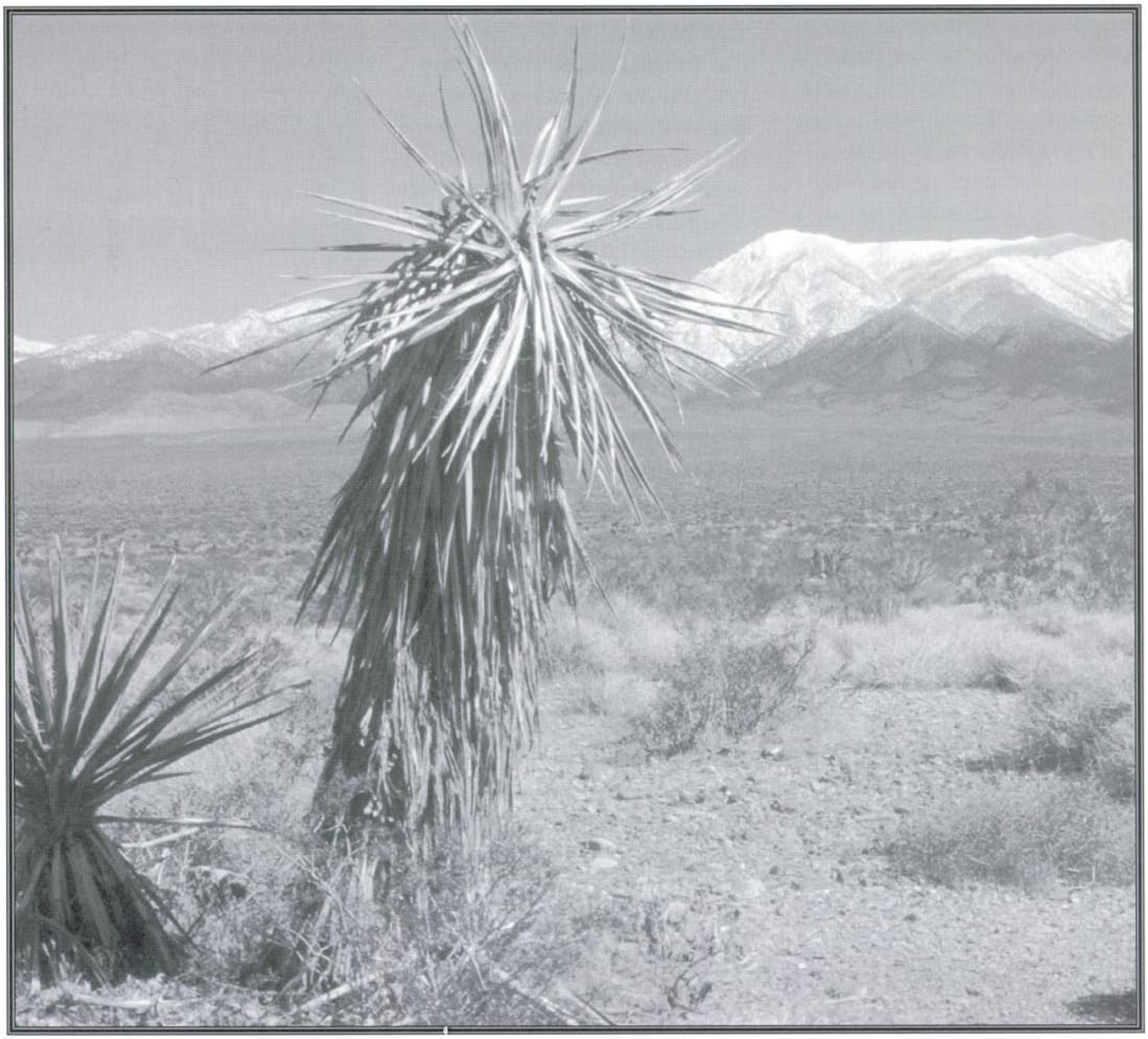
The Colorado River: Barrier to the West

The southwestern United States is a picturesque land of high mountains, deep canyons and scorching deserts. The Colorado River is its lifeline.

Originating among the snow-capped peaks of north-central Colorado, the river flows southwest and then south for more than 1,400 miles toward Mexico, and the Gulf of California. On its journey it is fed by several rivers, streams, and creeks, including the Green, San Juan, Little Colorado and Gila Rivers.

It drains 242,000 square miles of seven large Western states, or one twelfth of the U.S. continental land area, and 2,000 square miles in Mexico.

On it's southward journey, the river carries the reddish-brown sediments of the basin. These sediments provide the source for its name - Rió Colorado, or "red river." When it reaches the desert plains along its lower reaches, it flows through the driest regions in the United States and often the hottest, with temperatures as high as 125 degrees Fahrenheit (51.7 Celsius). The sun shines almost every day of the year and, except for devastating thunderstorms now and then, there is very little rain.



Snow capped mountains provide water for Southwestern lands.

The West: The Early Years

The history of water management in what was once northern Mexican Territory and is now the western United States stretches back to the beginning of civilization. The Hohokam, people who once lived in what is now Arizona, were diverting water from the Salt and Gila Rivers thousands of years before Spanish explorers traveled the region and settlers began tapping the river's water for the same purpose in the 1700s and 1800s. Exploration of the lower Colorado River basin by the Spanish continued periodically in the late 1700s with overland expeditions and upstream boat journeys that began in the Gulf of California. But the river blocked rather than helped exploration.

Travelers found it a dangerous obstacle and detoured hundreds of miles to avoid and bypass its canyons. The adventurous few who attempted to trace its course were challenged by extreme temperatures and a desolate landscape. Many died for their exploratory efforts.

In its lower reaches the river could be crossed at only a few points. When gold was discovered in California in 1848, many of those who flocked westward crossed the Colorado River near its junction with the Gila River in southwest Arizona.

In that same year, the U.S. and Mexico signed a treaty ending a two-year war. That and the Gadsden Purchase added the territories of New Mexico, Arizona, and California to the United States, encouraging further exploration of the unknown stretches of the lower Colorado River.

In 1857, Army Lieutenant J.C. Ives was ordered to proceed up the Colorado by boat as far as possible from the Gulf of California. Ives succeeded in bringing his steamboat, *The Explorer*, about 400 miles upstream before wrecking it on a submerged rock at the lower end of Black Canyon just south of where Hoover Dam stands today. His party then proceeded by skiff - boats about 12 to 15 feet long - through the canyon, past the point where Hoover Dam now stands, until he reached Las Vegas Wash, approximately 5 miles upstream of the dam.

Viewing the Colorado as a potential avenue of transportation, Ives believed it could be used to economically transport supplies to military outposts in New Mexico and Utah. However, of the Grand Canyon area, he said, *"The region last explored is, of course, altogether valueless. It seems intended by Nature that the Colorado River, along the greater portion of its lonely and majestic way, shall be forever unvisited and undisturbed."*

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1857-
Army Lieutenant
J.C. Ives

Twelve years later, Major John Wesley Powell successfully led a river expedition through the Grand Canyon of the Colorado, changing the river's fate forever. Powell's party traveled downstream from the Green River in Wyoming to the mouth of the Virgin River in Nevada. Powell and his companions, covering 1,000 miles of uncharted rapids and treacherous canyons, were the first documented, non-Native Americans to gaze from a boat up at the sheer walls of Grand Canyon and live to tell the story.

Major Powell saw the potential for large water projects to supply the lower river lands with a well-regulated supply of water. He realized that such an undertaking would require the assistance of the federal government. So, he began promoting the cause of federal reclamation of western lands.

Even before Lt. Ives and Maj. Powell explored the river, Spanish explorers and the indigenous people preceding them had seen the possibilities of using the river's water to irrigate the desert lands. The idea is reflected in several writings of the 1850s about southern California's Imperial Valley, but it was not until some 40 years later that actual development began.

In 1896, the privately owned California Development Company began constructing irrigation canals in the Imperial Valley, and the first Colorado River water reached its fields in 1901. The water flowed through a canal that looped through Mexico for about 60 miles, following the old Alamo River, one of the Colorado's overflow channels, but the vagaries of the river's flows could not assure a stable water supply for the valley's irrigated lands.

Eventually, the major political parties of the day endorsed the concept of settling and irrigating arid lands, but it took the leadership of President Theodore Roosevelt to implement the programs to achieve it. With the support of Roosevelt, federal reclamation became a reality with the enactment of the Reclamation Act of 1902, the centennial of which was observed and celebrated at Hoover Dam in June 2002.

Flood. . .and Drought

Like other western streams, the Colorado River usually ran high in the late spring and early summer. Fed by rapidly melting snows, the river frequently swelled to a torrent that swept over its banks and flooded land for miles around. Following these high water periods, the flow was often too low for diversion. These irregularities presented many difficulties for irrigators along the lower river in the early 1900s.

When it flooded, the sediment-laden river clogged diversion headworks and irrigation canals, which created serious water delivery and maintenance problems. The heavy flooding also led to high costs for building headworks and levees to handle the flows, or repair them after the floods subsided.

Low flows also caused difficulties. Without irrigation water, growing crops rapidly withered and died. Special diversion works were needed for these periods. The recurring low flows also limited the amount of land that could be successfully irrigated. Water diverted by users farther up the river caused shortages downstream, as well.

A particularly devastating and unseasonable flood hit the lower river in 1905, when a combination of flash floods and regular spring and early summer runoff caused the Colorado to change its course and flow uncontrolled into the Imperial Valley for more than a year.

The Imperial Canal, which originally carried Colorado River water to the Imperial Valley, diverted water from the river into California about 100 yards north of the U.S./Mexico border. The canal ran south from the diversion point, paralleling the Colorado for four miles. Then it turned west, away from the river, and followed the Alamo River channel, an old river course that led to the Salton Sink in southern California.

Southern Pacific Railroad tracks in the Imperial Valley were washed out during the 1905-1906 flood.

A spring flood in 1904 left the first four miles of the canal filled with silt. When the flood receded, not enough water could be channeled through the diversion works for irrigation. So a bypass channel was dredged directly from the river to the point where the canal made its westward turn.

No regulating gate was built for the bypass - it was supposed to be closed well before the next regular spring and summer floods. And winter floods had been so rare that there was no particular concern about one occurring. But the winter of 1904-05 proved an exception. By March 1905, three heavy floods had already come down the river. Following the third flood, measures were taken to close the bypass, but it was too late. A fourth and then fifth flash flood destroyed the dams intended to plug the bypass channel.

The flow from the river began eroding the sand and soft alluvial soil in the channel, making it deeper and deeper. Before long,

A rock and earth fill barrier was constructed at Imperial Canal inlet after the gates were destroyed in the 1906 flood.

the entire river had changed course, flowing through the bypass channel into the Alamo and New Rivers and on into the Salton Sink. The Colorado River was out of control.

For about 16 months the river wreaked havoc in the Imperial Valley, threatening lives, ruining farms and agricultural land, destroying highways and homes. The Southern Pacific Railroad, which was forced to move its tracks to higher ground, ultimately threw its resources and engineering skill into the battle. At a cost of nearly $3 million, the Colorado was forced back into its own channel on November 4, 1906, when the bypass channel was finally closed.

On December 5, a second flood came down the Gila and into the Colorado. It breached the levees that had been built, and again the river flowed to the Salton Sea through a break in the diversion canal. By this time, however, a technique for handling the unruly river had been developed. This break was closed February 10, 1907.

But the fight with the river didn't end. The continuing deposit of sediment at critical places required increasingly higher embankments. The costs of combating sediment and floods soon topped $500,000 a year, a large amount of money in the early 1900s, yet the threat did not stop. Without greater control over the Colorado, the situation would become intolerable.

A Bold Decision

Weary and confronted with constant cycles of flood and drought, the people of the Southwest appealed to the federal government for help. The responsibility for alleviating the situation fell on the Department of the Interior's Bureau of Reclamation. Operating under the authority of the Reclamation Act, the agency was charged with helping open the West through the development of irrigated agriculture.

Reclamation engineers clearly saw the solution to the problem - harness the river and control its flow. This would protect the low lying valleys against floods and assure a stable year-round water supply. But this would not be an easy task. Before a dam could be built, water rights issues between the seven Colorado River basin States had to be resolved.

Rights to Water

The most difficult legislative aspect concerned the equitable division of the Colorado's waters. The people living in the basin depended on this water wherever they lived; their right to use Colorado River water was far more valuable to them than their title to the land.

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Because of the laws governing water rights, the prospect of a large dam in the lower Colorado River Basin caused apprehension on the part of all the Basin States except for California.

The basic doctrine of water law recognized in all the Basin States, except California, was prior appropriation and use. In other words, the person or agency meeting the required preliminary legal formalities and first appropriating water for beneficial use had first right to the water.

California had a dual system of water rights. In addition to appropriation rights, the State also recognized riparian rights - the right of a landowner on the bank of a stream to use the water flowing past his property.
With construction of a large dam, California would be able to beneficially use a large amount of Colorado River water. The State seemed to have the financial resources and, obviously, the inclination, to proceed with a large irrigation development.

But there were concerns that not enough water would be available for all potential developments in the basin. The ideal solution, it appeared, would be for all the Basin States to agree in advance upon their respective rights. Without agreement, any large scale development on the Colorado would be impossible.

In 1920, representatives of the Governors of the Basin States met and endorsed a proposal for an interstate compact. In August 1921, President Warren G. Harding appointed Herbert Hoover, then Secretary of Commerce, as the Commission's federal representative.

The Colorado River drainage area is roughly divided into an upper and a lower basin which are about equal in area. This natural geographical division was used to simplify negotiations over the river's water. The "upper basin," it was agreed, should include the drainage area above Lee Ferry, a point one mile downstream from the mouth of the Paria River in northern Arizona. The "lower basin" would include all the drainage area below Lee Ferry.

The Commission members first tried to devise a compact that would divide the water among the individual States, but they could not agree on this proposition. Then Secretary Hoover made a proposal that cleared the way for agreement. Known as the Hoover Compromise, it proposed that the water be apportioned to two groups, the Upper and the Lower Basin States, and the division of water between the individual States of each basin would be left for future agreement.

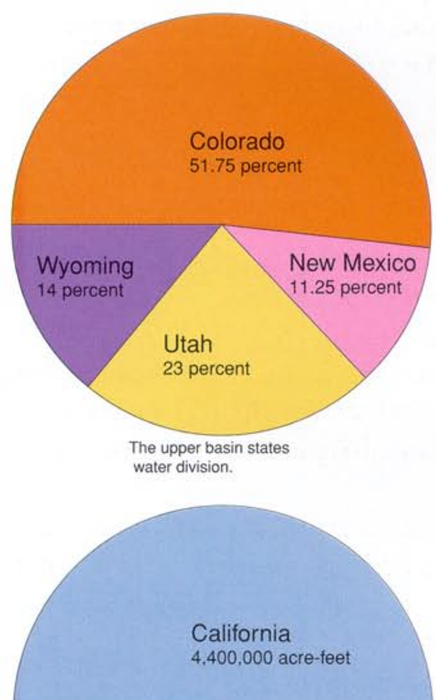
The resulting agreement, the Colorado River Compact, was signed by the Commission mem-

The Hoover Compromise proposed that the water be apportioned to two groups, the Upper and the Lower Basin States, and the division of water between the individual States of each basin would be left for future agreement.

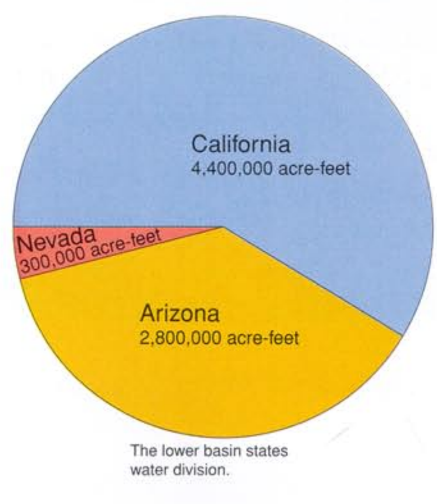
bers on November 24, 1922, in Santa Fe, New Mexico. For this reason, it is often referred to as the Santa Fe Compact. The compact was approved over a period of years by the Basin State legislatures and the United States. The Compact officially divided the Colorado River Basin into the Upper and Lower Basin divisions at Lee Ferry, which is on the mainstem of the Colorado River in northern Arizona, approximately 30 river miles south of the Utah/Arizona boundary.

The term "Upper Basin" means those parts of the States of Arizona, Colorado, New Mexico, Utah, and Wyoming from which waters naturally drain into the Colorado River system above Lee Ferry, and all parts of these States that are not part of the river's drainage system, but which may benefit from waters diverted from the system above Lee Ferry.

The term "Lower Basin" means those parts of the States of



The upper basin states water division.



The lower basin states water division.

Arizona, California, Nevada, New Mexico, and Utah, within and from which waters naturally drain into the Colorado River system below Lee Ferry, and all parts of these States that are not part of the river's drainage system, but which may benefit from waters diverted from the system below Lee Ferry.

The Colorado River Compact apportioned from the Colorado River system in perpetuity to the Upper Basin and to the Lower Basin, respectively, the exclusive, beneficial consumptive use of 7,500,000 acre-feet of water per year. In addition, the compact gave the Lower Basin the right to increase its annual beneficial consumptive use of water by 1,000,000 acre-feet.

This approach reserved water for future upper basin development and allowed planning and development in the lower basin to proceed.

The Compact did not apportion water to any State. This was left to the States in each Basin to resolve among themselves. On October 11, 1948, the Upper Basin States entered into the Upper Colorado River Basin Compact, which states how much of the Upper Basin's 7,500,000 acre-foot annual allotment each State is entitled to use.

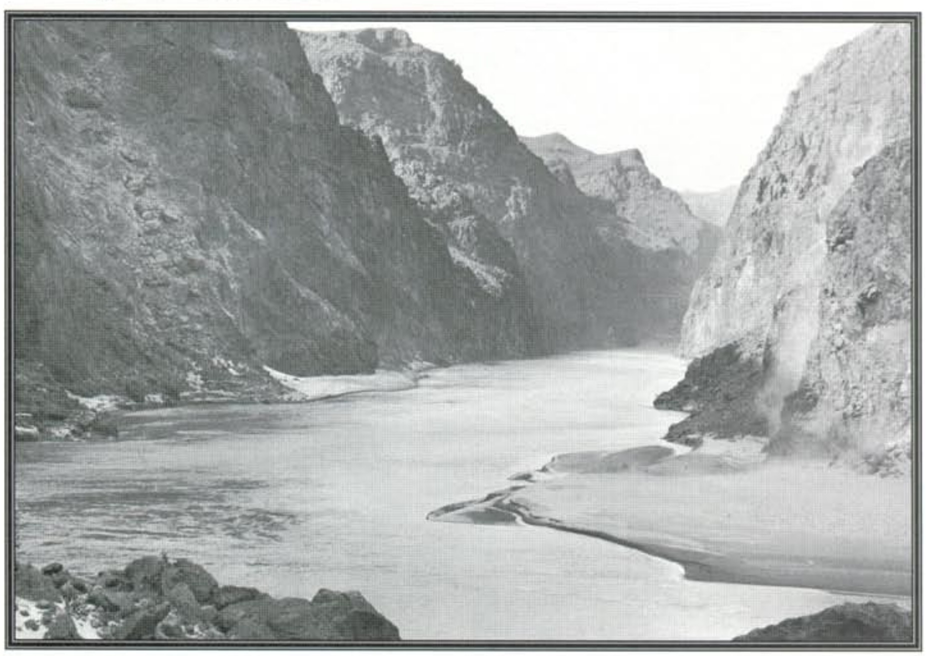
Although the Boulder Canyon Project Act of 1928 divided water among the three lower basin states and authorized them to enter into an agreement apportioning the Lower Basin entitlement, the States could not reach an agreement. In a suit filed before the U.S. Supreme Court in 1952, Arizona asked for a determination of how the river's water should be divided among the three States.

