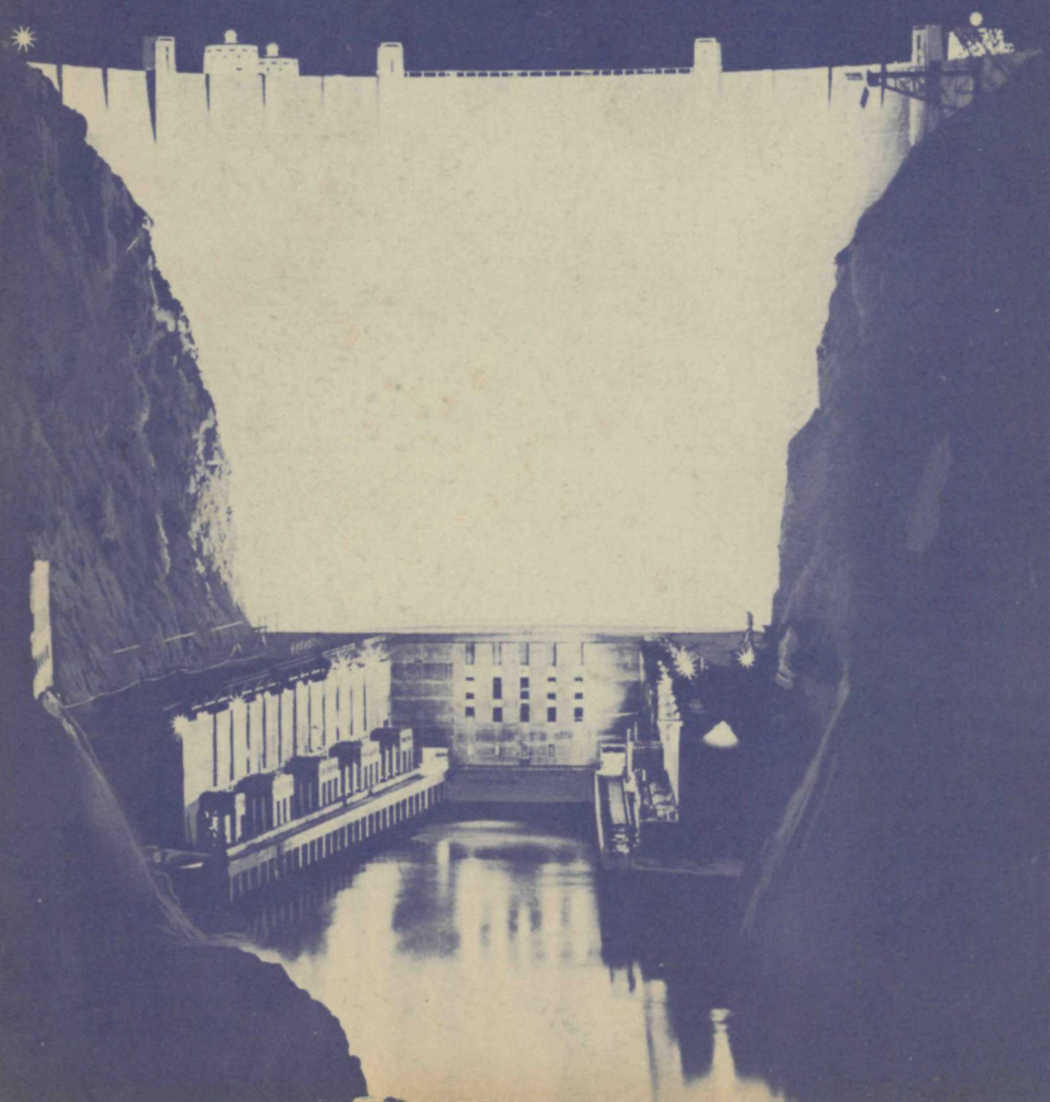