During the next eight years, a Special Master appointed by the Court heard testimony from the States and other interested parties. The Court issued an opinion in 1963 and a decree in 1964 stating that of the first 7,500,000 acre-feet of mainstem water delivered to the Lower Basin, California was entitled to 4,400,000 acre-feet; Arizona 2,800,000 acre-feet; and Nevada 300,000 acre-feet. On February 3, 1944, the United States and Mexico entered into a treaty, which guarantees Mexico 1,500,000 acre-feet of Colorado River water annually. This entitlement is subject to increase or decrease under certain circumstances provided for in the treaty.

Selecting a Site

While decisions to allocate the waters of the Colorado River were being made, Reclamation and U.S. Geological Survey engineers investigated 70 sites throughout the Basin in their search for a location to build a large dam that could protect the lower river from flooding and store enough water to minimize droughts.

Two excellent sites were found in the lower basin -- Boulder Canyon and Black Canyon near Las Vegas, Nevada. Each site offered a potential reservoir capacity of more than 30,000,000 acre-feet. However,



Hoover Dam Site

Rigger-rodmen working with topography survey party on Nevada side of Black Canyon at Hoover dam site.

"The overwhelming weight of opinion favors the Boulder or Black Canyon site. . . natural conditions at these sites are extremely favorable for the construction of a great dam at a minimum cost."

1928- The Senate Committee on Irrigation and Reclamation

each site also posed unprecedented engineering problems. Even nature seemed to conspire against the plan. Summer temperatures of 125 degrees Fahrenheit in the canyon floor, cloudbursts, high winds, and sudden floods battered the surveyors, but the work moved steadily ahead.

While investigations for a suitable damsite were underway, similar investigations were being conducted to find a route in southern California for a canal to carry water from the Colorado River to the Imperial Valley, an "All-American" canal that would not run through Mexico.

In 1921, Arthur P. Davis,

Bureau of Reclamation signs the contract with Six Companies, Inc., for the construction of Hoover Dam, powerplant, and appurtenant works. The $48,890,995.50 contract was the largest construction contract let by the United States government up to that time.

Director of Reclamation, reported the results of the preliminary Colorado River investigations to Secretary of the Interior Albert B. Fall. In February 1922, their joint Fall-Davis report was sent to the U.S. Senate, recommending that the federal government construct a high dam at or near Boulder Canyon on the Colorado River, and an "All-American" Canal along the U.S.-Mexico border.

In 1924, Reclamation's chief engineer, F.E. Weymouth, submitted eight volumes of precise data to the Interior Secretary. This "Weymouth Report," which represented two additional years of survey work and investigations, emphasized the feasibility of a dam at Boulder or Black Canyon.

In March 1928, the Senate Committee on Irrigation and Reclamation agreed that "The overwhelming weight of opinion favors the Boulder or Black Canyon site. Natural conditions at these sites are extremely favorable for the construction of a great dam at a minimum cost." A board of consulting engineers also reviewed the two lower basin sites. This board agreed with Bureau of Reclamation engineers that Black Canyon was the better choice in several respects: the depth to bedrock was less; the geologic structure was better; and a dam of lesser height would give the same reservoir capacity. Thus, the site of the proposed dam was settled.

The Boulder Canyon Project Act

On December 21, 1928, President Calvin Coolidge signed the Boulder Canyon Project Act into law. The Act:

- Approved the Colorado River Compact;

- Provided that in the event only six States, including California, should ratify the compact, it would become effective as a six State compact; and that California should agree to limit its use of water for the benefit of the other six States;

- Authorized construction of a dam at Black Canyon or Boulder Canyon with a special "Colorado River Dam Fund" to finance the construction of the project and authorized the transfer of $165 million from the U.S. Treasury to the fund;

- Authorized construction of the All- American Canal system connecting the Imperial and Coachella Valleys with the Colorado River; and

- Authorized $165 million for construction of the entire project.

The stage for construction was set. Work could begin. The Bureau of Reclamation had a job which would demand all the skill

Survey party in 1922 investigating Black Canyon site

and knowledge it had obtained in its quarter century of experience.

On September 17, 1930, Secretary of the Interior Ray Lyman Wilbur announced that a new dam, to be built in Black Canyon, would be called Hoover Dam. The dam was often called Boulder Dam because of the initially proposed site, but Congress affirmed the name Hoover to honor the then–President of the United States. Use of the name Boulder Canyon Dam and Boulder Dam occurred both during and after construction, but the name Hoover Dam was made official by Congress in April 1947.

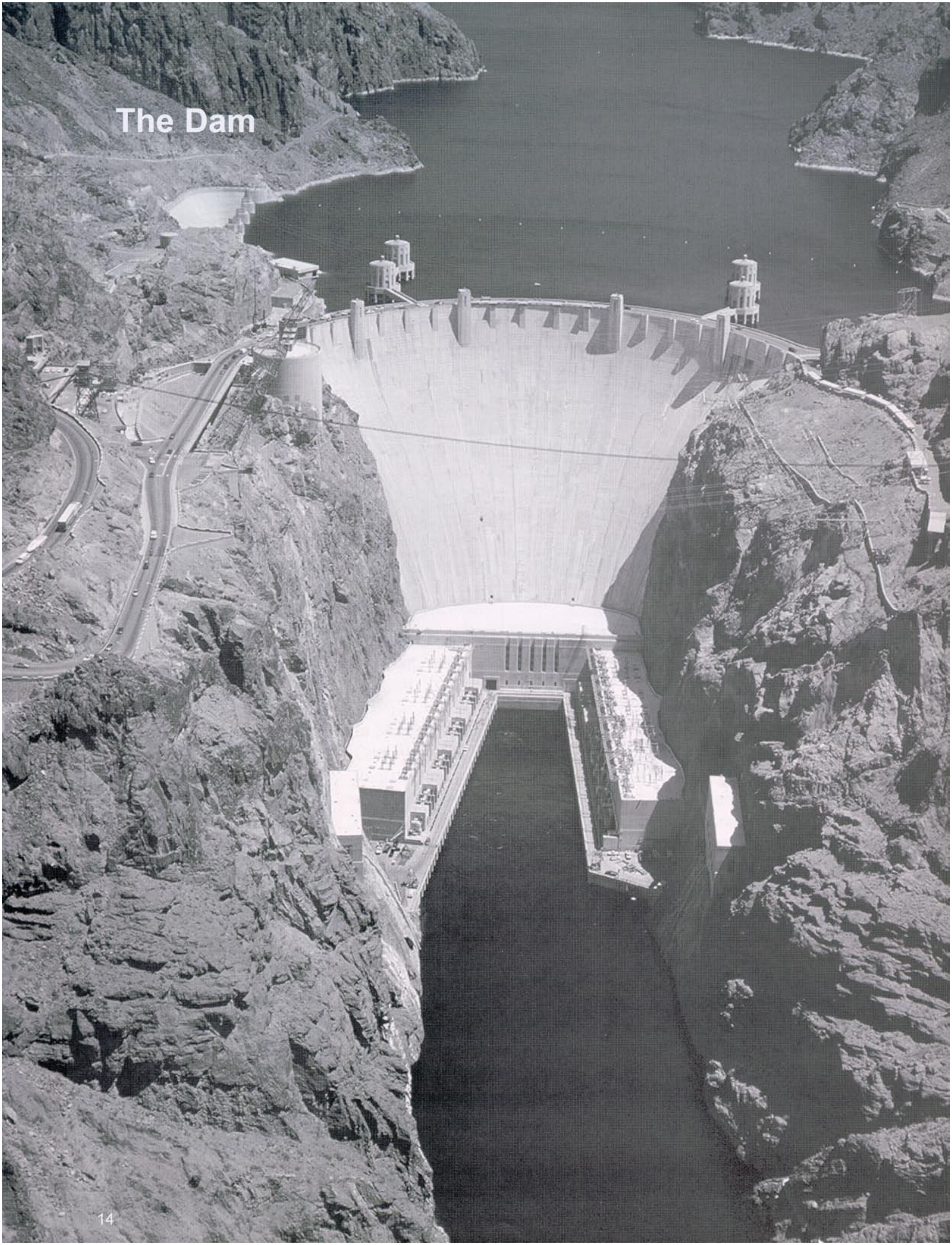
The Boulder Canyon Project Act of 1928 stated, in order, the purposes of the dam were to be:

1. river regulation, improvement of navigation, and flood control;

2. storage of water for irrigation and domestic use and satisfaction of present perfected rights; and

3. hydroelectric power generation.

The Dam



The Fundamental Problem

After Hoover Dam was authorized, the problem of construction was placed squarely before Reclamation engineers. To achieve the purposes set forth in the legislation, the low-lying valleys of Arizona and southern California had to be protected from the yearly threat of flood, and the annual spring runoff needed to be stored for later use. The reservoir created by the dam would have to be large enough to store the vast quantities of sediment annually carried downstream by the river. And a powerplant large enough to economically use the full flow of the river, serve growing power markets in the Southwest, and assure repayment of the project had to be provided.

To effectively harness the river and obtain the desired objectives, a dam more than 700 feet high would have to be constructed. The reservoir created by a structure this massive would safely store two years of the river's average annual flow. Measured by volume, the reservoir would be the largest artificial lake in the world. When filled to maximum, it would impound more than 31 million acre-feet of water, or enough to cover the State of Pennsylvania one foot deep.

As is often the case in undertakings without precedent, there was opposition. Some critics viewed the dam as a potential white elephant. Some believed it would take many years for the power market to absorb the energy produced by the dam. Others believed the fluctuating water levels of the reservoir behind the dam would disturb the earth's crust and stimulate destructive earthquakes. And some feared that if the dam failed it would cause utter destruction for the whole area south of Black Canyon.

There were serious problems to be solved. What contractor, for instance, would dare undertake such an enormous job? The proposed dam site was in a desolate region, where there were no transportation facilities or living quarters and where protection from the harsh and unfriendly natural elements did not exist. The nearby community of Las Vegas had only about 5,000 residents at the time, and Boulder City had not yet been established.

Not the least perplexing problem was the question of how to finance so large an undertaking. When plans for the construction of Hoover Dam began to take shape, Reclamation planners recognized that hydroelectric power could be produced and sold, and the revenues from these sales returned to the United States Treasury. Moreover, they believed enough power could be generated and sold to make the project self-funding. Power made construction of Hoover Dam possible.

As solutions were found to these problems and issues, exploration and preliminary work proceeded steadily. Engineering and design challenges were encountered, but none that could not be overcome. Geologic examinations revealed that faults which passed through the block of rock on which the dam was to rest had long since healed - the block was sound. The job could, and did, proceed.

Contract specifications for the work were completed in September 1930, six months ahead of schedule. On March 11, 1931, the Secretary of the Interior awarded the contract for construction of Hoover Dam to the lowest bidder, Six Companies, Inc., of San Francisco, California. The joint-venture Six Companies, known on the job as the "Big Six," was composed of the Utah Construction Co.; the Pacific Bridge Co.; Henry J. Kaiser and W. A. Bechtel Co.; MacDonald & Kahn Co., Ltd.; Morrison Knudsen Co.; and J.F. Shea Co. All members of the group were major western contracting firms. The bid for the dam itself was $48,890,995.50, the largest construction contract let by the federal government up to that time.

General view of Boulder City, February 1932.

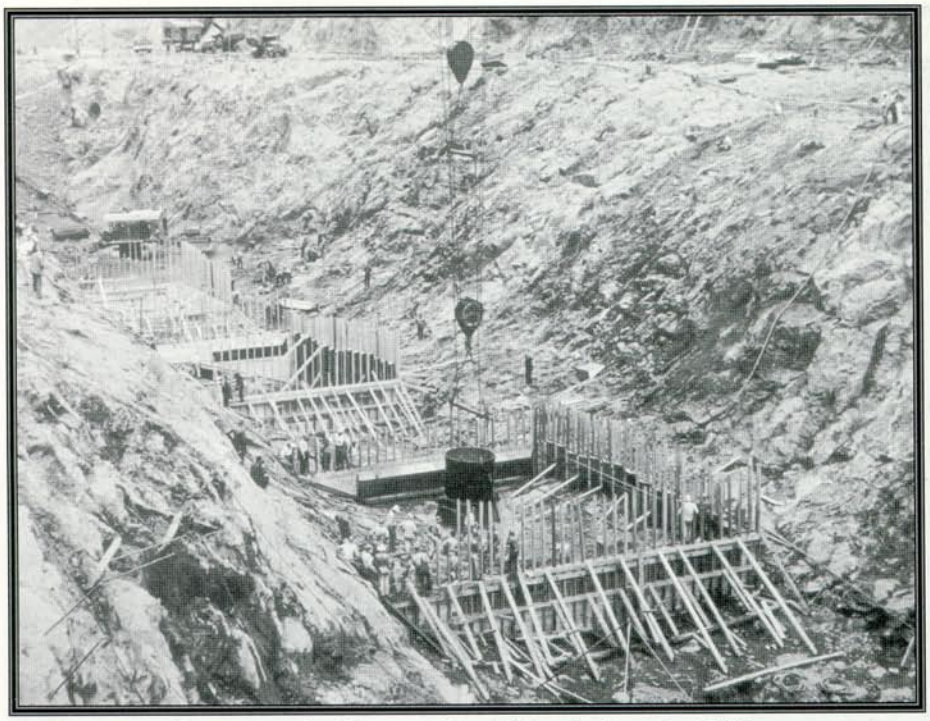
Preliminary Construction Steps

Before construction of Hoover Dam could begin, plans had to be prepared for living and working in the desert. Incomplete planning would mean costly delays in construction due to staffing and materials shortages. It was the responsibility of Reclamation engineers and the contractors to plan this project so well that nothing would be overlooked.

Construction materials would be required in quantities never before shipped to a single construction job. Additionally, a never before attempted project like construction of Hoover Dam demanded specialized machinery. And a plant that would provide the aggregate for the enormous volume of concrete needed for the job would be the largest of its type.

Finally, recruiting an army of laborers for the work presented special problems in spite of the fact that the Nation was in a depression. It was imperative that men qualified to do the work be selected, and that they and their families could be housed and fed throughout the years of project work.

The federal government and the contractors together employed 5,218 men at the peak of construction, with a gross monthly payroll of more than $750,000. The workmen ate at a mess hall that could feed 1,300 men at once. Single men were each charged $1.60 a day for meals, rooms, and transportation to and from the construction site. Married men rented unfurnished houses from the contractor for $15 to $50 a month.



First bucket of concrete for Hoover Dam placed, June 6, 1933.

The general plan for building Hoover Dam was to drive tunnels through the canyon walls around the dam site and divert the Colorado through the tunnels.

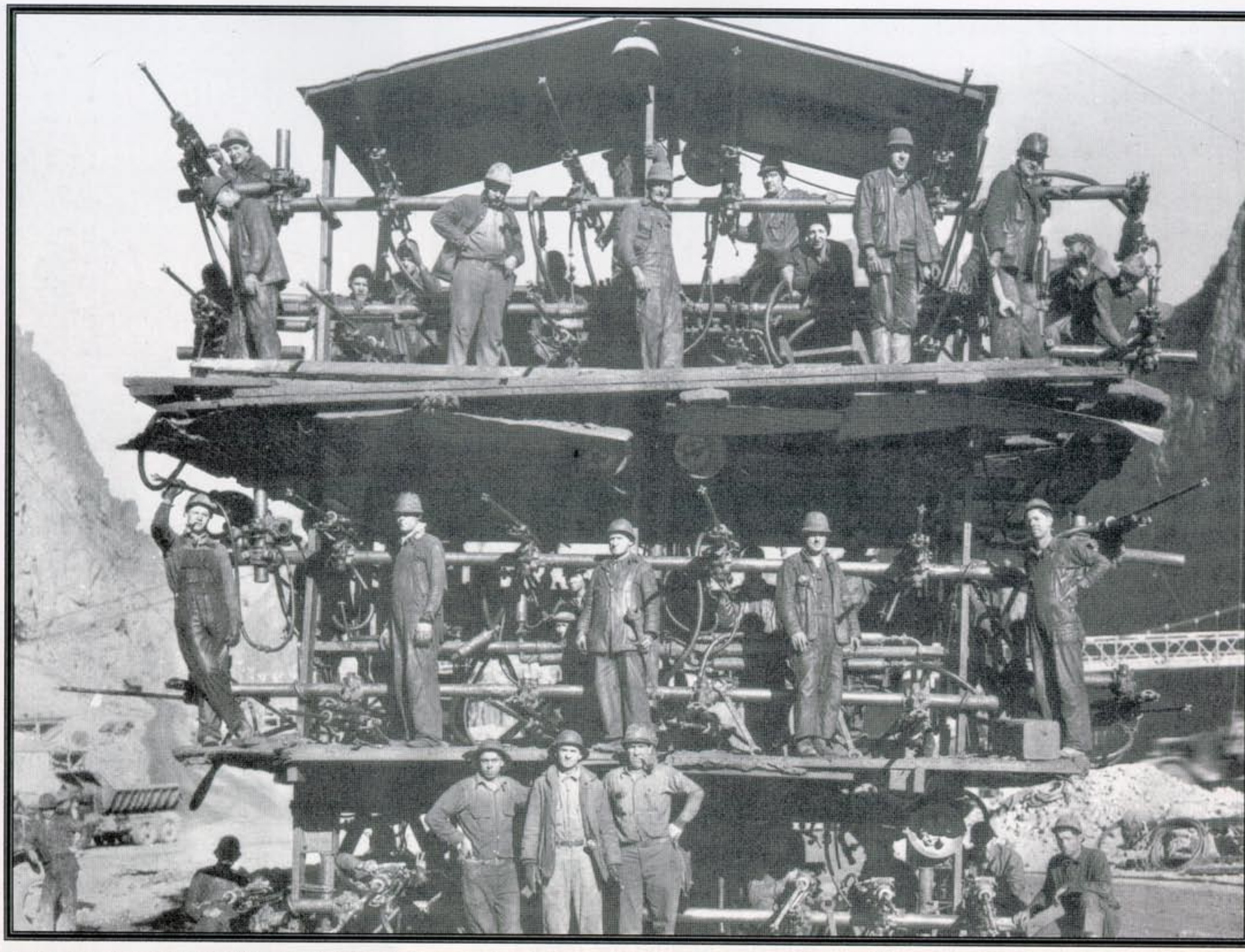
Plan of Attack

The general plan for building Hoover Dam was to drive tunnels through the canyon walls around the dam site and divert the Colorado through the tunnels. After the river was routed around the work site, workers would excavate the river sediments down to bedrock and build the dam and powerplant in the dry area.

The narrow width of the canyon, the spread of activity up and down the river, and the possible large fluctuation of the river's flow made the job of diverting the river a difficult one.

The engineers decided to drive four diversion tunnels, two on each side of the river. The four tunnels would be incorporated into the dam's operating works when they were no longer needed as diversion tunnels. The two outer tunnels would become outlets for the huge spillways, which would allow overflow water from the reservoir to be diverted around the dam. Penstocks, or large pipes, would be installed in the inner tunnels to carry water from intake towers in the reservoir the dam would create to the powerplant, or to the outlet valves that would release extra water from the reservoir in emergency conditions if necessary.

Tunnel excavation began in June 1931 and was completed in November 1933. The tunnels were constructed by traditional drill and blast methods. After batteries of compressed air drills penetrated 10 to 20 feet into solid rock, dynamite was loaded



A truck mounted drill rig, or "jumbo" was devised for use in the upper portions of the diversion tunnels. This rig is shown as it gets ready to approach the tunnel heading in April 1932.

into all of the holes. Each electrically fired blast, which shook the canyon walls, extended the tunnels an average of 17 feet and resulted in about 1,000 cubic yards of rock debris, which were loaded into trucks and dumped into side canyons.

During one 24-hour period, 256 feet of tunnel were driven, and the highest total for a single month was 6,848 feet. It required 3,561,000 pounds of dynamite, or 2.38 pounds per cubic yard, to remove the 1-1/2 million cubic yards of rock, enough to fill 150,000 dump trucks.

Each of the four tunnels was drilled and blasted to a 56-foot diameter, then lined with concrete three feet thick, resulting in a finished 50-foot-diameter tunnel. Their combined length is approximately three miles.

The River Is Turned

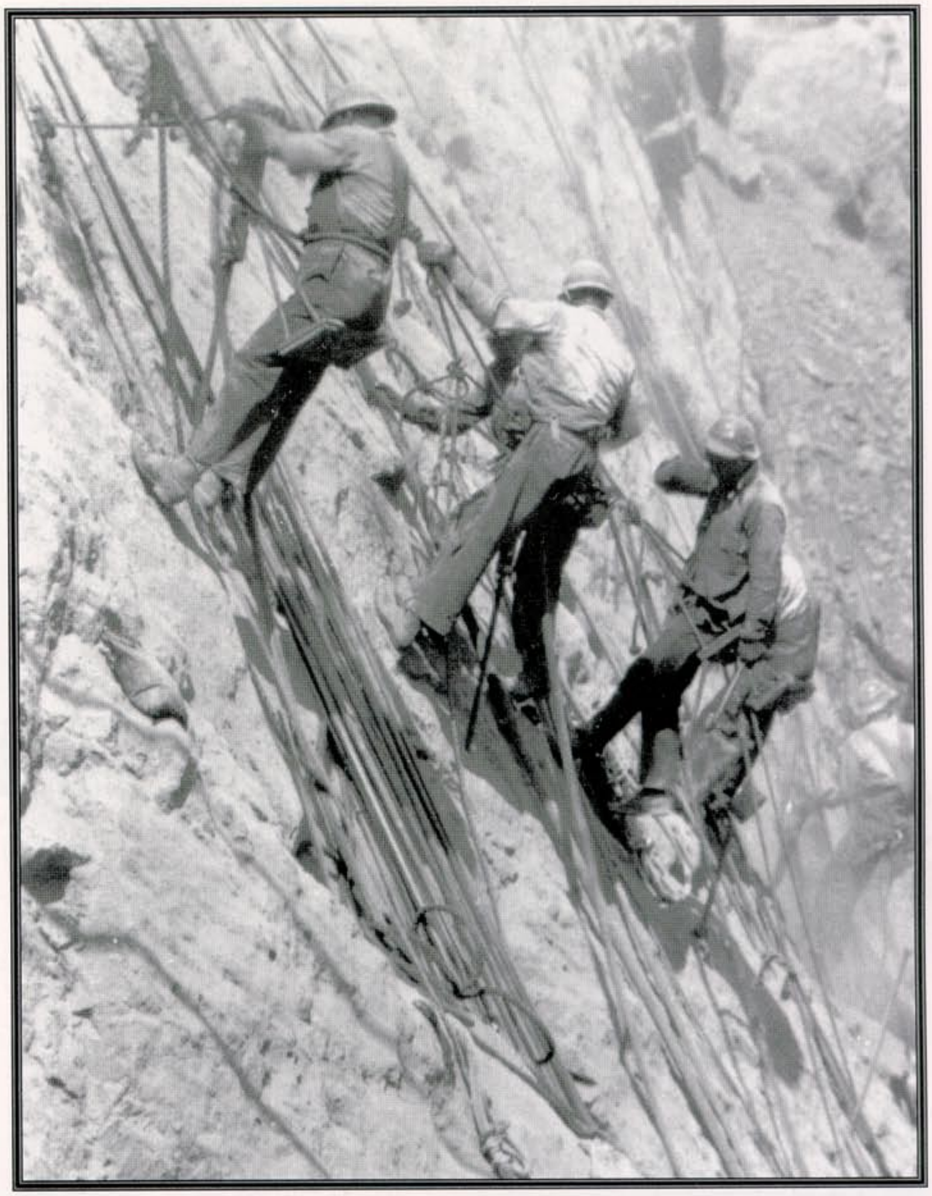
When the two Arizona tunnels were complete, the river's flow was diverted out of its historic channel.

To divert the river, a small earth and rock dam known as a cofferdam was needed just below the tunnel inlets.

At the same time, another cofferdam was built across the river channel below the dam site but above the tunnel outlets. This prevented the river from backing up into the construction area. After 24 hours of construction, the upstream coffer dam was high enough to block the channel and force the river through the tunnels. On November 14, 1932, the mighty Colorado River was diverted out of its historic channel and into the dam's concrete-lined diversion tunnels!

Now, excavation for the dam and powerplant foundation proceeded swiftly. Manning huge power shovels, draglines, and other equipment, men labored 24 hours a day, digging through the mud and silt of the river channel before reaching solid bedrock, 135 feet down. More than 500,000 cubic yards of muck were removed.

Six Companies' workers were also removing loose and projecting rock from the canyon walls to provide a smooth surface for the dam's abutments and to prevent rock falls. To reach the desired spots, "high scalers" either climbed up ropes or were suspended from anchors sunk in the canyon walls. These men swung in safety belts or "bosun" chairs, pendulum fashion, hundreds of feet above the river, and gouged at weak spots or drilled blasting holes. In this manner, nearly one million cubic yards of rock were dislodged from the walls of the canyon.



Highscalers on canyon walls removed more than one million cubic yards of loose rock.

With the river diverted and the foundation prepared, the contractor could now begin placing concrete. On June 6, 1933, the first bucket of concrete was placed, and the dam began rising from its foundation. At the top of Black Canyon a series of cableways were stretched across the canyon. Operated like massive cranes, these cableways delivered the huge buckets filled with eight cubic yards of concrete, each weighing 22 tons.

The buckets were swung out into the canyon and carefully lowered to the forms below. The work continued seven days a week, 24 hours a day, with a bucket of concrete arriving at each of the forms every two-and-one-half minutes. This work continued incessantly for two years, until the last concrete was placed in the dam on May 29, 1935. Approximately 160,000 cubic yards of concrete were placed in the dam per month. Peak placements were 10,462 cubic yards in one day (including some concrete placed in the intake towers and power plant), and slightly over 275,000 cubic yards in one month.

One of the innovative ideas used during the dam's construction was a method to cool the concrete. Without artificial cooling, it would have taken more than a century for the dam to lose the heat created by the setting concrete, and the concrete would have shrunk and cracked as it cooled.

The dam as seen from the control tower of the 150-ton cableway on Nevada rim of Black Canyon, December 1933.

One of the innovative ideas used during the dam's construction was a method to cool the concrete. Without artificial cooling, it would have taken more than a century for the dam to lose the heat created by the setting concrete, and the concrete would have shrunk and cracked as it cooled. The solution, Reclamation engineers determined, was to build the dam in pier-like blocks and cool the concrete by running ice cold water through pipes embedded in the blocks. As the blocks contracted and gaps appeared between them, cement grout was pumped into the breaches, making the structure monolithic–of one piece.

Building the Penstocks

When the time came to install the dam's penstocks - the huge pipes that would carry water from the reservoir to the powerplant through the canyon walls - the engineers faced a major problem.

The penstocks were to be built of nearly 3-inch thick plate steel pipe. Approximately 2-3/4 miles of this pipe, weighing more than 44,000 tons, would be needed. It was obvious that the pipe sections could not be built and shipped from plants in the Midwest or on the East Coast - standard railroad cars couldn't handle the weight, and the sections wouldn't fit through a normal railroad tunnel.

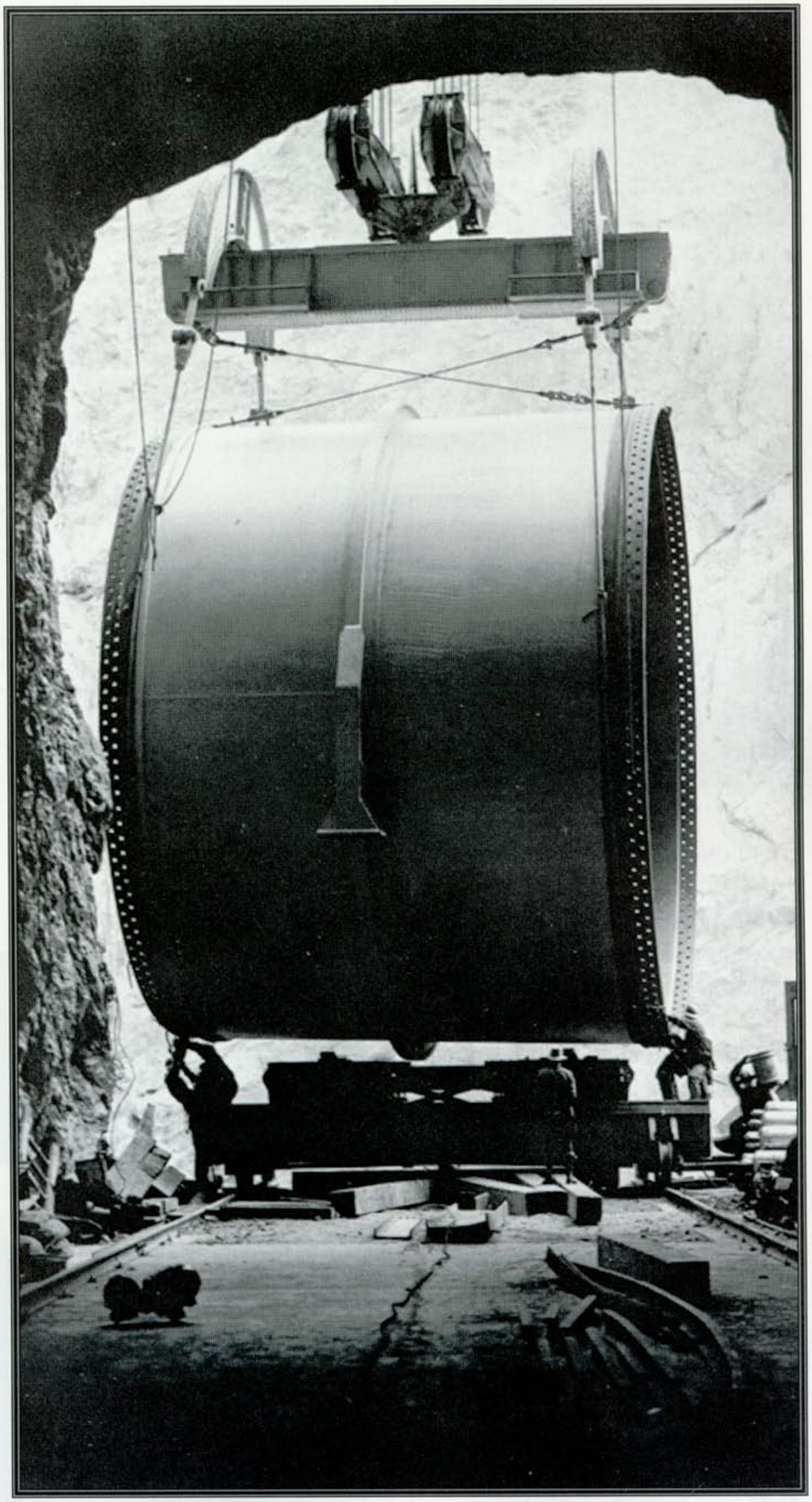
To resolve this problem, a plate steel fabricating plant was built along the construction railroad one-and-one-half miles from the dam site on the Nevada side of the canyon. Flat steel plates were shipped to the plant and made into the required penstock sections.

Special equipment was required for fabricating the pipe sections and for transporting them to the dam site. Planers, rollers, electrical equipment for welding the plates, and x-ray equipment for examining the welds was installed in the plant. A 200-ton trailer, pulled and controlled by two 60-horsepower crawler tractors, transported the heavy pipe sections from the plant to the canyon rim. From here the pipe was lowered to the portal of one of the construction passages by a 150-ton cableway. A specially–constructed car received each section and carried it to the penstock tunnel, where the pipe was then pulled into position by winches and hoists.

Except for the 8-1/2 foot outlet conduits, which were hot riveted, and a few miscellaneous sections that were welded, all pipe sections were joined with steel pins, the largest of which is 3 inches in diameter and weighs 13 pounds.

The River Harnessed At Last

As the dam, intake towers, and outlet works neared completion,



Penstock pipe sections were lowered into the canyon by a 150-ton capacity cableway, then carried into the tunnels on railway cars.

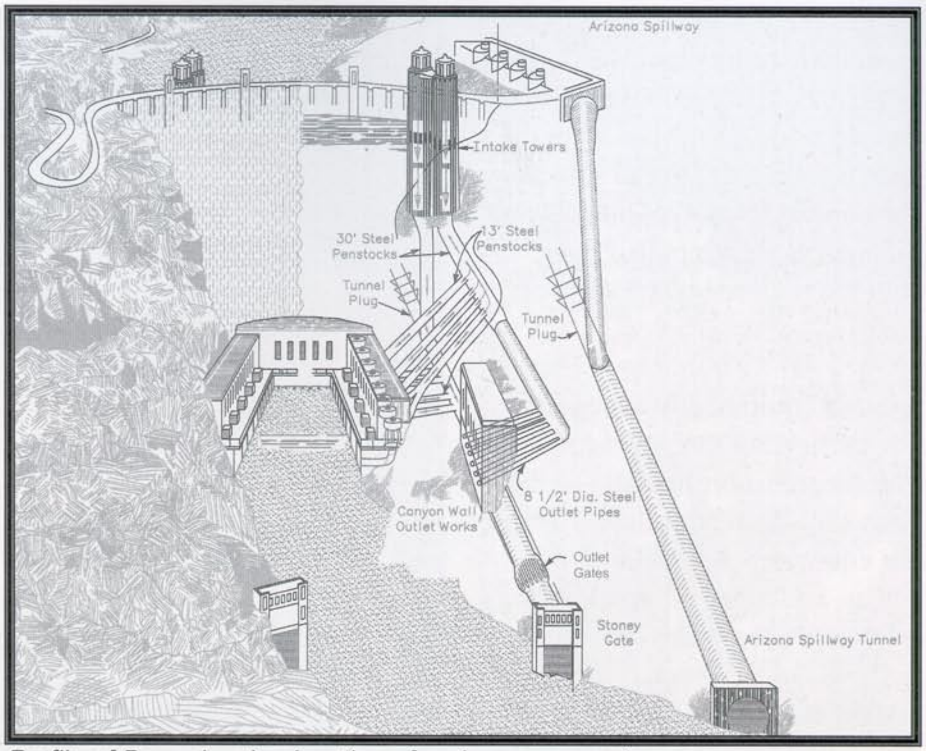
the upstream portions of the two inner diversion tunnels were plugged with concrete, and a steel gate was lowered at the outer diversion tunnel inlet on the Arizona side of the river, leaving one tunnel with gates and valves, so water could continue to be delivered downstream. On February 1, 1935, behind the unfinished dam, water started to rise. For the first time in history, the Colorado River had been harnessed and its waters began to form Lake Mead.

When the waters of reservoir had risen to the base of the intake towers, 260 feet above the riverbed, the remaining tunnel on the Nevada side was closed, and water deliveries began from the dam.

By midsummer the new reservoir held more than 3 million acre-feet of water and had a maximum depth of 271 feet. The muddy river was transformed into a lake of clear blue water sparkling in the desert sun as the sediment began settling in the reservoir. No longer would the lower basin of the river flow reddish-brown.

Concrete placement continued, and the crest of the dam was reached March 23, 1935. By the summer of 1936 all concrete – 3,250,335 cubic yards or 6,600,000 tons – was in place.

In less than two years, 5,000 workers had built a structure greater in volume than the largest pyramid in Egypt, which, according to Herodotus, an ancient Greek historian who lived more than 2,000 years ago, required 100,000 men working 20 years to complete.

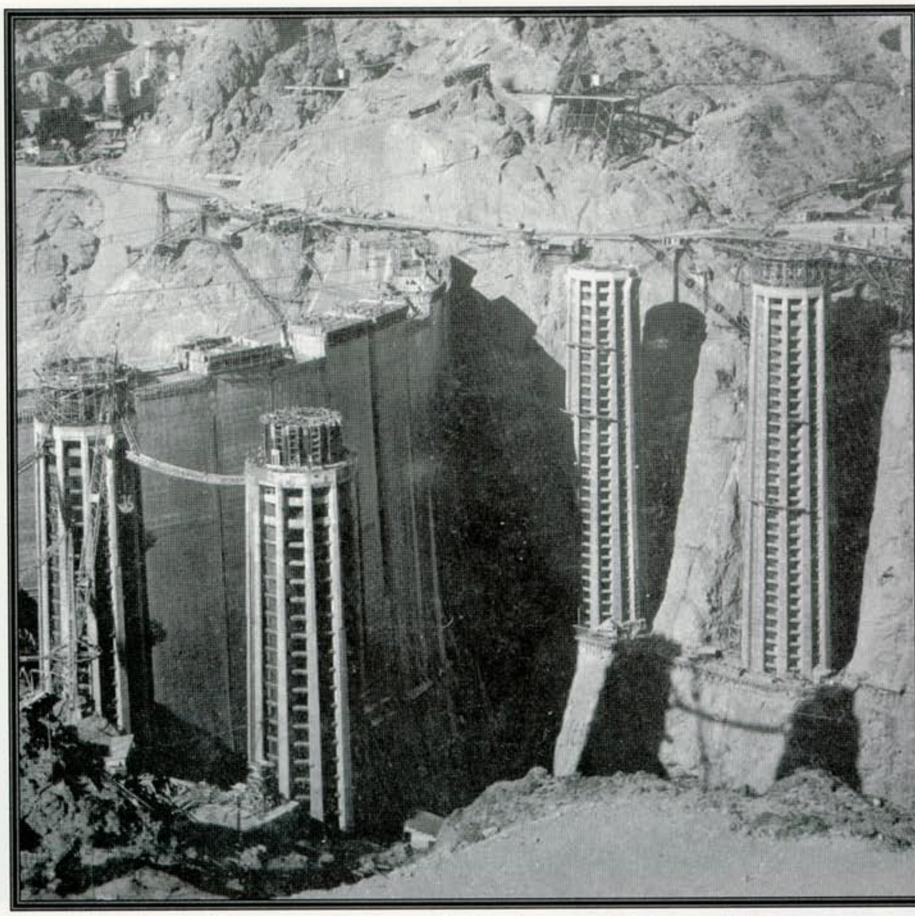


Profile of Dam showing location of major components.

The dam towers 726.4 feet above bedrock, a distance equivalent to the height of a 70 story building. It has a base thickness of 660 feet, or the length of two ordinary residential blocks; is 45 feet thick at the crest; and

Height of Hoover Dam compared to other structures.

In less than two years, 5,000 workers had built a structure greater in volume than the largest pyramid in Egypt, which, according to Herodotus, an ancient Greek historian who lived more than 2,000 years ago, required 100,000 men working 20 years to complete.