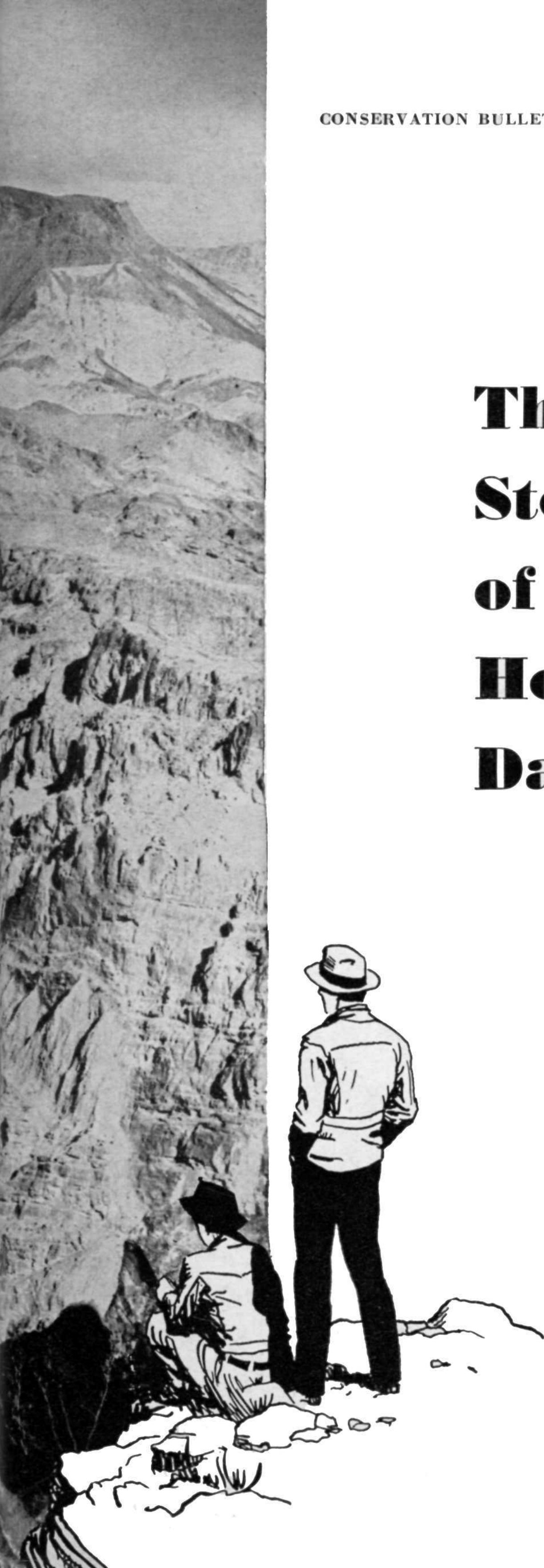