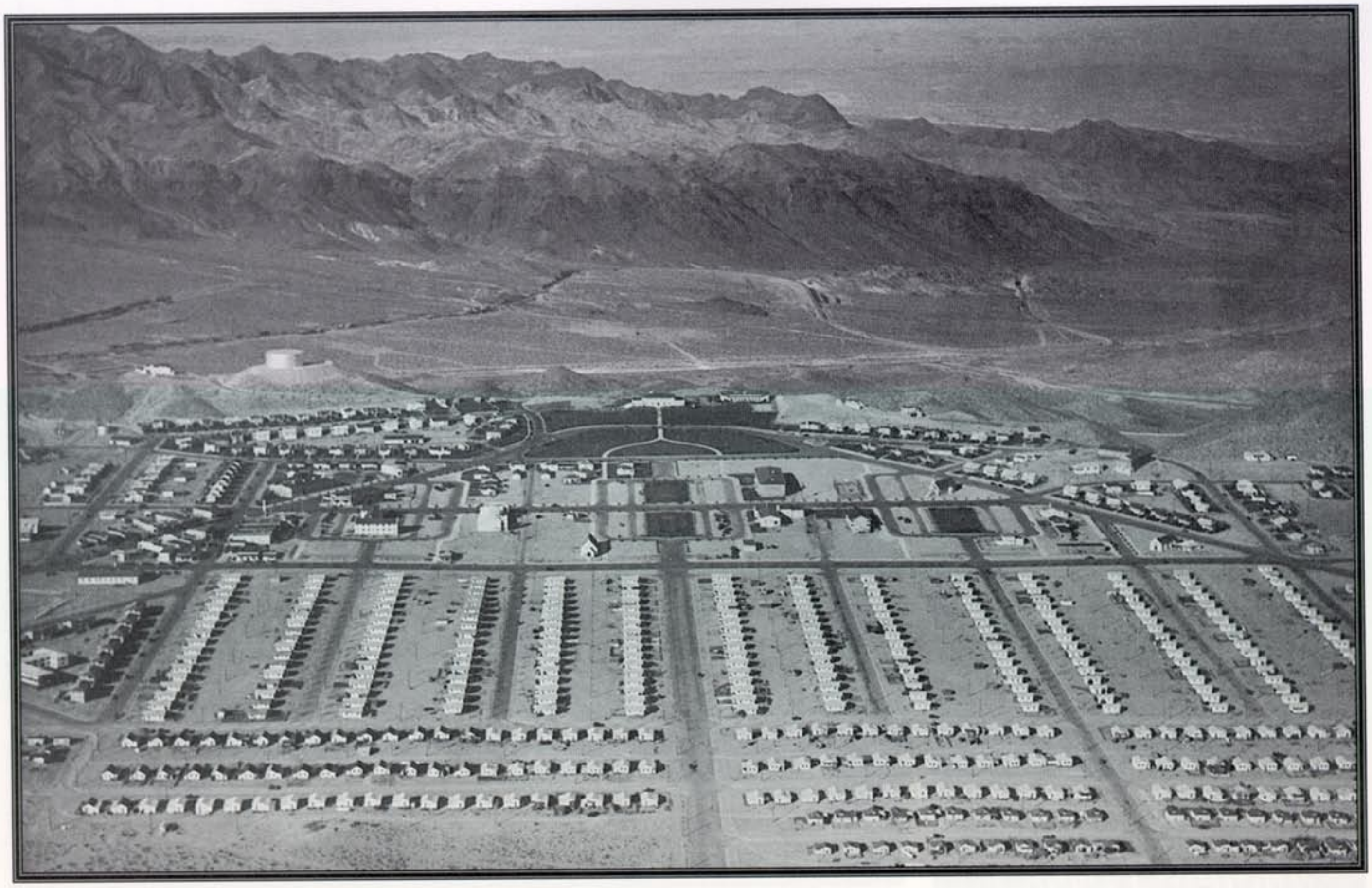
Upstream face of Hoover Dam and intake towers, February 1935.

stretches 1,244 feet or nearly a quarter of a mile between the Nevada and Arizona walls of Black Canyon.

The Government's contract had given Six Companies, Inc., seven years to finish the job. Using efficient personnel, innovative techniques, the finest equipment of the time, and detailed planning before the start of construction, the company completed the contract two years ahead of schedule.

With its completion, Hoover Dam and its powerplant, which are operated by the Department of the Interior's Bureau of Reclamation, were now permanent assets that had been added to the Nation's economy. The years of study, the plans, and the blueprints had materialized into lasting structural achievement. And within a few short years, far more quickly than anyone expected, Hoover Dam amply demonstrated its economic and social worth to the Southwest and to the Nation.

In the summer of 1995, a major addition to the dam was completed and partially opened. A new visitor center and parking structure, in their first year of operation, welcomed more than 890,000 visitors. The visitor



Boulder City, December 1934

center is a 110-foot diameter circular concrete structure with a rooftop overlook. The five-story parking structure holds more than 400 passenger cars and 20 buses. Also located there are a gift shop and food concession.

Boulder City, Nevada

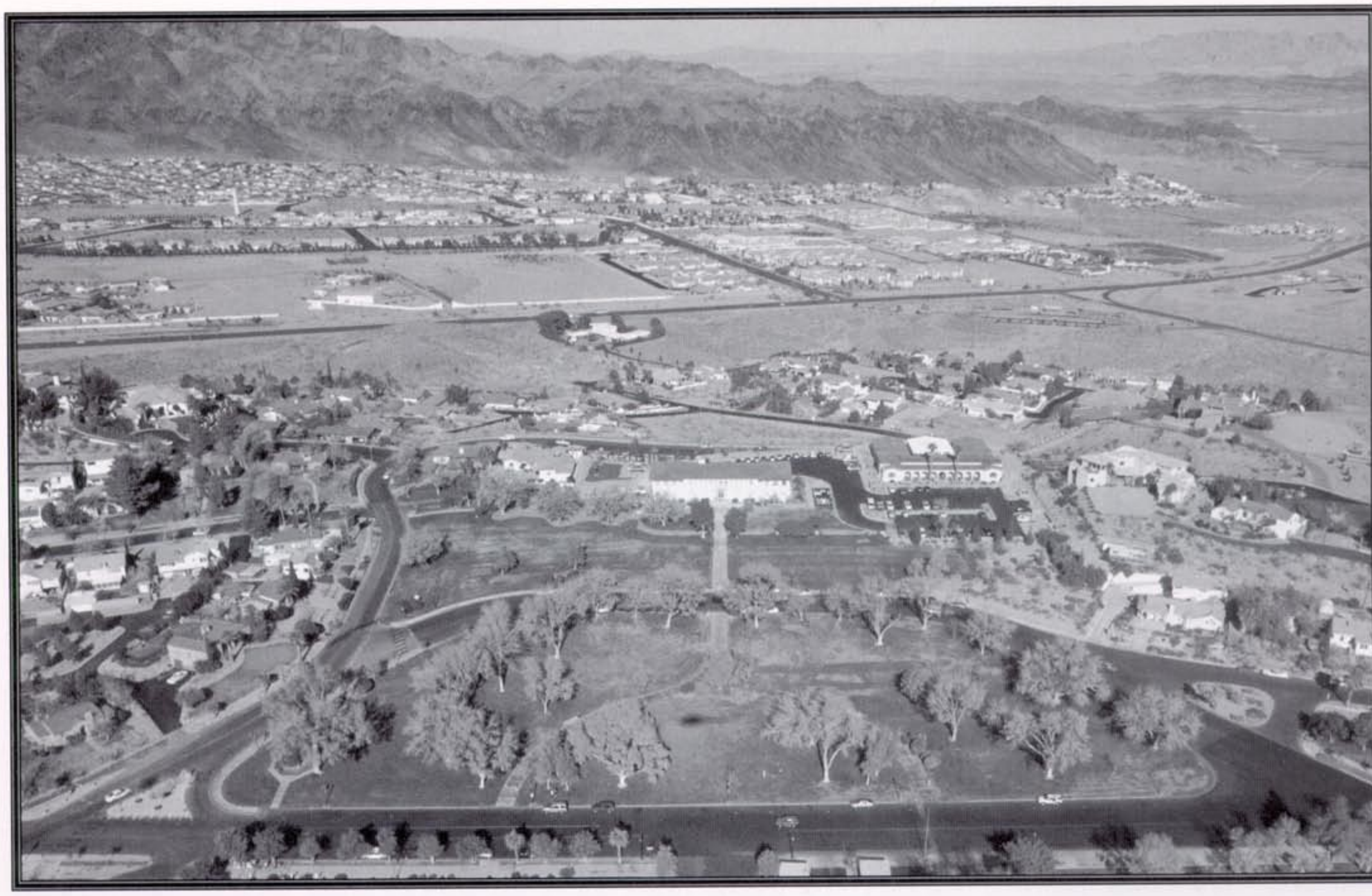
A major argument against constructing a dam in Black Canyon was that no facilities existed for housing the workers who would build the project. But engineers who conducted the preliminary surveys knew suitable living quarters would be vital to construction progress, and had planned a new town as part of the project.

A permanent camp in the vicinity of the dam was out of the question - the summer heat would have made living conditions unbearable. So the search began for an acceptable town site.

Several factors figured in the choice of a high plateau about seven miles southwest of the dam as the town site. With an elevation of about 2,500 feet above sea level, the plateau is more than 1,800 feet above the Colorado River, more than 1,200 feet higher than the crest of Hoover Dam, and nearly 500 feet higher than nearby Las Vegas. Temperatures recorded during the town site selection showed the climate would be more tolerable here than at other locations.

Named Boulder City after the Boulder Canyon Project, the new town was laid out in a triangle, with the apex pointing north. The Bureau of Reclamation's administration building, still in use today, was erected at this apex, with the city's principal streets fanning out from it.

The town site was on federal land, and title to all land was retained by Reclamation. Private citizens were granted land leases and permitted to erect buildings.



Boulder City today

No land taxes were levied, but the lessee was charged a ground rental by the federal government.

Boulder City began rising from the desert early in 1931. Streets were surveyed and paved, trees and lawns planted, and spacious parks laid out. Reclamation and the contractors building the dam constructed houses and other buildings. Private businesses were licensed and were soon in operation. Sewer, water, and electricity were provided. By mid 1932, more than 2,500 people resided in Boulder City. By 1934, with a population of slightly more than 6,000, Boulder City was Nevada's third largest town.

As the dam neared completion the contractors and many workers began moving to other jobs. The population gradually declined until, by 1940, fewer than 3,000 people were left in Boulder City. Some believed the decline would continue until the only remaining residents would be those concerned directly with operation and maintenance of the dam and its associated facilities.

Then came World War II. Although Hoover Powerplant was the world's largest in 1940, the demand for power in the industrial areas of the Pacific Southwest was so great that additional generating units were ordered. Workers were needed to install these units and, with other industries moving into the area, Boulder City began to grow once again.

In 1941, the Defense Plant Corporation began constructing a huge magnesium plant in Henderson, halfway between Boulder City and Las Vegas. This new plant brought thousands of workers and their families into the area, with resultant overcrowding in Las Vegas and Boulder City.

During World War II, Hoover Dam was under military protection, and all traffic was escorted across the dam.

When Boulder City was planned, only the requirements foreseen for the dam's construction were taken into account. Government buildings and some houses had been built as permanent structures, but many of the buildings were designed to serve during the construction period only. And all the original leases negotiated in 1931 were good only until 1941.

With Boulder City facing a housing shortage in 1941 and with the original leases expiring, there was an urgent need for additional housing and an extension of the leases then in effect. For the most part, all leases were renewed for another 10 years. And as it became apparent that the new structures would be permanent, some 20 year leases were issued.

Boulder City showed steady though not phenomenal growth. The Bureau of Reclamation built 100 temporary houses and 40 semi-permanent housing units in 1941-42, and added 16 permanent residences in 1949-50. The Defense Plant Corporation erected 60 houses and 26 apartment units, in addition to the considerable building being done in Boulder City by individuals.

As time went on, it became clear that Boulder City's development was not temporary. With growth and expansion there came an air of permanence and stability.

After World War II, all municipal facilities were expanded. In 1951, the Secretary of the Interior ordered that the city be separated from the Boulder Canyon Project and incorporated under the laws of Nevada. After several years of study and preparation, Congress approved the Boulder City Act of 1958, giving the Secretary permission to dispose of the city. The community's citizens overwhelmingly approved a charter providing for incorporation, which was effective October 1959.

In January 1960, the Bureau of Reclamation transferred ownership of some 33 square miles of land; municipal electric, water, and sewer systems; municipal

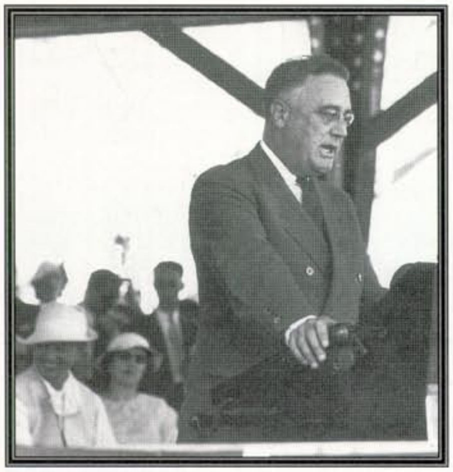
All-American Canal near interstate 10 in Southern California.

buildings; streets, sidewalks and curbs; parks and parkways, and other equipment and property to Boulder City's government. Reclamation retained only those facilities necessary for operation and maintenance of Hoover Dam and the agency's Lower Colorado Regional office.

All-American Canal

In 1940, the 85-mile long All-American Canal, authorized as part of the Boulder Canyon Project, was completed. Bringing water from the Colorado River to the citizens and agricultural industry of the Imperial Valley, it replaced the former canal, which served the same function, but traveled partly through Mexico (hence the name "All-American"). The canal, one of the largest in the United States, travels through one of the hottest and driest places in the country, and is the sole source of water for the nation's fourth most productive, as well as most arid, agricultural region.

The Benefits



President Franklin D. Roosevelt at dedication of Hoover Dam on September 30, 1935.

On September 30, 1935, less than five years after construction started, President Franklin D. Roosevelt dedicated Hoover Dam. *"This is an engineering victory of the first order,* he said, *"another great achievement of American resourcefulness, skill and determination. This is why I congratulate you who have created Boulder Dam and on behalf of the Nation say to you, 'well done'."*

Hoover Dam is significant beyond its physical proportions and the construction skills and techniques it represents. It is also significant because of the benefits it confers on the entire lower Colorado River Basin.

When the U.S. Senate Committee on Irrigation and Reclamation endorsed construction of Hoover Dam in March 1928, it made this prophecy, "A mighty river, now a source of destruction, is to be curbed and put to work in the interests of society."

Fulfillment of this prophecy has brought about several major benefits:

- Flood control - lives and property formerly at the mercy of the unbridled river are less likely to be destroyed by destructive floods.

- Water for irrigating millions of acres of some of the richest land in this country and thousands more in Mexico. The fertile valleys in the lower river basin had been under cultivation when Hoover Dam was built, but crop success or failure was dictated largely by the vagaries of the river.

- Water for domestic, industrial, and municipal use by the people of the Southwest.

- Extensive reduction of the damaging, clogging sediment that cost more than a million dollars yearly to remove from canals and irrigation ditches prior to the dam's construction.

- A major national land and water playground and recreation area.

- Fish and wildlife conservation.

- Generation of pollution-free, low-cost hydroelectric power, to help meet power needs in Arizona, California and Nevada.

"This is an engineering victory of the first order, another great achievement of American resourcefulness, skill and determination. This is why I congratulate you who have builded Boulder Dam and on behalf of the Nation say to you, 'well done'."

President Franklin D. Roosevelt at dedication of Hoover Dam on September 30, 1935.

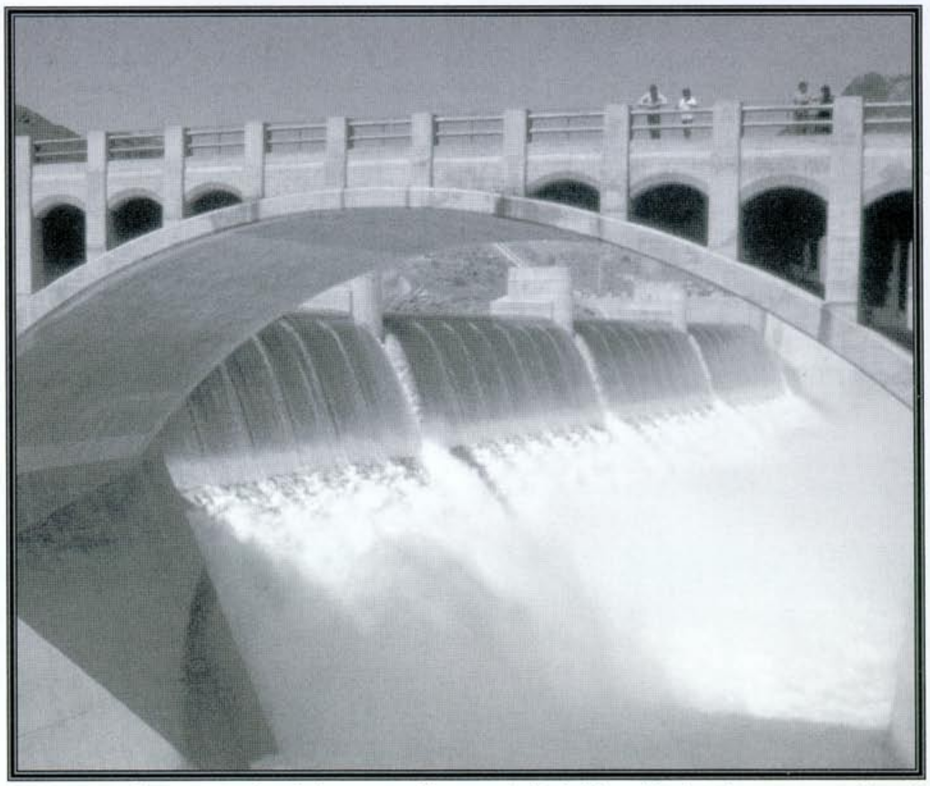
Controlling the Floods

Captured behind Hoover Dam, the waters of the Colorado River form Lake Mead, so named in honor of Dr. Elwood Mead, Bureau of Reclamation Commissioner from 1924 to 1936.

Lake Mead is the largest man-made lake in the United States. At maximum capacity, it can hold 28.537 million acre-feet of water, or nearly two years of the river's annual average flow. At full pool, the lake extends 110 miles upstream from the dam, has a maximum depth of 500 feet and a water surface area of 157,900 acres.

Flood control is the primary authorized purpose of Hoover Dam. With the help of upstream dams and other reservoirs, Lake Mead controls not only flash floods that may occur at any time, but also the high runoff that normally occurs each spring and summer.

Hoover Dam is operated for flood control purposes under criteria established by the Bureau of Reclamation and the U.S. Army Corps of Engineers. Fulfilling this function, and meeting the seasonal needs of storing or releasing water for irrigation and municipal use, causes the lake's level to fluctuate annually. From about February to June each year, the lake gradually lowers as water is released to meet downstream commitments. Between June and February, water released from Glen Canyon Dam upstream, coupled with lowered downstream demands, allows the lake's level to gradually rise again.



Water rushing over the Arizona spillway at 13,944 cubic feet per second and 4-1/2 feet above spillway gates, July 1983.

Because of this ability to adjust releases to changing conditions, and because levees and other protective works are maintained on the lower river's channels, the homes and highly productive farmlands in the low, flat valleys of southern California and southwestern Arizona are less likely to be flooded. However, flood control does not mean flood prevention.

During 1983, the Colorado River experienced record flows. On July 24 of that year, the lake reached its highest elevation ever, 1,225.85 feet above mean sea level. For several days, more than four feet of water flowed over the raised Nevada and Arizona spillway gates.

A Vital Water Supply

Hoover Dam provides a reliable, year 'round water supply for both irrigation and municipal uses in Nevada, Arizona, California, and Mexico. Millions of acres of some of the richest agricultural soil in the western hemisphere, and more than 20 million people in these states are served with dependable Colorado River water supplies through the Colorado River Aqueduct (California), the Central Arizona Project (Arizona), the Robert B.

Griffith Project (southern Nevada) , and other facilities and structures that divert and deliver the river's water.