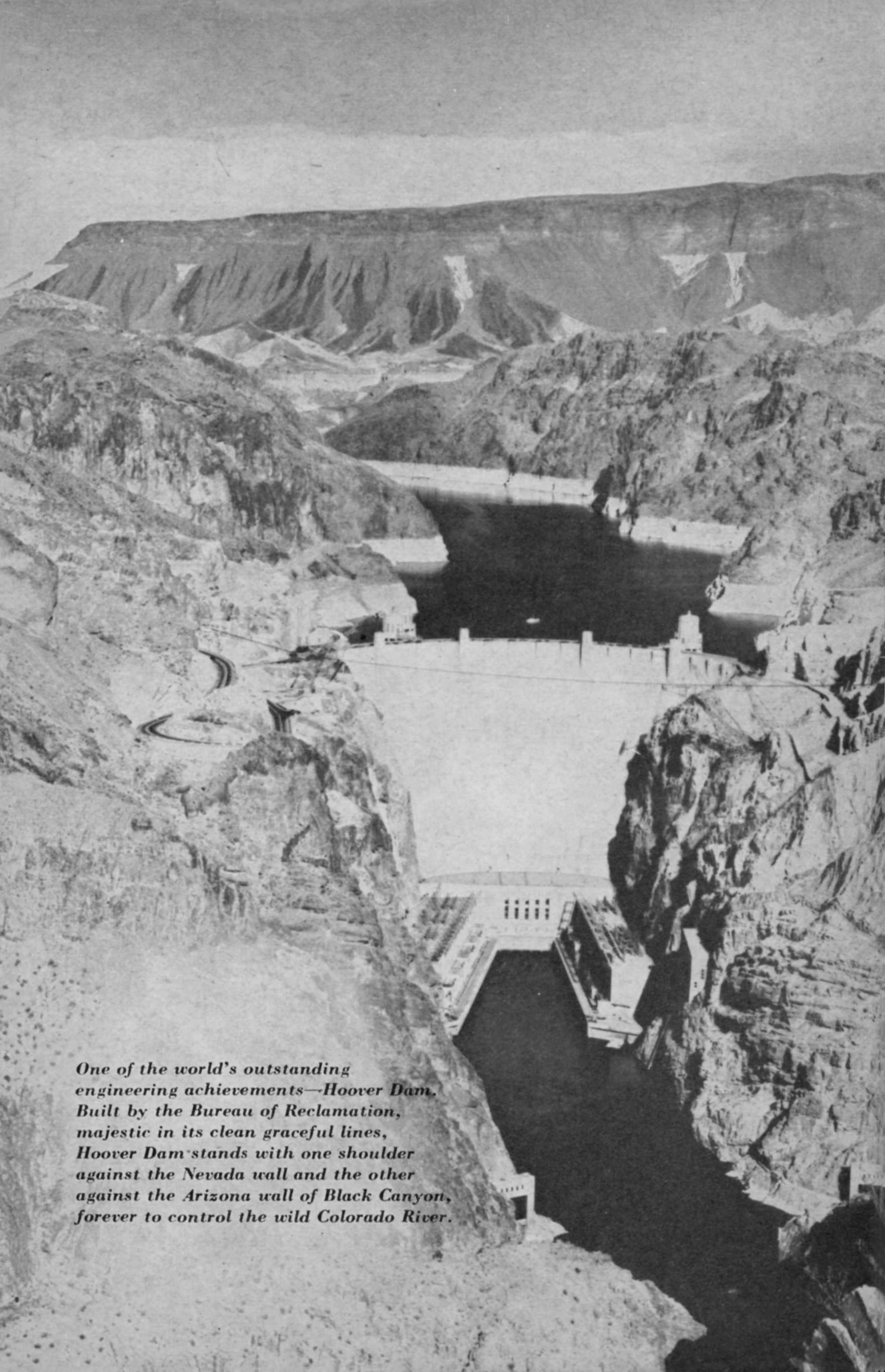
The Story of
Hoover Dam