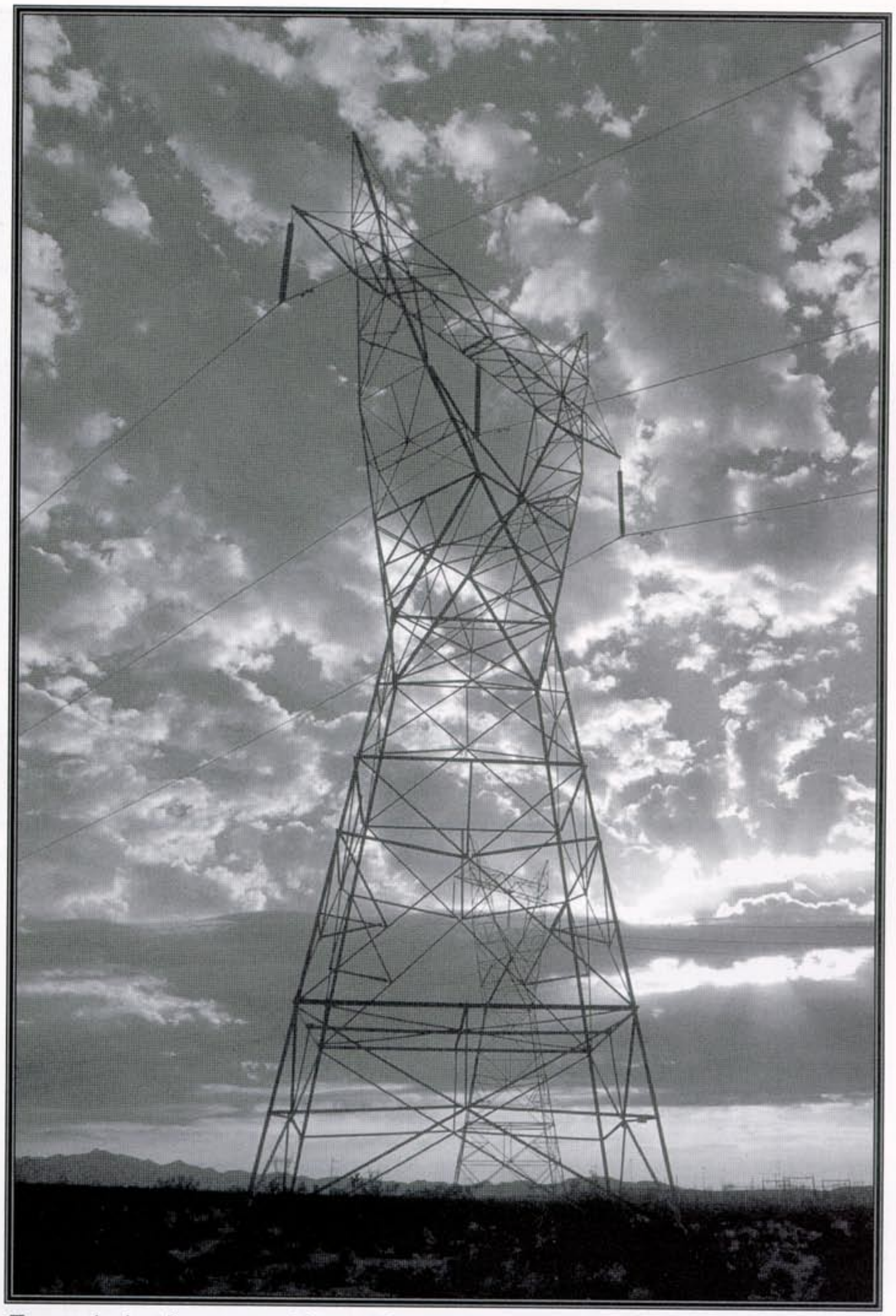
Hydroelectric Power

A major benefit of Hoover Dam is the pollution-free, low-cost electrical energy it generates.

The Hoover Dam Powerplant has 17 commercial generating units. These units were installed between 1936 and 1961, as the demand in the Southwest for electrical power increased. The powerplant has a rated capacity of 2,078 megawatts, and generates more than four billion kilowatt-hours of electricity each year or enough for about 1.3 million people. Hundreds of miles of transmission lines carry the power from the dam to farms, factories, pumping plants, refineries, and other destinations throughout southern California, southern Nevada and Arizona. This power helps conserve one of the world's most used non-renewable natural resources - oil.

The power generated by Hoover Dam is sold through long-term contracts to entities in Arizona, Nevada, and California. The initial contracts were from 1937 to 1987, the current contracts are from 1987 to 2017.

Power revenues have repaid the original construction costs, and still pay for operations, maintenance and replacement needs.



Transmission lines carry Hoover Dam power across the Nevada desert to southern California.

There are fifteen principal contractors who receive the energy generated at Hoover Dam. The energy is allocated to the State of Arizona through the Arizona Power Authority (18.9527 percent); Nevada through the Colorado River Commission of Nevada (23.3706 percent); Metropolitan Water District of Southern California (28.5393 percent); City of Burbank, CA (0.5876 percent); City of Glendale, CA (1.5874 percent); City of Pasadena, CA (1.3629 percent); City of Los

Angeles, CA (15.4229 percent); Southern California Edison Co., CA (5.5377 percent); City of Azusa, CA (0.1104 percent); City of Anaheim, CA (1.1487 percent); City of Banning, CA (0.0442 percent); City of Colton, CA (0.0884 percent); City of Riverside, CA (0.8615 percent); City of Vernon, CA (0.6185 percent); and City of Boulder City, NV (1.7672 percent).

A Nation's Playground

A fortuitous result of Hoover Dam's construction is the creation of the Lake Mead National Recreation Area.

The recreation area was created under a 1936 agreement between the Bureau of Reclamation and the National Park Service. On October 8, 1964, Congress gave the National Park Service direct administration of the area for recreational purposes. Today, the Lake Mead National Recreation Area is one of the Nation's outstanding attractions.

Lake Mead National Recreation Area, as originally established, included all the lands surrounding Lake Mead and extending downstream from Hoover Dam on both sides of the Colorado River for almost 40 miles. In 1947, the area was enlarged to encompass Lake Mohave and a short stretch of the river below Davis Dam, 67 miles down river from Hoover.

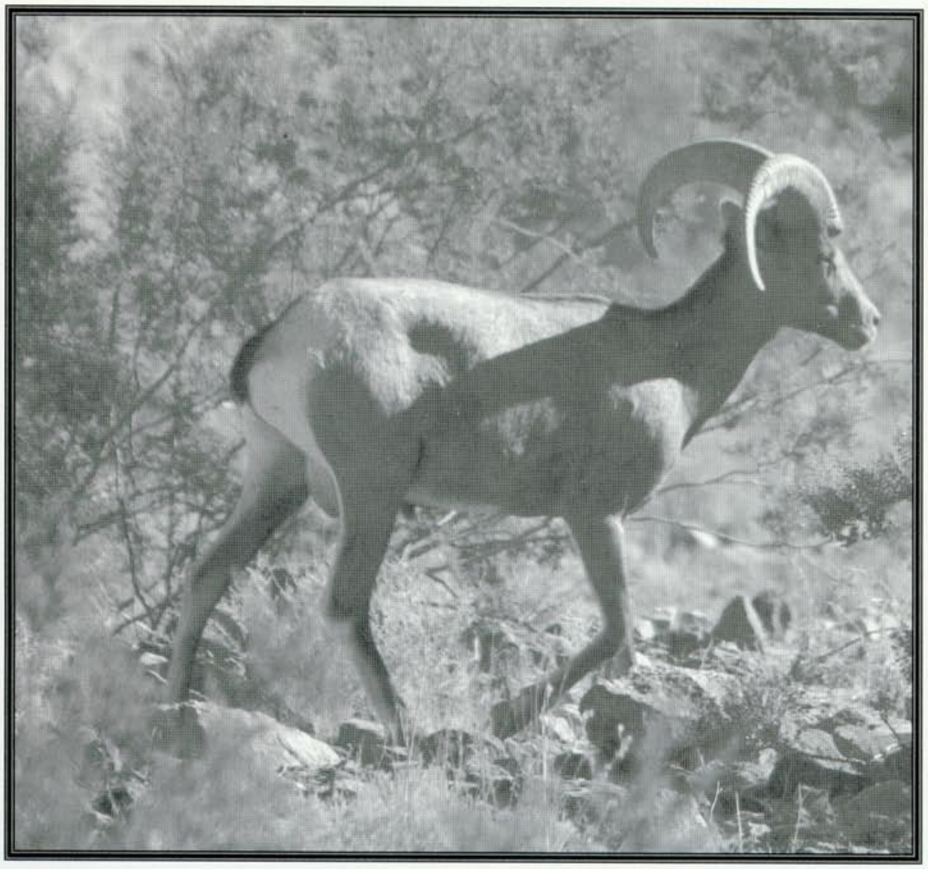
Lake Mead is a favorite recreation site for people from throughout the Southwest.

Visitors to the recreation area average in the millions per year. These visitors come from all parts of the United States and from many foreign lands. With their hundreds of miles of shoreline, Lakes Mead and Mohave afford wonderful possibilities for camping, swimming, boating, and fishing.

Temperatures are high during the summer, but relative humidity is extremely low. Three of North America's great desert ecosystems - the Sonoran, Mohave and Great Basin - meet in the recreation area, providing visitors unique opportunities to view a wide diversity of birds, reptiles and other wildlife.

In 1959, the Bureau of Reclamation, the National Park Service, and the U.S. Fish and Wildlife Service jointly built a fish hatchery at Willow Beach, Arizona, approximately 15 miles below Hoover Dam. At full operation it provided trout for the lower Colorado River, contributing much to the overall economic development and recreation facilities in the region. Today it has been modified to raise endangered fish species.

In 1973, Nevada's Department of Wildlife began operating its trout hatchery at Lake Mead. Trout from this facility were initially stocked in the lake. More recently, they have been stocked in Lake Mohave and in other waters throughout Nevada. Except for a closed and posted



Wildlife such as the desert bighorn sheep are plentiful in the Lake Mead National Recreation Area.

area extending one-half mile below Hoover Dam, and where Arizona and Nevada State regulations may forbid fishing during the winter trout spawning season, there are no restrictions on Lake Mead National Recreation Area fishing. Numerous marina facilities are located throughout the recreation area. See http://www.nps.gov/lame/.

Tourism

Hoover Dam itself is a major tourist attraction. Since 1937, when tours of the facility first began, more than 41 million people have taken a guided tour of the dam. Not included in the total are the hundreds of thousands of people estimated to visit the dam annually without taking a guided tour.

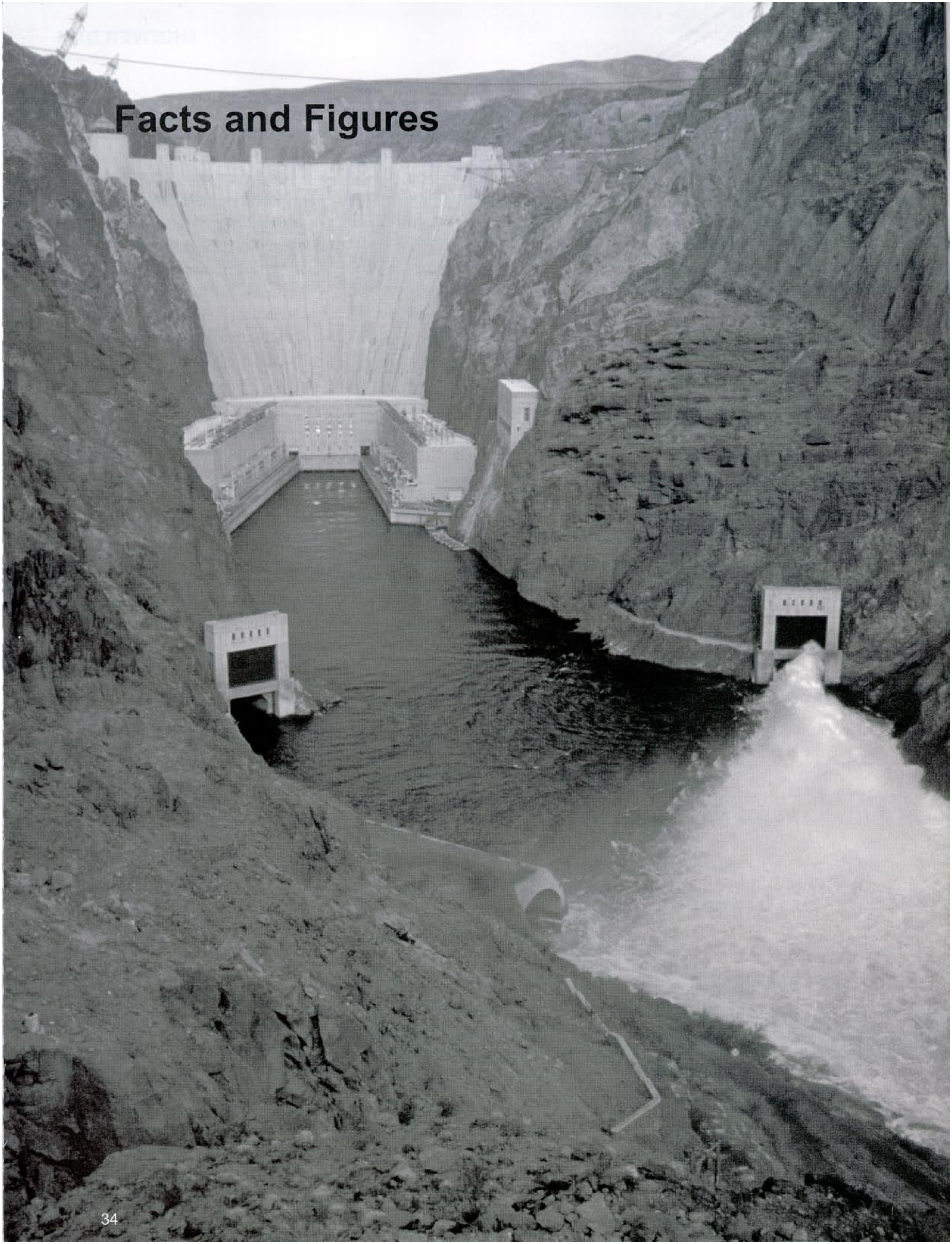
Wildlife Benefits

The reservoirs formed by Hoover and other lower Colorado River dams provide excellent habitat for game fish and favorable conditions for their propagation. In addition, these reservoirs serve as huge waterholes for mountain sheep and other wildlife of adjacent mountain and mesa uplands. It is known today that construction of the dam has had some impact on the downstream riverine environment. To help mitigate the dam's construction, several refuges were built along the river by the U.S. Fish and Wildlife Service.

Reclamation also participates in numerous other programs, such as the Native Fish Work Group, that focus on restoring and developing native riparian habitat, and preserving and increasing native fish and other species' populations.

The Lower Colorado River Multi-Species Conservation Program, the largest and most comprehensive of these programs, provides habitat and species benefits while ensuring the certainty of existing water and power operations.

Facts and Figures



Colorado River Water Allocation

What States have beneficial interests in the Colorado River system?

Those lying within the Colorado River Basin: Arizona, California, Colorado, Nevada, New Mexico, Utah, and Wyoming. Each of these States is party to the Colorado River Compact entered into in Santa Fe, New Mexico, on November 24, 1922.

How is the Colorado River Basin divided?

The Colorado River Compact divided the Colorado River Basin into the Upper Basin and the Lower Basin. The division point is Lee Ferry, a point in the mainstem of the Colorado River about 30 river miles south of the Utah/Arizona boundary. The "Upper Basin" includes those parts of the States of Colorado, New Mexico, Utah, and Wyoming within and from which waters naturally drain into the Colorado River system above Lee Ferry, and all parts of these States that are not part of the river's drainage system but may benefit from water diverted from the system above Lee Ferry.

The "Lower Basin" includes those parts of the States of Arizona, California, and Nevada, within and from which waters naturally drain into the Colorado River system below Lee Ferry, and all parts of these States that are not part of the river's drainage system but may benefit from water diverted from the system below Lee Ferry.

Aerial view of Hoover Dam.

How is Colorado River water apportioned?

The 1922 Colorado River Compact apportioned to each basin the exclusive, beneficial consumptive use of 7,500,000 acre feet of water per year from the Colorado River system in perpetuity. In addition, the compact gave to the Lower Basin the right to increase its annual beneficial consumptive use of such water by 1,000,000 acre feet.

How much water did the Colorado River Compact apportion to each State?

The Colorado River Compact did not apportion water to any State.

On October 11, 1948, the Upper Basin States entered into the Upper Colorado River Basin Compact, which apportioned use of the Upper Basin waters among them. The compact permits Arizona to use 50,000 acre feet of water annually from the upper Colorado River system, and apportioned the remaining water to the Upper Basin States in the following percentages: Colorado, 51.75 percent; New Mexico, 11.25 percent; Utah, 23 percent; and Wyoming, 14 percent.

The Lower Basin States of Arizona, California, and Nevada were not able to reach agreement. The Boulder Canyon Project Act of 1928 apportioned 4.4 million acre-feet to

California, 2.8 million acre-feet to Arizona, and 300,000 acre-feet to Nevada. In 1952, Arizona filed suit in the United States Supreme Court to determine how the waters of the Lower Basin should be divided. The Court issued a 1963 opinion that of the first 7,500,000 acre feet of main-stem water in the Lower Basin, California is entitled to 4,400,000 acre feet, Arizona 2,800,000 acre feet, and Nevada, 300,000 acre feet. The 1964 Decree upheld this opinion.

The U.S. Secretary of the Interior has contracted with the States of Arizona and Nevada and with various agencies in Arizona, California, and Nevada, for the delivery of Colorado River water. These contracts make delivery of the water contingent upon its availability for use in the respective States under the Colorado River Compact and the Boulder Canyon Project Act.

Does Mexico have rights to Colorado River water?

Yes. The United States and Mexico entered into a treaty on February 3, 1944, which guarantees Mexico 1,500,000 acre feet of Colorado River water annually. This entitlement is subject to increase or decrease under certain circumstances provided for in the treaty.

The Dam

Where is Hoover Dam?

Hoover Dam is on the Colorado River in Black Canyon about 30 miles southeast of Las Vegas, Nevada.

What does the Boulder Canyon Project include?

The Boulder Canyon Project includes Hoover Dam, Imperial Dam and the All-American Canal.

How high is Hoover Dam?

It is 726.4 feet from bedrock to the roadway at the crest of the dam, equal to a 72-story building.

How much does Hoover Dam weigh?

The dam weighs 6,600,000 tons, the equivalent of about one million African bull elephants.

What type of dam is Hoover?

The dam is a concrete arch gravity type, meaning the sheer weight of the concrete holds the Colorado River back, while the arch transfers the load or weight of the water into the rock walls of Black Canyon.

What is the maximum water pressure at the base of the dam?

The water pressure at the base of the dam is 45,000 pounds per square foot, or about 22.5 tons pressing against one square foot.

How much concrete is in the dam?

There are 3,250,000 cubic yards of concrete in Hoover Dam and another 1,100,000 in the powerplant and appurtenant works. This would be enough concrete to build a highway from San Francisco to New York City. If this amount of concrete was piled on a city block, it would rise 435 ft higher than the Empire State Building (1250 ft).

How much cement was required?