CONSERVATION BULLETIN NO. 9

The Story of Hoover Dam





One of the world's outstanding engineering achievements—Hoover Dam. Built by the Bureau of Reclamation, majestic in its clean graceful lines, Hoover Dam stands with one shoulder against the Nevada wall and the other against the Arizona wall of Black Canyon, forever to control the wild Colorado River.

foreword

ROLLING SWIFTLY on its tortuous course through the hot, arid, southwestern United States, battering its way through deep canyons, the Colorado was considered America's most dangerous river.

Man's desperate need of water caused him early to turn speculating eyes on the Colorado, but whenever he tampered with the river he brought disaster upon himself!

Farmers, tempted by fertile desert soil, tapped the Colorado for water to irrigate and create rich gardens—but annually the river rose in destructive floodtide to destroy their crops, and annually the river's flow dwindled away so that all living things were faced with water shortages.

A great cry finally arose for the control and conservation of the waters of the Colorado, the most valuable natural resource of a desert empire.

The cry was answered. Bureau of Reclamation engineers successfully mastered the Colorado by creating one of the most significant engineering achievements of all time—Hoover Dam.

The dramatic achievement of building Hoover Dam and the benefits resulting from the completed project have aroused world-wide interest. To tell, briefly, the basic story of these achievements and to trace the ramifications of the resulting benefits is the province of this booklet.

contents

UNITED STATES DEPARTMENT OF THE INTERIOR
Douglas McKay, *Secretary*
BUREAU OF RECLAMATION, W. A. Dexheimer, *Commissioner*
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chronology

1540 Alarcon discovers the Colorado River and explores its lower reaches. Cardenas discovers the Grand Canyon.

1776 Father Escalante explores the upper Colorado and its tributaries.

1857–8 Lt. J. C. Ives navigates the Colorado River and, with his steamboat, *The Explorer*, reaches the lower end of Black Canyon.

1869 Maj. John Wesley Powell makes the first recorded trip through the Grand Canyon.

1902 President Theodore Roosevelt signs the Reclamation Act. Reclamation engineers initiate their long series of investigations and reports on control and utilization of the Colorado River.

1905–7 The Colorado River breaks into Imperial Valley, causing great damage and creating the Salton Sea.

1916 Unprecedented flood pours down the Gila River into the Colorado, and flood waters sweep into Yuma Valley.

1918 Arthur P. Davis, reclamation director and chief engineer, proposes control of the Colorado by a dam of unprecedented height in Boulder Canyon.

1919 All-American Canal Board issues report recommending construction of the All-American Canal. Bill introduced to authorize construction of the All-American Canal.

1920 Congress passes Kinkaid Act authorizing Secretary of the Interior to investigate problems of Imperial Valley.

1922 Fall-Davis report on *Problems of Imperial Valley and Vicinity*, prepared as a result of the Kinkaid Act and submitted to Congress on February 28, recommends construction of the All-American Canal and a high dam on the Colorado River at or near Boulder Canyon. Representatives of the seven Colorado River Basin States sign the Colorado River Compact at Santa Fe, N. Mex., on November 24. First of the Swing-Johnson bills to authorize a high dam and a canal is introduced in the Congress.

1924 Weymouth report expands Fall-Davis report and further recommends Boulder Canyon project construction.

1928 Colorado River Board of California reports favorably on feasibility of project. Boulder Canyon Project Act, introduced by Senator Johnson and Representative Swing, passes the Senate on December 14, the House on December 18, and is signed by the President on December 21

1929 Six 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 on March 4, awards contracts to Six Companies, Inc., on March 11, and gives contractor notice to proceed on April 20.

1932 River is diverted around dam site November 14. Repayment contract for construction cost of All-American Canal is completed with Imperial Irrigation District.

1933 First concrete is placed in dam June 6.

1934 All-American Canal construction begins in August. Repayment contract between the United States and the Coachella County Water District covering cost of Coachella Main Canal executed on October 15.

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 generator, N–2, goes into full operation October 26. Second generator, N–4, is placed in operation November 14. Third generator, N–1, starts production December 28.

1937 Generators N–3 and A–8 go into operation March 22 and August 16.

1938 Water stored in Lake Mead reaches 24 million acre-feet, and lake extends 115 miles upstream. Generators N–5 and N–6 placed in operation June 26 and August 31.

1939 Storage in Lake Mead reaches 25 million acre-feet, more than 8,000 billion gallons. Generators A–7 and A–6 are put into operation June 19 and September 12. Installed capacity reaches 704,800 kilowatts, making the Hoover powerplant the largest of its kind in the world—a distinction which it held until surpassed by Grand Coulee in 1949.

1940 Orders are placed for three more generators. Generation for the year totals 3 billion kilowatt-hours. All-American Canal is placed in operation. Metropolitan Water District's Colorado River aqueduct is tested successfully. Boulder Canyon Project Adjustment Act approved on July 19.

1941 Lake Mead elevation reaches all-time high of 1,220.45 feet above sea level July 30; lake is 580 feet deep, 120 miles long. Storage reaches 31 million acre-feet. Spillways are tested for first time August 6. Generator A–1 placed in service October 9. Dam is closed to public, 5:30 p. m., December 7, and traffic moves over dam under convoy for duration of World War II hostilities.

1942 Generator A–2 is placed in operation July 11.

1943 Generator A–5 is placed in service January 13.

1945 Dam reopened to the public September 2.

1946 Decennial of commercial power production observed at the dam on October 23, with Secretary of the Interior, Commissioner of Reclamation, and dignitaries of the seven Basin States participating.

1947 The 80th Congress passes legislation officially designating the Boulder Canyon project's key structure "Hoover Dam" instead of "Boulder Dam." On November 26 the city of San Diego receives its first Colorado River water through its newly built aqueduct connecting with the Metropolitan Water District's Colorado River aqueduct at San Jacinto tunnel. Repayment contract between the United States and the Coachella Valley County Water District covering cost of the Coachella Canal distribution system executed on December 22.

1951 More than 2 million persons visit Lake Mead national recreation area, setting a new record.

1952 Generators A–9, A–4, and A–3 placed in service April 1, May 1, and September 19. Federal and State officials and other dignitaries gather at dam April 29 to dedicate the State of Arizona's two generators, A–3 and A–4, and celebrate the Golden Jubilee of Reclamation.

1953 Two records were set in 1953. Maximum generation to date of 6,397 million kilowatt-hours at transmission voltage occurred in operating year 1952–53. Also, a record high in annual visitors was set when 448,081 persons took the guided tour through the dam and powerplant during the year.

the river

The setting of this story is in the southwestern United States, a picturesque land of high mountains, deep canyons, and scorching deserts, of Joshua trees and giant cacti, of bighorn sheep and Gila monsters. The principal character is the treacherous, destructive Colorado River.

One of the longest rivers in the Union, the Colorado rises in the snow-capped mountains of northcentral Colorado, zigzags southwest for 1,400 miles, and finally pours into Mexico's Gulf of California far to the south.

The Colorado's drainage basin is vast. It covers 242,000 square miles in the United States, or one-twelfth of the country's continental land area, and 2,000 square miles in Mexico. Parts of seven large Western States lie within its confines.

The mighty river slashes through all in its path. It has gouged the rock of the mesas into gorges and chasms. One of the gorges, the Grand Canyon, is world famous—a titanic cleft 217 miles long, from 4 to 18 miles wide, and a mile deep.

Below the canyons, the Colorado makes its way through wide, sloping desert plains bordered by low mountain ranges—the hottest, driest region in the United States. Here temperatures can run as high as 125° Fahrenheit. The sun shines almost every day in the year and, except for devastating thunderstorms now and then, there is very little rain. Bone-dry and shimmering in the heat, this is an American Sahara.

The Exploring Spaniards Come

Venturing north from Mexico into what is now southern Arizona, Spanish conquistadors and missionaries were the first white men to penetrate this

Aerial view of Hoover Dam and surrounding area.

forbiddingly arid land. They found the desert wastes peopled to some extent with Indians—Pimas, Maricopas, Papagos, and, near the junction of the Gila and Colorado Rivers, the Yumas and the Cocopahs.

The Spaniards discovered also traces of earlier inhabitants who had, apparently, developed cultures of a fairly high order. Imposing ruins of communal architecture—multifamily dwellings sometimes three and four stories high—testified to the achievements of a bygone age.

How the Indians and their predecessors wrung a living from the desert was explained by the canals and ditches which the Spaniards saw bringing precious river water to fields of maize, beans, calabashes, squash, and melons. Cotton and possibly tobacco also were grown by the primitive irrigators. Thus the art of irrigation, probably introduced into the area around the beginning of the Christian era, has been underwriting human existence and promoting a succession of cultures in the lower Colorado River basin for nearly 2,000 years.