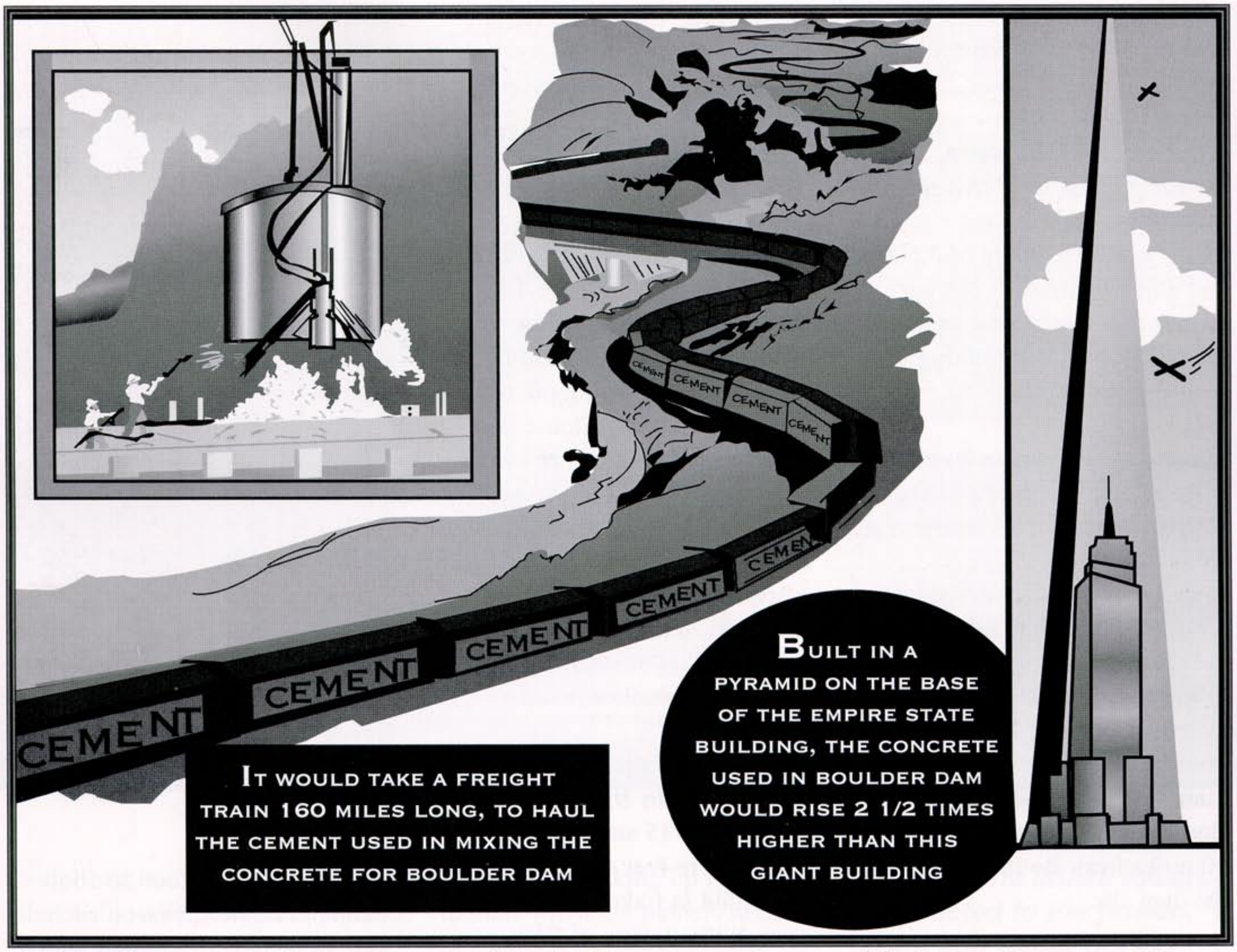
More than 5 million barrels or 855,000 metric tons. The daily demand during construction of the dam was from 7,500 to 10,800 barrels.

What was an unusual feature of Hoover Dam's construction?

The dam was built in blocks or vertical columns varying in size from about 60 feet square at the upstream face of the dam to about 25 feet square at the downstream face. Adjacent columns were locked together by a system of ridges (or "keys") along the joints. Concrete placement in any one block was limited to five feet in 72 hours. After the concrete was cooled, a cement and water mixture called grout was forced into the spaces created between the columns by the contraction of the cooled concrete to form a monolithic (one piece) structure.

What were the principal items of work?

The principal work was excavation of four diversion tunnels to divert the Colorado River around the work site, each tunnel extending approximately 4,000 feet through solid rock.



Additionally, upper and lower cofferdams were constructed to isolate the working area from water. The major structures that were built included the dam, powerplant, spillways, valve houses and intake towers.

What were the quantities of principal materials used in the dam?
Reinforcement steel, 45,000,000 pounds; gates and valves, 21,670,000 pounds; plate steel and outlet pipes, 88,000,000 pounds; pipe and fittings, 6,700,000 pounds or 840 miles; structural steel, 18,000,000 pounds; miscellaneous metal work, 5,300,000 pounds.

Did the Government buy these materials?
Yes.

What is the geology at the dam site?
The foundation and abutments are rock of volcanic origin geologically called "andesite breccia" or dam conglomerate. The rock is some of the hardest found.

What were the excavation depths from the river's low water surface to foundation rock?
In the upstream cutoff trench, 139 feet of material was excavated. The remaining excavation depths from low water surface to foundation rock average 110 to 130 feet.

How long did it take to build the dam, powerplant, and appurtenant works?
Five years. The contractors were allowed seven years from April 20, 1931, but concrete placement in the dam was

completed May 29, 1935, and all features were completed by March 1, 1936.

How many men were employed during the dam's construction?

There was an average of 3,500 and a maximum of 5,218 per month which occurred in June 1934. The average monthly payroll was $500,000.

What construction excavation work was necessary before operations started at the dam site?

(1) Construction of seven miles of highway connecting Boulder City to the dam site.

(2) Construction of 22.7 miles of railroad from the Union Pacific main line in Las Vegas to Boulder City and an additional 10 miles from Boulder City to the dam site.

(3) Construction of a 222-mile-long-power transmission line from San Bernardino, California, to the dam site to supply energy for construction.

Lake Mead

What is the reservoir's area?

About 156,800 acres or 247 square miles at water surface elevation 1219.6 feet.

How long and wide is the reservoir?

At elevation 1,219.6, Lake Mead extends approximately 110 miles up the Colorado River, and about 35 miles up the Virgin River. The width varies from several hundred feet in the canyons to a maximum of eight miles.

How much water will Lake Mead hold?

At elevation 1219.6, it would contain 25,876,000 acre-feet of water. An acre-foot is the amount of water required to cover one acre to a depth of one foot, or 325,851 gallons. The lake can store the entire average flow of the river for two years, or enough water to cover the State of Pennsylvania to a depth of one foot. (For operational purposes, Lake Mead is considered "full" at elevation 1,219.6 feet above sea level.)

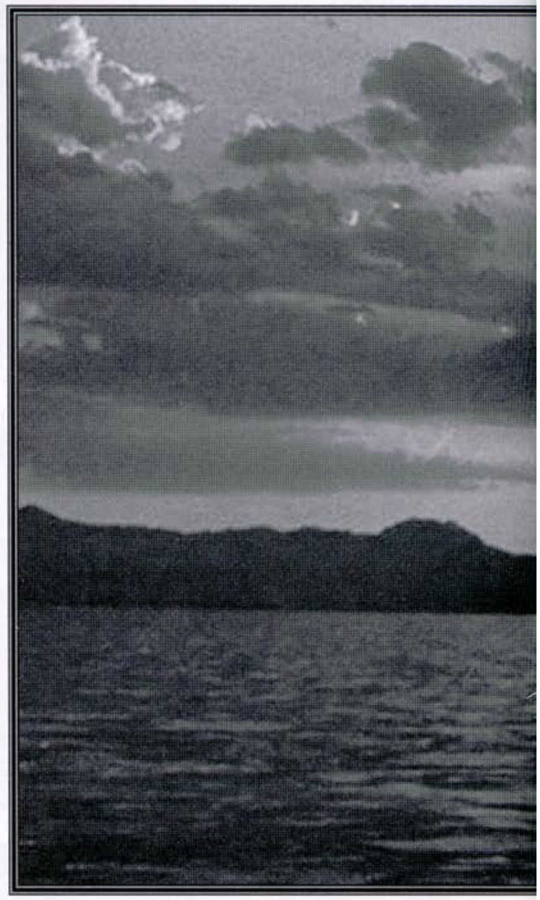
How much sediment will be deposited in the reservoir?

Between 1935 and 1963, about 91,500 acre-feet of sediment was deposited in Lake Mead each year. With closure of Glen Canyon Dam in 1963 about 370 miles upstream, only 300,000 acre-feet has been deposited in Lake Mead over the past 40 years. That's approximately 7,900 acre-feet of sediment per year, making the life of Lake Mead indefinite.

Tunnels, Towers, Penstocks, and Spillways

How was the river diverted during dam construction?

The river was diverted in 1932 by constructing an earth—and rock-fill cofferdam, which forced the river through four 50-foot-diameter tunnels, two on each side of the river. Together the tunnels have a total length of 15,946 feet or about 3 miles, and could carry over 200,000 cubic feet – or almost 11 and a half million gallons – of water per second per spillway.



Lake Mead at sunset.

After being used for river diversion, how were the tunnels used?

The two inner tunnels were plugged with concrete approximately one-third their length below the inlets, and the outer tunnels were plugged approximately half way. The lower portions of the two inner tunnels

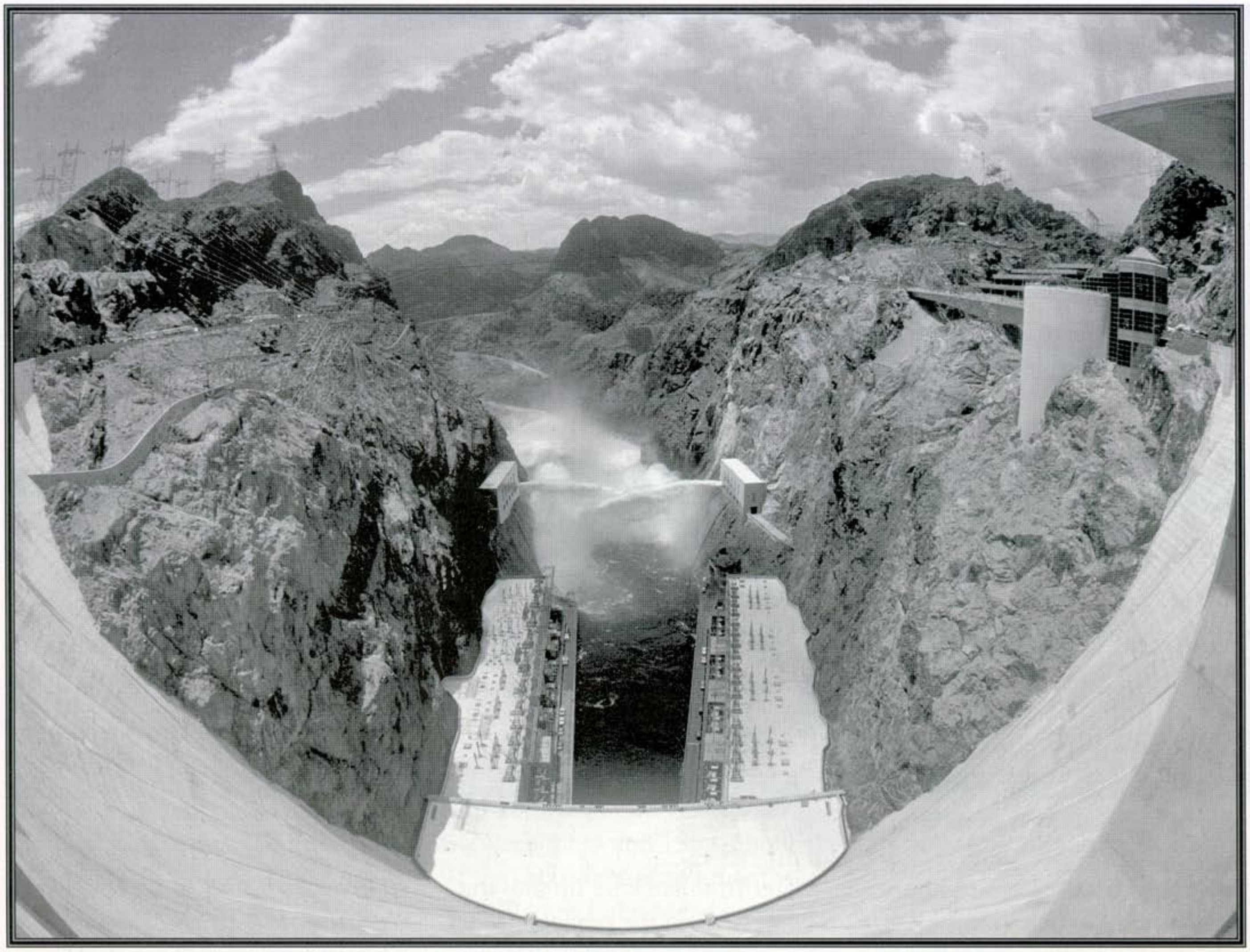
were then transformed to house the 30-foot diameter steel pipes which connect the intake towers in the reservoir to the generators inside the powerhouse and the canyon wall outlet works. The downstream halves of the two outer tunnels are used for spillway outlets.

The inlets of the two outer tunnels are permanently closed with 50 by 50 foot bulkhead gates. Each gate, with steel frame, weighs about 3,000,000 pounds, and required 42 railroad cars for shipment. At the outlets of the two inner tunnels, 50-by 35-foot steel gates were installed. These gates can be closed to keep water from backing up into the tunnels when the tunnels need to be emptied for inspections or repairs.

What are the intake towers?
They are four reinforced concrete structures located upstream of the dam, two on each side of the canyon. The diameter of these towers is 82 feet at the base, 63 feet 3 inches at the top, and 29 feet 8 inches inside. Each tower is 395 feet high and each controls one fourth the supply of water for the powerplant turbines. The four towers contain 93,674 cubic yards of concrete and 15,299,604 pounds of steel.

How are the intake towers connected to the powerplant and outlet works?
From the intake towers, water from Lake Mead flows through 30-foot diameter inclined pipes called penstocks to 30-foot-diameter pipes located in tunnels inside the canyon walls.

How do the 30-foot diameter penstocks deliver water to the generating units and outlet works?
There are 16 plate steel penstocks, each 13 feet in diameter, that branch off from the 30-foot diameter penstocks to deliver the water to the generating units. Smaller penstocks 8-1/2 feet in



Jet flow gates in Hoover Dam's outlet works release water during a test in June 1998. The flow was about 42,000 cfs, or 315,000 gallons per second.

diameter–branch off the 30-foot penstocks to deliver water to the outlet works.

How is water released through the outlet works?

Water releases from the outlet works are controlled by "jet flow gates." There are two of these gates in each of the valve houses, which are concrete structures located 180 feet above the river on each side of the canyon downstream of the dam, and four gates in each of the lower outlets at river level. The valves can be used to bypass water around the dam under emergency or flood conditions, although they have never been used for that purpose. Primarily, they are used to empty the penstocks for maintenance work.

What are the main characteristics of the penstock and outlet pipes?

The penstock and outlet pipes range from 8-1/2 to 30 feet in diameter, and have a total length of about 14,800 feet. The pipes were fabricated from 44,000 tons of 2-3/4-inch boilerplate steel. Each 22-foot section of pipe used to construct the penstocks weighed between 135 and 186 tons.

What is the maximum water release capacity of the generating units and outlet works?

With all valves open and all generators operating, the generating units and outlet works can release 96,000 cubic feet of water per second from Lake Mead. That's enough to fill about 34 average-size swimming pools each second.

Is there any other way to release water from Lake Mead?

Yes, water can also be released through Hoover Dam's spillways.

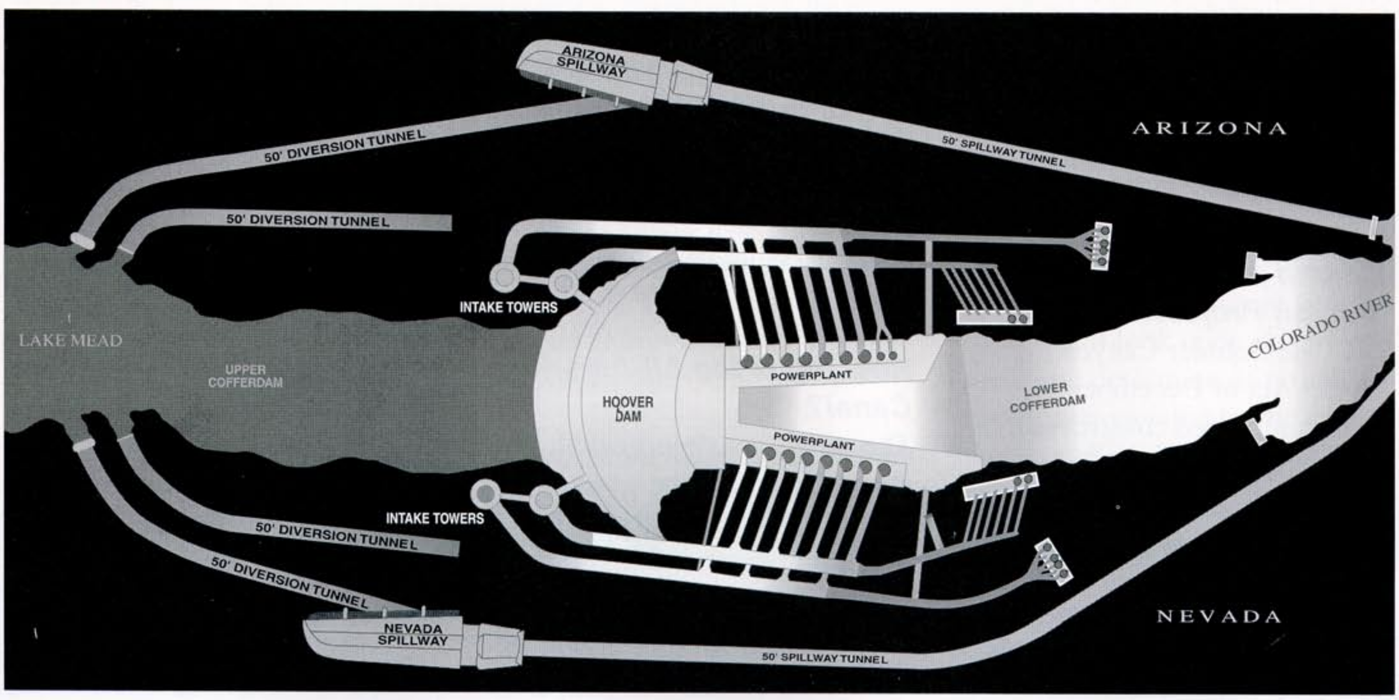
What are the spillways?

They are concrete-lined open channels about 650 feet long, 150 feet wide, and 170 feet deep located on each side of the canyon upstream of the dam. The spillways are designed to prevent water from flowing over the top of the dam, protecting the powerhouse below. Each spillway is large enough to float a U.S. Navy battleship.

How often are the spillways used?

The spillways have only been used once, in 1983, for operational purposes.

Hoover Dam spillway



How is water discharged from the spillways?

Water is discharged from the spillways through inclined, concrete-lined tunnels that are 50 feet in diameter and 600 feet long. The water flows down the tunnels at up to 175 feet per second, or more than 120 miles an hour, into the lower part of the outer diversion tunnels built to carry Colorado River water around the dam site. From there, the water is carried through the canyon walls around the dam and discharged into the river downstream.

What is the maximum discharge capacity of the spillways?

Each spillway can discharge 200,000 cubic feet per second. If the spillways were operated at full capacity, the energy of the falling water would be about 25,000,000 horsepower. The flow over each spillway would be about the same as the flow over Niagara Falls.

All-American Canal System

Is the All-American Canal System part of the Boulder Canyon Project?

Yes. The Boulder Canyon Project Act of December 21, 1928, authorized construction of a main canal from the Colorado River to the Imperial and Coachella Valleys in southern California.

Why the name All-American?

The canal is built entirely within the United States. The old Alamo Canal, which formerly served Imperial Valley, ran partway through Mexico.

Where is the All-American Canal intake?

The intake for the canal is at Imperial Dam (a diversion structure) and the All-American Canal desilting works, about 18 miles northeast of Yuma, Arizona, and 293 miles south of Hoover Dam.

What type of structure is Imperial Dam?

Imperial Dam is a concrete slab and buttress overflow structure that raises the river water surface about 23 feet, diverting Colorado River water to the west into the All-American Canal in California and into the Gila Canal in Arizona on the east. The All-American Canal desilting works, located below the California headworks, consist of three large basins, each 540 feet wide and 770 feet long. The basins remove the silt picked up by the river on its 148 mile journey from Parker Dam.

How big is the All-American Canal?

The canal's maximum width is about 232 feet at the water surface and 160 feet at the bottom. Maximum depth is 20.6 feet. Maximum carrying capacity of the canal is 15,155 cubic feet of water per second.

How long is the canal?

The canal extends westward for 80 miles through Imperial Valley. The 123-mile-long Coachella Canal diverts from the All-American Canal about 20 miles west of Yuma and runs northwest to a point near Indio, California. The Coachella Canal supplies domestic and irrigation water to lands and communities north of the Salton Sea.