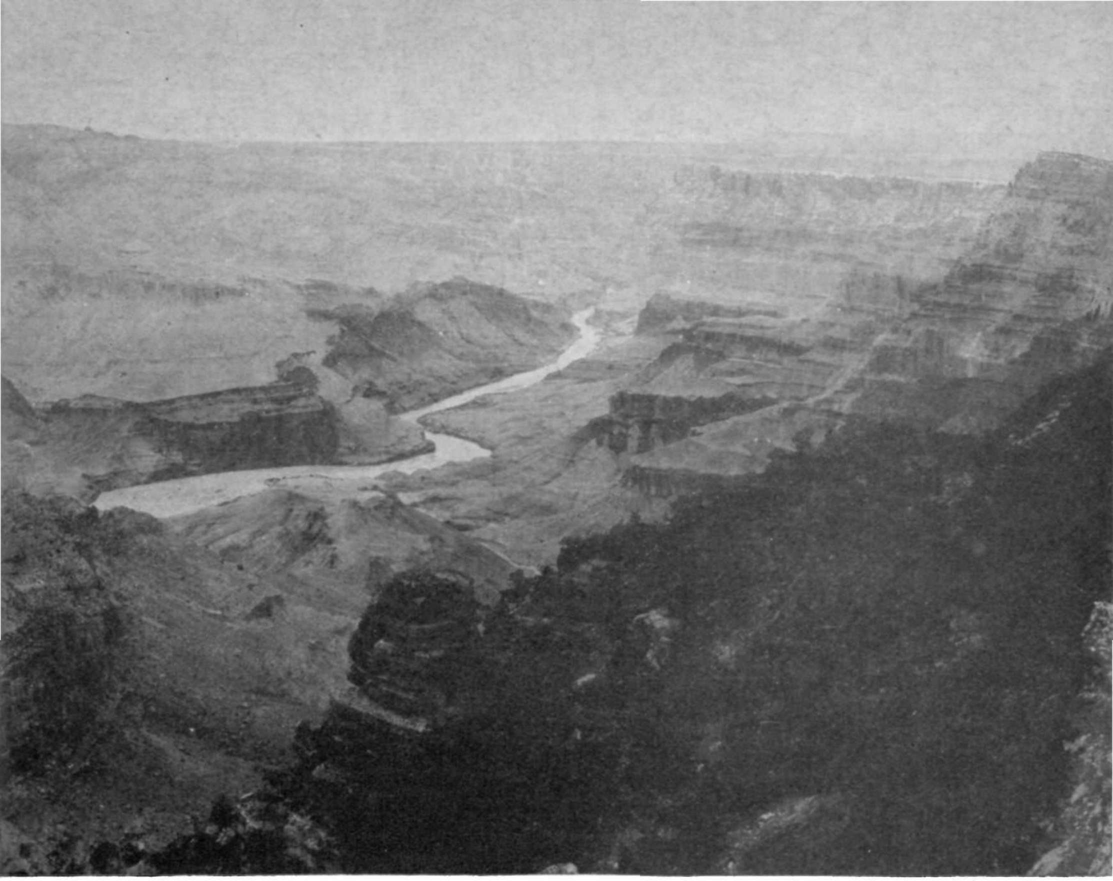
In 1539 the Spanish explorer Francisco de Ulloa sailed into the Gulf of California with a fleet of three vessels. Reaching the head of the Gulf, he deduced from the roiling, turbid waters the existence of a large stream somewhere in the immediate proximity. Although he did not see the river, he drew a map showing its supposed location.

The following year—in 1540—Hermando de Alarcon was dispatched to the Gulf with instructions to sail up the coastline until he made contact with Coronado's overland expedition, just then starting northward from Mexico to search for the fabled seven cities of Cibola. Alarcon could not carry out his assignment—the geography of the area was not quite what those early adventurers supposed—but he did discover the Colorado River. He ascended the stream for a short distance, making his way to a point a little above the Gila River's junction with the Colorado.

It was in 1540 also that Cardenas, one of Coronado's lieutenants, led a small expedition of a dozen men across the Hopi Indian country in northern Arizona—and suddenly found himself on the brink of the Grand Canyon. But he did not linger long beside the mighty chasm he had discovered. Food and other supplies were difficult to obtain, and the very nature of the terrain made even a rough reconnaissance of the canyon itself impossible. After several abortive attempts to descend the sheer rock walls, Cardenas and his men turned back eastward.

Nor was Cardenas the last to be halted on the brink of the canyon. Early explorers and missionaries were consistently balked by the awful depths, and it was not until two centuries had elapsed that a river crossing in the canyon country was successfully negotiated.

On July 29, 1776, a party of ten led by Father Silvester Velez de Escalante left Santa Fe, N. Mex., to find a northern route to Monterey on the Pacific Coast. Crossing the Colorado River just west of Grand Valley, Colo., the party made its way westward, crossed and came down the western slope of the Wasatch Mountains to Utah Lake, near Provo, by way of the Spanish Fork. Then, beset by the rigors of winter, Father Escalante and his com-



Grand Canyon of the Colorado—View from Navajo water tower.

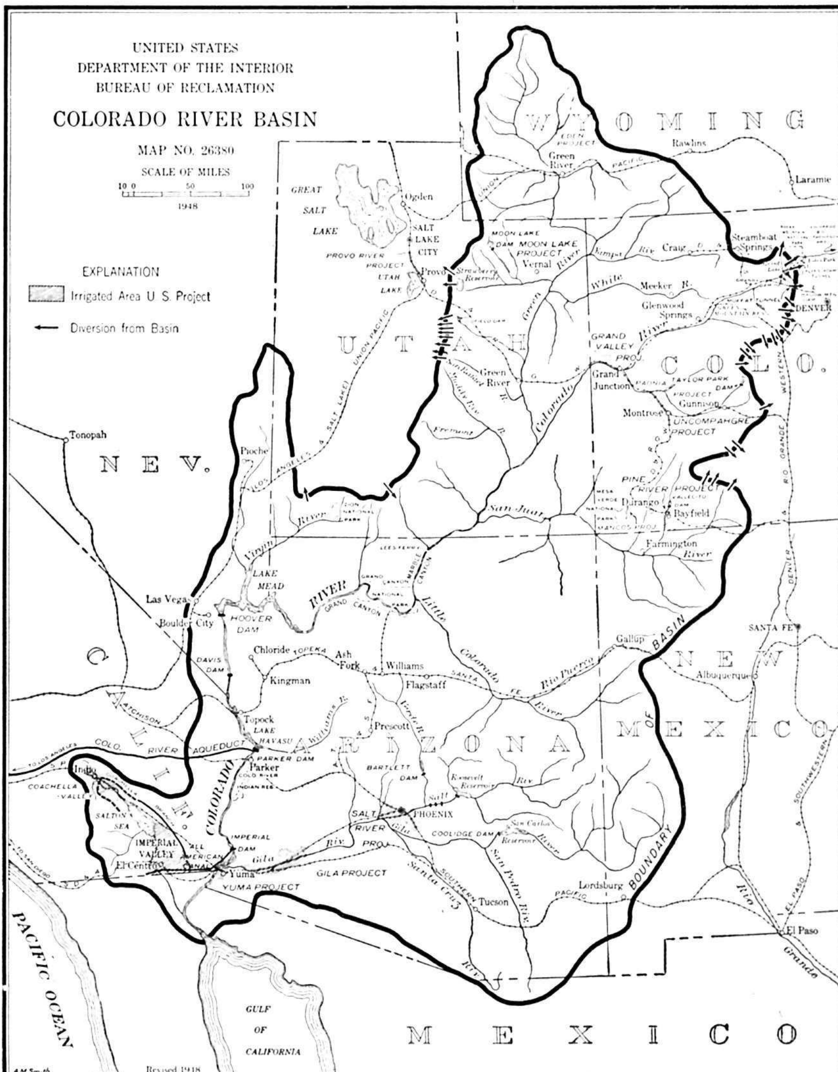
panions abandoned their original plans and turned south to return to Santa Fe. They crossed the Virgin River into northwestern Arizona and turned east across the Kanab. Food ran out, and they encountered incredible hardships. Early in November they reached the Colorado and finally achieved a crossing just north of Lee Ferry in Glen Canyon at a point thereafter to be known as the "Crossing of the Fathers."