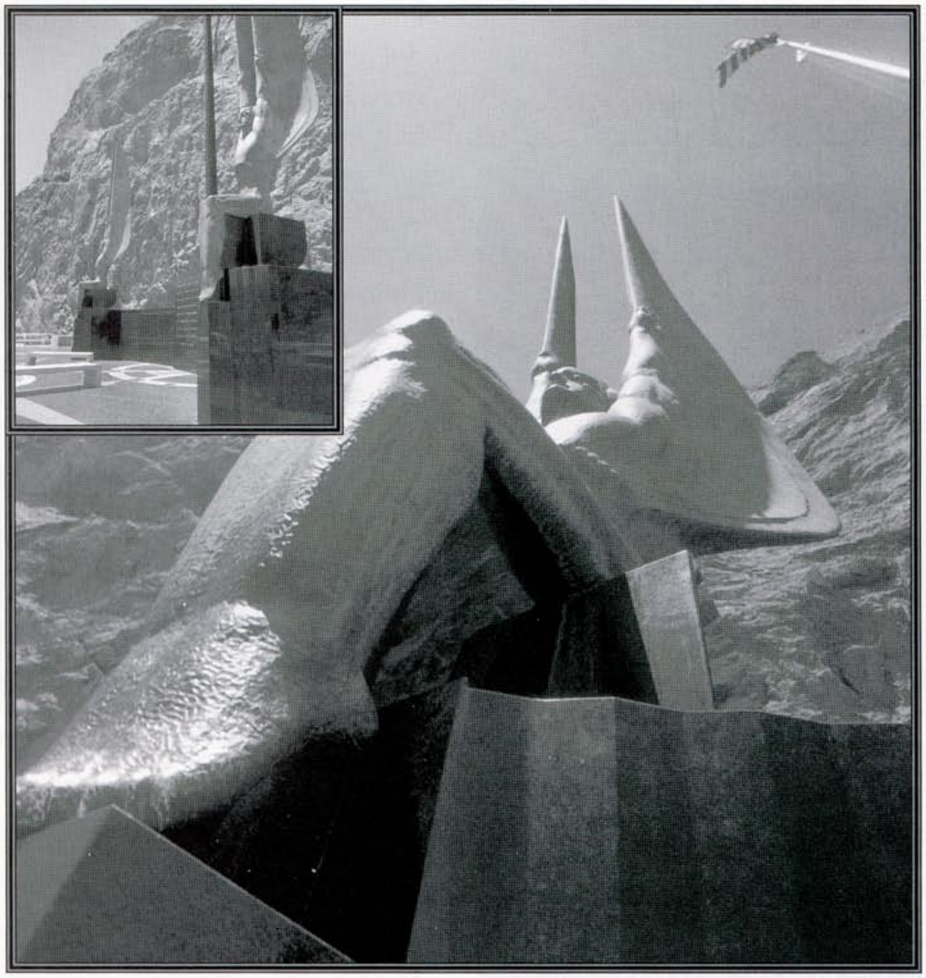
Hoover Dam Sculptures

Many people who visit Hoover Dam are impressed by the sculpture work they find. Much of the sculpture is the work of Norwegian born, naturalized American Oskar J.W. Hansen. Mr. Hansen fielded many questions about his work while it was being installed at the dam. In response to those questions, he later wrote about his interpretation of his sculptures.

Hoover Dam, said Hansen, represented for him the building genius of America, "a monument to collective genius exerting itself in community efforts around a common need or ideal." He compared the dam to such works as the great pyramids of Egypt, and said that, when viewing these man made structures, the viewer often asks of their builders "What manner of men were these?"

The sculptor, according to Hansen, tries to answer this question objectively, by "interpreting man to other men in the terms of the man himself." In each of these monuments, he said, can be read the characteristics of these men and on a larger scale, the community of which they are part. Thus, mankind itself is the subject of the sculptures at Hoover Dam.

Hansen's principal work at Hoover Dam is the monument of dedication on the Nevada side. Here, rising from a black, polished base, is a 142-foot flagpole flanked by two winged figures, which Hansen calls the *Winged Figures of the Republic*. They express "the immutable calm of intellectual resolution, and the enormous power of trained physical strength, equally enthroned in placid triumph of scientific accomplishment."



Winged Figures of the Republic

The winged figures are 30 feet high. Their shells are 5/8-inch thick, and contain more than 4 tons of statuary bronze. The figures were formed from sand molds weighing 492 tons. The bronze that forms the shells was heated to 2,500 degrees Fahrenheit, and poured into the molds in one continuous, molten stream.

The figures rest on a base of black diorite, an igneous rock. In order to place the blocks without marring their highly polished finish, they were centered on blocks of ice, and guided precisely into place as the ice melted. After the blocks were in place, the flagpole was dropped through a hole in the center block into a predrilled hole. Surrounding the base is a terrazzo floor, inlaid with a star chart, or celestial map. The chart preserves for future generations the date and time on which President Franklin D. Roosevelt dedicated Hoover Dam - at noon on September 30, 1935.

The apparent magnitudes of stars on the chart are shown as they would appear to the naked eye at a distance of about 190 trillion miles from Earth. In reality, the distance to most of the stars is more than 950 trillion miles.

In this celestial map, the bodies of the solar system are placed so exactly that those versed in astronomy could calculate the precession (progressively earlier occurrence) of the Pole Star for approximately the next 14,000 years. Conversely, future generations could look upon this monument and determine, if no other means were available, the exact date on which Hoover Dam was completed.

Near the figures and elevated above the floor is a compass, framed by the signs of the zodiac.

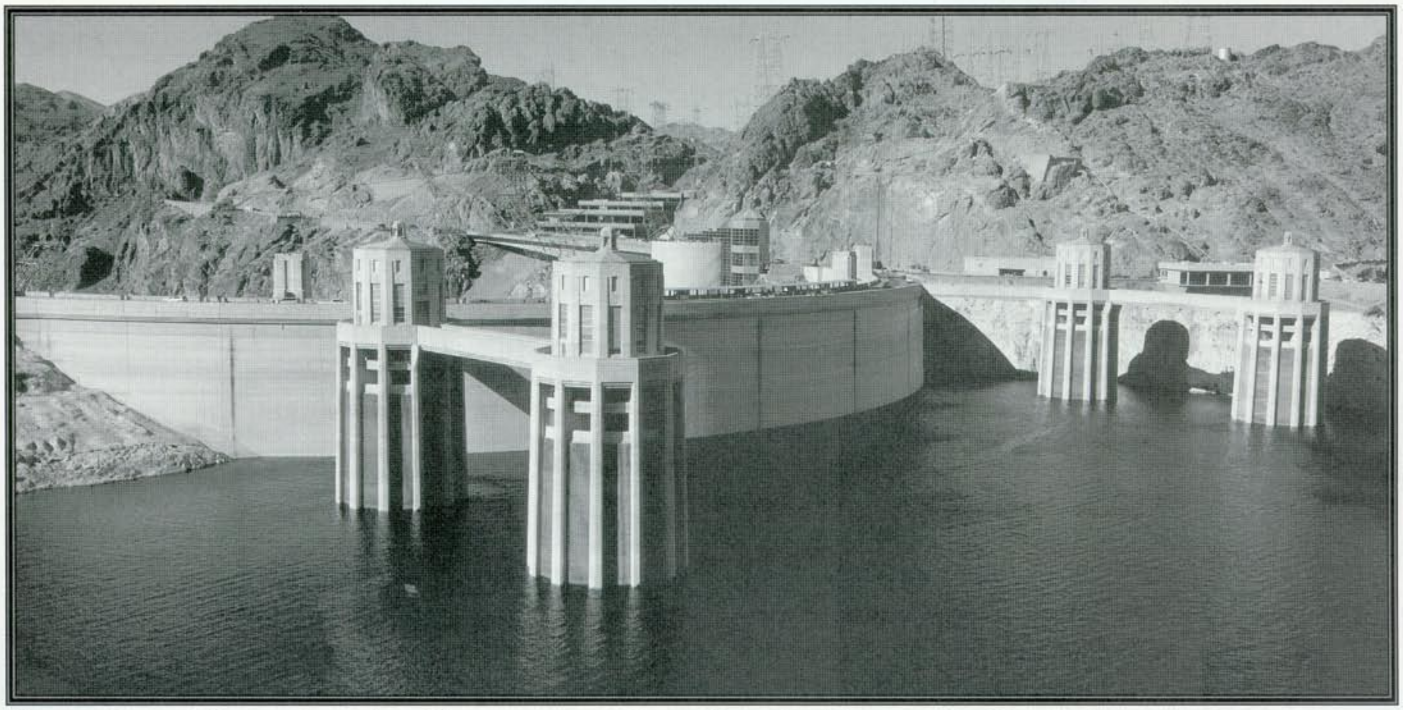
"The building of Hoover Dam belongs to the sagas of the daring. The winged bronzes which guard the flag therefore wear the look of eagles. To them also was given the vital upward thrust of an aspirational gesture; to symbolize the readiness for defense of our institutions and keeping of our spiritual eagles ever ready to be on the wing."

Oscar J.W. Hansen

Hansen also designed the plaque commemorating the 96 men who died during the construction of Hoover Dam, as well as the bas relief series on both the Nevada and Arizona elevator towers. The plaque reads:
"They died to make the desert bloom. The United States of America will continue to remember that many who toiled here found their final rest while engaged in the building of this dam. The United States of America will continue to remember the services of all who labored to clothe with substance the plans of those who first envisioned the building of this dam.

The five bas reliefs on the Nevada elevator tower show the multipurpose benefits of Hoover Dam - flood control, navigation, irrigation, water storage, and power.

On the Arizona elevator tower is a series of five bas reliefs depicting "the visages of those Indian tribes who have inhabited mountains and plains from ages distant." Accompanying the illustrations is the inscription, *"Since primordial times, American Indian tribes and Nations lifted their hands to the Great Spirit from these ranges and plains. We now with them in peace buildeth again a Nation."*



Hoover Dam, visitor center and parking garage, as viewed from the Arizona wall of Black Canyon.

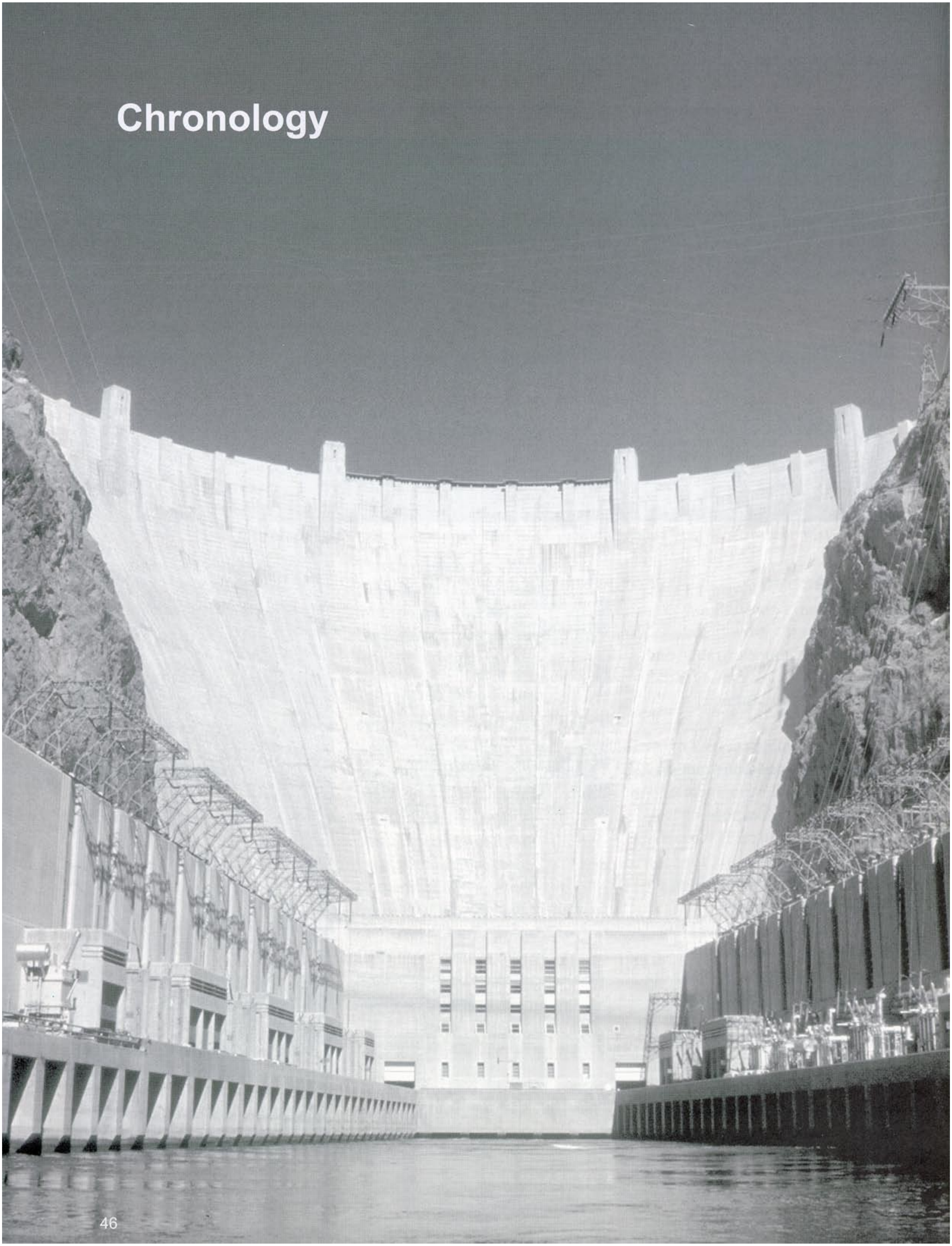
Perspective

Hoover Dam's contribution to the Southwest's growth and economy are immeasurable, and its influence is felt far beyond the Southwest's confines.

The uncontestable success of Hoover supported construction and continued development of other great multipurpose Reclamation structures throughout the West. There are, for example, Grand Coulee Dam on the Columbia River in Washington State, Shasta Dam on California's Sacramento River, Glen Canyon Dam on the Colorado River upstream of Hoover Dam, and other dams too numerous to mention. All these dams provide multipurpose benefits that have greatly strengthened the economies of the local areas they serve and often reach into areas far away from their immediate surroundings.

Hoover Dam also made it possible to construct other dams in the Colorado River Basin. These dams help control the river and its tributaries, allowing the stored waters to be beneficially used along the stream's entire length.

Chronology



600 Ancient Pueblo and Hohokam Indians develop water distribution systems along the Colorado River.

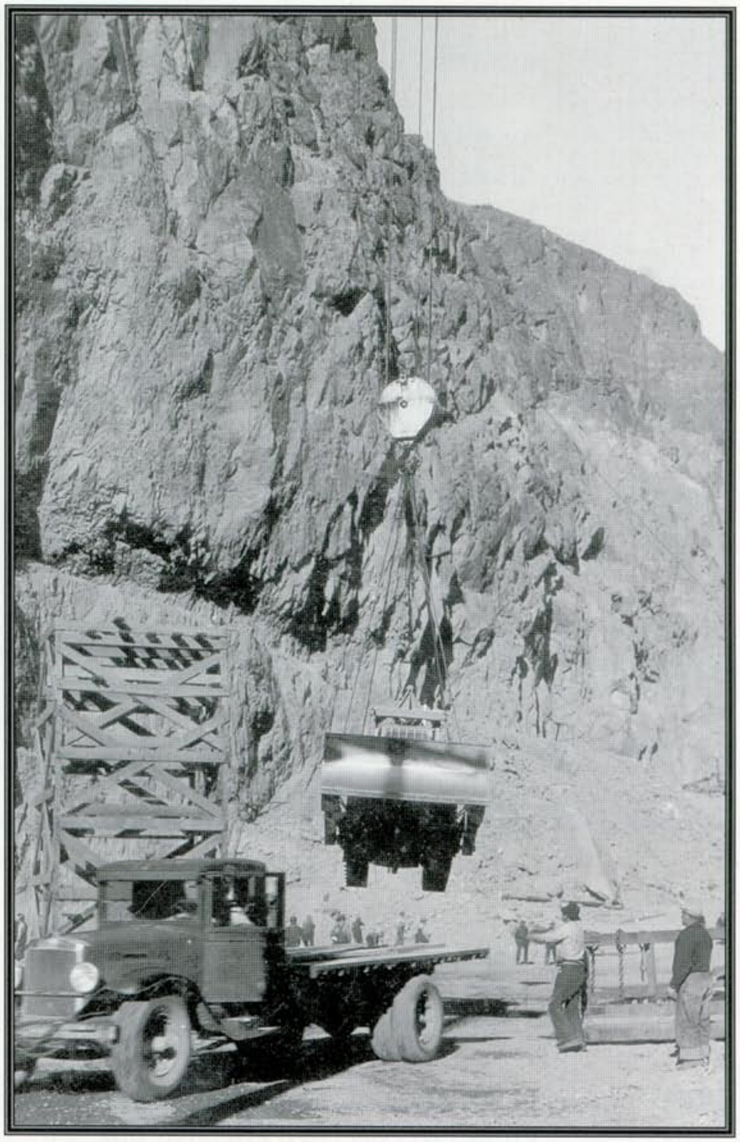
1540 Spanish explorer Hernando de Alarcon reaches the river and names it Rió Colorado, because of its reddish-colored sediment, and explores its lower segment. Spanish explorer Garcia Lopez de Cardenas discovers the Grand Canyon.

1776 Father Silvestre Velez de Escalante explores the upper Colorado and its tributaries.

1857-58 Army Lt. J. C. Ives navigates the Colorado River and, with his steamboat "The Explorer," reaches the lower end of Black Canyon, below present-day Hoover Dam.

1859 Oliver Wozencraft promotes the idea of irrigating the Imperial Valley.

1869-71 Civil War veteran Maj. John Wesley Powell makes the first recorded trip through the entire length of the Grand Canyon and issues his report in 1875.



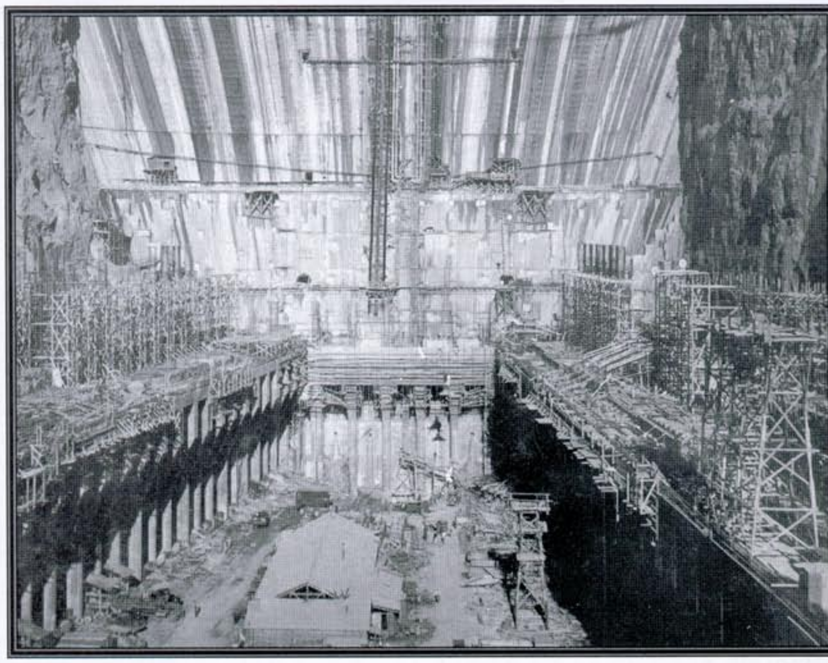
Workers handling heavy equipment from overhead cableway in Black Canyon, near the diversion tunnels, ca 1933.

1902 President Theodore Roosevelt signs the Reclamation Act, creating the United States Reclamation Service, now the Bureau of Reclamation. Reclamation engineers begin their long series of investigations and reports on control and use of the Colorado River.

1905-07 The Colorado River breaks into Imperial Valley, and flows into the Salton Sink for 16 months, causing extensive damage and creating the modern Salton Sea.

1918 Arthur P. Davis, Reclamation director and chief engineer, proposes control of the Colorado by a dam of unprecedented height in Boulder Canyon on the Arizona-Nevada border.

1919 All-American Canal Board recommends construction of the All-American Canal. Bill introduced to authorize its construction.



Looking upstream at Hoover Dam through power plant tailrace, 1935.

1922 Fall-Davis report, submitted to Congress February 28, recommends construction of the All-American Canal and a high dam on the Colorado River at or near Boulder Canyon.
Colorado River Compact negotiated by Secretary of Commerce Herbert Hoover and the seven basin states, dividing the use of Colorado River water between upper and lower basins. Representatives of six of the seven States sign the Colorado River Compact in Santa Fe, New Mexico, November 24 (Arizona did not sign until 1944).
First bill to authorize a high dam and a canal is introduced in Congress.

1928 Boulder Canyon Project Act authorizing construction of Hoover Dam and the All-American Canal passes the Senate on December 14, the House on December 18, and is signed by President Calvin Coolidge on December 21.

1929 Legislatures of the seven Basin States approve Colorado River Compact. Boulder Canyon Project Act declared effective June 25.

1930 Contracts for the sale of electrical energy to cover dam and powerplant financing are completed.

1931 Bureau of Reclamation opens bids for construction of Hoover Dam and Powerplant March 4, awards contract to Six Companies March 11, and gives contractor notice to proceed April 20.

1932 Colorado River is successfully diverted around the dam's construction site on November 14. Repayment contract for construction of All-American Canal is completed.

1933 First concrete for dam is placed on June 6.

1934 All-American Canal construction begins in August.

Government housing under construction in Boulder City, 1931.

1935 Dam starts impounding water in Lake Mead February 1. Last concrete is placed in dam May 29. President Franklin D. Roosevelt dedicates dam September 30.

1936 First power generated by Unit N-2 in October.

1938 Lake Mead storage reaches 24 million-acre feet, and lake extends 110 miles upstream.

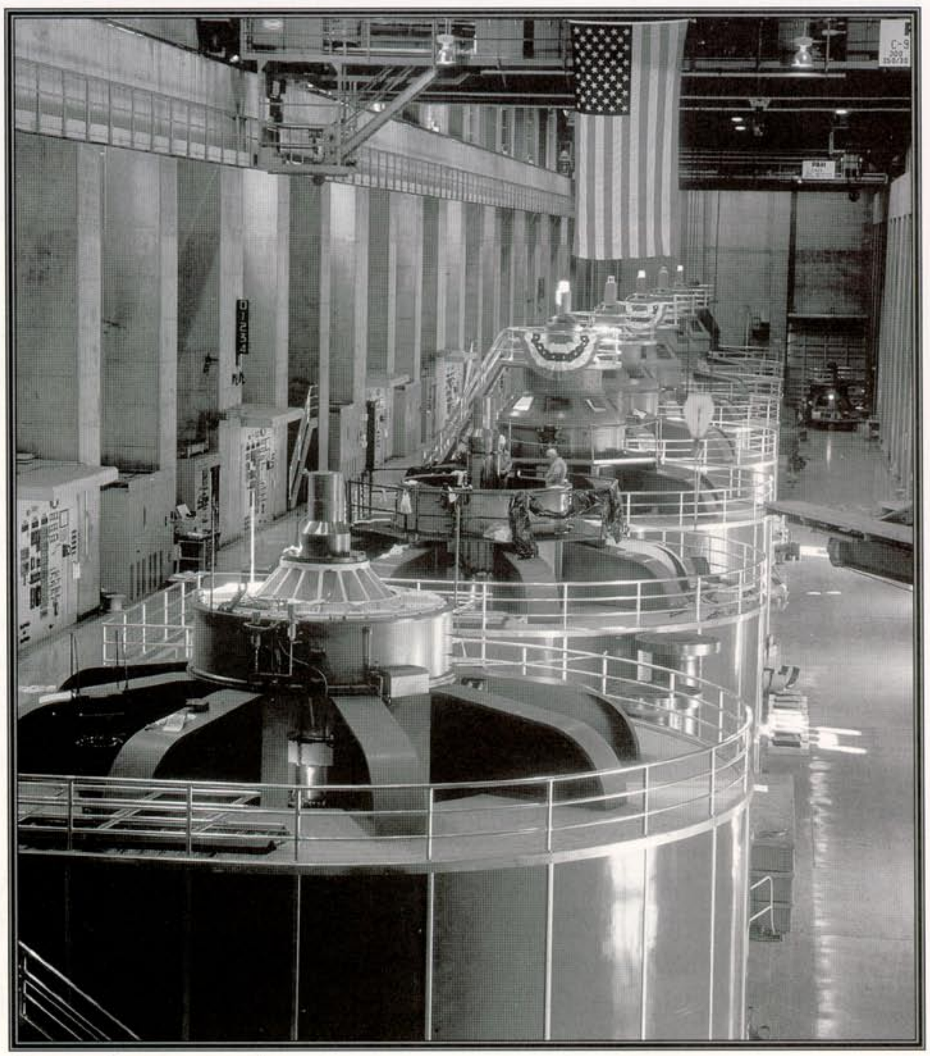
1939 Storage in Lake Mead reaches 25 million acre-feet, more than 8,000 billion gallons. Hoover Dam's powerplant, with nine generators operating, has an installed capacity of 704,800 kilowatts, making it the largest hydroelectric facility in the world, a distinction it held until surpassed by the Grand Coulee Dam in 1949.

1940 All-American Canal placed in operation.

1941 Lake Mead elevation reaches 1,220.45 feet above sea level on July 30. The lake is 580 feet deep and 120 miles long. Spillways are tested on August 6, the first time they have ever been used. Hoover Dam closes to the public at 5:30 p.m. on December 7, and all traffic over the dam moves in convoy fashion under military escort for the duration of World War II.

1945 Dam reopens to the public September 2.

1946	Hoover Dam's tenth year of commercial power production is observed on October 23.
1947	80th Congress passes legislation officially designating the Boulder Canyon Project's key structure "Hoover Dam" in honor of President Herbert Hoover.
1951	More than 2 million people visit Lake Mead, setting a new annual record and contributing to the establishment of the Lake Mead National Recreation Area 13 years later.
1952	Federal and State officials and other dignitaries gather at dam to celebrate Reclamation's 50th Anniversary.
1953	Generation of 6,397 million kilowatt-hours in operating year 1952-53 is new record. A record 448,081 people visit the dam and powerplant during the year.
1955	Hoover Dam selected by the American Society of Civil Engineers as one of seven modern civil engineering wonders of the United States.
1959	Visitors number 472,639 for this year, the highest number recorded since visitor service began in 1937.
1960	Hoover Dam celebrates its 25th anniversary on May 29.
1961	The power installation at Hoover Dam is complete when the final generating unit, N-8, goes "on-line" December 1. The installed generating capacity of Hoover powerplant, including station service units, reaches 1,334,800 kilowatts.



Hoover Dam generators.

1962 Visitors for the year exceed 500,000 for the first time.

1963 The dam closes to visitors on November 25, a day of mourning for assassinated President John F. Kennedy.

1964 Lake Mead National Recreation Area established by Congress as the nation's first national recreation area in the National Park system. August 10, the 10 millionth visitor tours the dam.

1967 The number of yearly visitors exceeds 600,000 for the first time.

1969 The dam closes to visitors March 31, a day of mourning for former President Dwight D. Eisenhower.

1970 Power Generating units N-1, N-2, N-3, and N-4 receive stainless steel turbine runners to replace original cast steel runners.

1972 The 15 millionth visitor tours the dam and powerplant October 20.

1976 October 26 ceremonies mark 40 years of power generation at Hoover Dam and 726,000 visitors are recorded for the year, marking the first time the visitor total surpassed 700,000 in one year.

1977 The Department of Energy's Western Area Power Administration begins marketing Hoover Dam power.

1980 20 millionth visitor is recorded May 30.

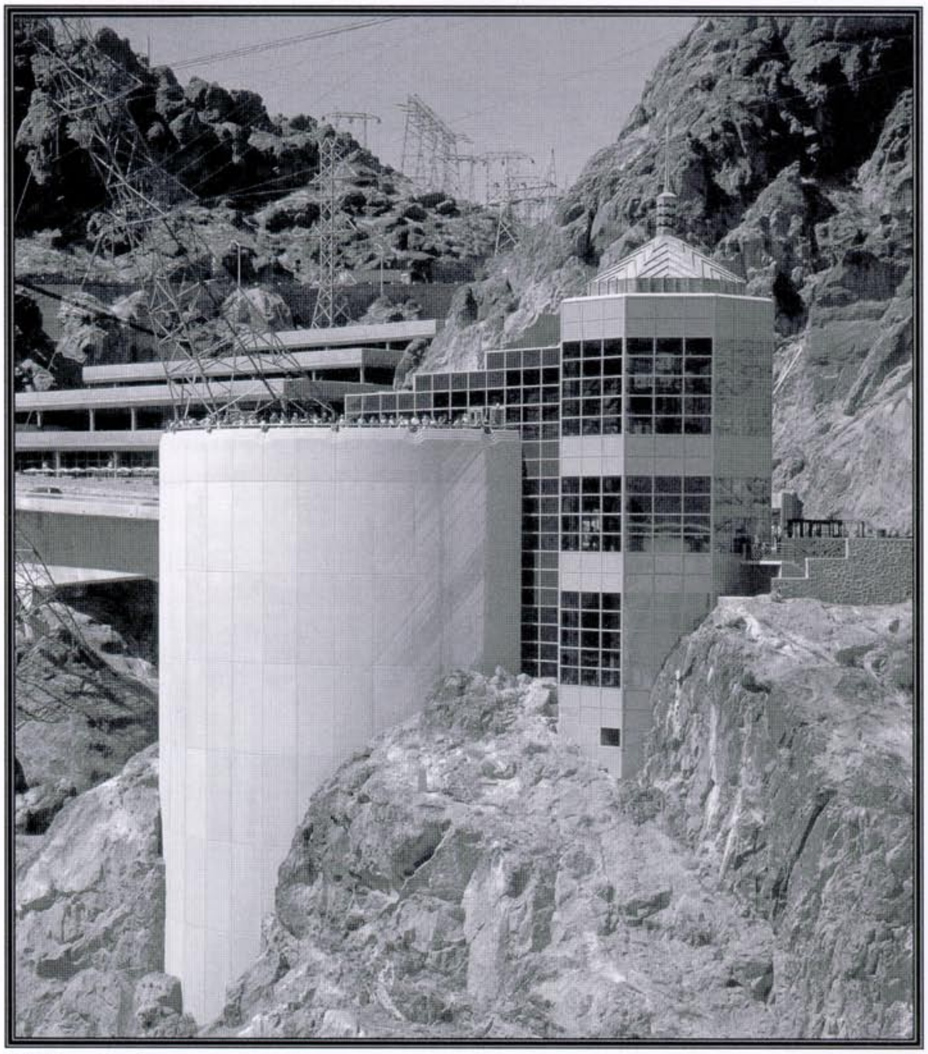
1983 Unpredicted record-high runoff sweeps the Colorado River. Lake Mead storage reaches and flows over the top of raised spillway gates in the late evening of July 2, the first uncontrolled spill since 1941, when releases were made to test the spillways. Reservoir system crests at 1225.83 feet July 24 (4.43 feet above raised spillway gates). Lake level recedes to 1221.4 and spill ceases September 6.

1984 Congress authorizes construction of new visitor facilities and a bypass bridge, and uprating of 15 of the dam's generators (two were already completed).

1985 Hoover Dam celebrates 50th anniversary.

1987 Bureau of Reclamation assumes operation of Hoover Dam powerplant from Los Angeles Department of Water and Power and Southern California Edison Co. as initial 50-year power contracts expire. Power contracts re-negotiated and implemented for 30-year period (1987-2017).

1993 Uprating of powerplant is finished, raising plant's nameplate capacity from 1,334,800 kilowatts to 2,078,000 kilowatts.


Visitor Center.

1995 New visitor center opens to public on June 21.

1996 Tours exceed one million visitors in one year for first time.

1999 35 millionth visitor tours dam and powerplant.

2001 Hoover Dam halts tour operations and closes to the public following Sept. 11, attacks in New York and Washington, D.C. Modified tour program begins in December. Power lines are relocated and the old switch yard is removed in preparation for the construction of the Hoover Dam Bypass Bridge.

2002 Hoover Dam re-opens to the public with a new "Discovery Tour." Reclamation's Centennial celebration is held at Hoover Dam. Construction begins on the Arizona and Nevada approaches of the Bypass Bridge.

Hoover Dam's Awards

An Engineering Icon *- Hoover Dam has been recognized by some of the nation's most prestigious associations as an icon of extraordinary engineering and design. Honors bestowed on the dam include:*

- **1955** - Named one of America's Seven Civil Engineering Wonders by the American Society of Civil Engineers.
- **1985** - Named a National Historic Civil Engineering Landmark by the American Society of Civil Engineers.
- **1994** - Named one of America's Seven Modern Engineering Wonders by the American Society of Civil Engineers.
- **1999** - Selected as #5 in the Top 10 Construction Achievements of the 20th Century by members of the Construction Industry Manufacturers Association, the National Aggregates Association, and the National Ready Mixed Concrete Association.
- **2001** - Named a Civil Engineering Monument of the Millennium by the American Society of Civil Engineers.
  Named one of the Top 10 Public Works Projects of the Century by the American Public Works Association.
- **2002** - Hoover Dam Penstock System declared a Historical Welded Structure by the American Welding Society.
- **2005** - Hoover Dam and Lake Mead were designated the 2005 Outstanding Environmental and Engineering Geologic Project by the Association of Engineering Geologists.

Glossary

Acre (ac): Unit for measuring land, equal to 43,560 square feet, 4,840 square yards or 0.405 hectare.

Acre-foot (AF or af): A term used in measuring the volume or amount of water needed to cover 1 acre (43,560 square feet) 1 foot deep (325,851 gallons or 1,233.5 cubic meters).

Arch dam: A concrete or masonry dam which is curved upstream in plan so as to transmit the major part of the water load to the abutments to keep the dam in compression. A solid concrete dam curved upstream in plan. An arch dam is most likely used in a narrow site with steep walls of sound rock.

Arch-gravity dam: An arch dam that is only slightly thinner than a gravity dam.

Aqueduct: Man-made canal or pipeline used to transport water.

Average annual runoff: For a specified area, the average value of annual runoff amounts calculated for a selected period of record that represents average hydrologic conditions.

Canal: A channel, usually open, that conveys water by gravity or by pumping.

Canal headworks: The beginning of a canal.

Capacity: In power terminology, the load for which a generator, transmission line or system is rated, expressed in kilowatts. The amount of electric power delivered or required for which a generator, turbine, transformer, transmission circuit, station, or system is rated by the manufacturer. The maximum load that a machine, station, or system can carry under existing service conditions.

Cofferdam. A temporary barrier, usually an earthen dike, constructed around a worksite in a reservoir or on a stream, so the worksite can be dewatered or the water level controlled.

Cubic foot per second (cfs or ft3/s): A measure of the volume of water passing a reference point in 1 second of time. One cubic foot per second equals 7.48 gallons per second or 0.02832 cubic meters per second.

Cubic yard: 27 cubic feet or 0.7645549 cubic meter.

Dam: A barrier built across a watercourse to impound or divert water. A barrier, usually built across a stream, that obstructs, directs, retards, or stores the flow of water. A structure built to hold back a flow of water.

Dam foundation: The excavated surface or undisturbed material upon which a dam is placed.

Discharge capacity: The maximum amount of water that can safely be released from a given waterway.

Drainage basin: All of the area drained by a river system. The drainage basin is a part of the surface of the earth that is occupied by a drainage system, which consists of a surface stream or a body of impounded surface water together with all tributary surface streams and bodies of impounded surface water. The area of land that drains its water into a river.

Elevation (El. Elev.): The height of a point above a plane of reference. Generally refers to the height above sea level.

Energy: Force or action of doing work. Measured in terms of the work it is capable of doing; electric energy, the electric capacity generated and/or delivered over time, is usually measured in kilowatt hours (kWh).

Foot: Twelve US inches or 0.3048 meter.

Forebay: Impoundment immediately upstream from a dam or hydroelectric plant intake structure. The term is applicable to all types of hydroelectric developments (storage, run-of-river, and pumped-storage).

Gallon: A unit of measure equal to four quarts or 0.004 cubic meters.

Gated spillway: Overflow section of dam restricted by use of gates that can be operated to control releases from the reservoir to ensure the safety of the dam.

Generation: Process of producing electric energy by transforming other forms of energy; amount of electric energy produced is generally expressed in kilowatt-hours.

Generator: Machine that converts mechanical energy into electrical energy.

Generator nameplate capacity: The full-load continuous rating of a generator or other electric power production equipment under specific conditions as designated by the manufacturer. Installed generator nameplate rating is usually indicated on a nameplate physically attached to the generator.

Gigawatt (gw): Unit of power equal to 1 billion watts.

Gigawatt-hour (gWh): One billion watt-hours of electrical energy.

Gravity dam: A dam constructed of concrete and/or masonry which relies on its weight and internal strength for stability.

Horsepower (hp): A unit of rate of doing work, the force required to lift 33,000 pounds one foot in one minute, or 745.8 watts (British), 746 watts (US) or 736 watts (Europe).

Hydroelectric power: Electrical energy produced by flowing water.

Hydroelectric powerplant: A building in which turbines are operated by the energy of natural or artificial water flow to drive generators.

Jet-flow gate: A high-pressure device designed for regulating flow. Jet flow gates have a wheel-mounted leaf that is moved vertically into or out of a water passageway, such as a pipe, by a motor-driven screw hoist.

Kilowatt (kW): An electrical unit of work or power equal to 1000 watts, or about 1.34 horsepower.

Kilowatt-hour (kWh): A unit of energy equivalent to one thousand watt-hours and equal to an average of one kilowatt of power applied over one hour. For example, ten 100-watt light bulbs burning for one hour equals one kilowatt-hour.

Mechanical or electrical force or energy: The rate at which work is done by an electric current or mechanical force, generally measured in watts or horsepower.

Megawatt (MW): One million watts of electrical power (capacity).

Megawatt-hour (MWh): One million watt-hours of electrical energy.

Outlet works: A series of components located in a dam through which normal or flood releases can be made from a reservoir.

Penstock: A pipe or conduit that conveys water from a forebay or reservoir to power-producing turbines, or to pump units.

Power: Electrical energy generated, transferred, or used; usually expressed in kilowatts.

Powerplant capacity: The nameplate rating of a facility, in kilowatts. At Hoover Dam, this includes the 17 main generating units as well as the two station service units that provide power for the dam, powerplant, visitor center and other associated facilities.

Reservoir: An artificial lake into which water flows and is stored for future use.

Spillway: A structure that passes normal and/or flood flows in a manner that protects the structural integrity of a dam. Overflow channel of a dam or impoundment structure. A structure over or through which flow is discharged from a reservoir.

Station use: Energy used in a generating plant as necessary in producing electricity. Includes energy consumed for plant light, power, and auxiliaries regardless of whether such energy is produced at plant or comes from another source.

Structural height: The structural height of a concrete dam is the vertical distance between the top of the dam and lowest point of the excavated foundation area, excluding narrow fault zones.

Tailrace (afterbay): The body of water immediately downstream from a powerplant or pumping plant; a reservoir or pool that regulates fluctuating discharges from a hydroelectric power plant or a pumping plant.

Transmission line: Facility for transmitting electrical energy at high voltage from one point to another point.

Turbine: A machine for generating rotary mechanical power from the energy of a stream of fluid (such as water, steam, or hot gas).

Uprate: An increase of greater than 15 percent in powerplant unit output at an existing facility through modifications or replacement of equipment.

Water surface elevation: The elevation of a water surface above or below an established reference level, such as sea level.

Watt (W): Basic unit of electrical power produced at one time. One watt equals one joule per second.

Watt hour(Wh): An electrical energy unit of measure equal to one watt of power supplied to, or taken from, an electrical circuit steadily for one hour.

Weir: An overflow structure built across an open channel to raise the upstream water level and/or to measure the flow of water