It is not surprising that Colorado River lore during the two centuries that followed the advent of the white man consisted more of legend than of fact. The idea that the river was a long, narrow strait separating California from the mainland persisted for many years. Then there were rumors that the stream ran a subterranean course for hundreds of miles. In any case, it was agreed, to attempt a voyage downstream by boat from the river's higher reaches would be to court certain death.

A Dangerous Obstacle

Many rivers have served as arteries for exploring the wilderness. But the Colorado blocked rather than helped exploration. Travelers found it a dangerous obstacle and often detoured hundreds of miles to avoid its hazards and bypass its canyon sections. The venturesome few who attempted to trace its course were punished for their temerity with extraordinary hardship and even with death.

The river, during the days of early western travel, could be crossed at only a few favorable points. When gold was discovered in California late in 1848, hordes of adventurers flocked westward in response to its beckoning gleam. Many of them followed a southern route that took them across the Colorado near its junction with the Gila—10,000 people, accord-



ing to one historian, crossed the Colorado at the mouth of the Gila in 1849–50. But the canyon area several hundred miles to the north still remained an unconquered obstruction for man to master at some future date.

The treaty ending the Mexican War in 1848, and the Gadsden Purchase which was ratified in 1854, added the territories of New Mexico, Arizona, and California to the United States. With lands along the lower Colorado thus passing into this country's possession, the generally unknown stretches of the river needed to be explored.

In 1857 the War Department dispatched Lt. J. C. Ives to the task, instructing him to proceed up the river by boat as far as navigation was practicable. Ives started his trip early in 1858 and, although encountering many difficulties, 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. He then proceeded by skiff through the canyon, past the point where Hoover Dam would one day interpose its mighty bulk, and reached Las Vegas Wash approximately 3 miles upstream from the gorge.

Interested primarily in the Colorado's potential as an avenue of transportation, Ives submitted a report which was generally favorable, if conservative. In his letter of transmittal, addressed to Capt. A. A. Humphreys, he said:

> I would again state my belief that the Colorado would be found an economical avenue for the transportation of supplies to military posts in New Mexico and Utah. . . . The first organization of transportation establishments, to connect the upper part of the river with the interior of the Territories mentioned, would be attended with expense and trouble; but I am convinced that it would ultimately be productive of a great saving in both. . . .

Of the Grand Canyon area farther up the river, which he also visited, Ives had this to say, however:

> The region last explored is, of course, altogether valueless. It can be approached only from the south, and after entering it there is nothing to do but to leave. Ours was the first, and will doubtless be the last, party of whites to visit this profitless locality. It seems intended by Nature that the Colorado River, along the greater portion of its lonely and majestic way, shall be forever unvisited and undisturbed.

In 1869 Major John Wesley Powell succeeded in leading a river expedition, conducted under the auspices of the Illinois State Natural History Society, through the canyons of the Colorado. Funds for the undertaking were supplied by various individuals and by institutions such as the Illinois State Normal University, the Illinois Industrial University (now University of Illinois), and the Chicago Academy of Sciences.

Powell's party traveled downstream from the Green River in Wyoming to the mouth of the Virgin River in Nevada. Covering 1,000 miles of uncharted rapids and treacherous canyons, Powell and his companions became the first white men to gaze up at the sheer walls of Grand Canyon and live to tell the story.

Even before Lieutenant Ives and Major Powell were exploring the upper river, there were those who saw the possibilities of using water from the lower Colorado to irrigate the rich and fertile lands in southern California's Imperial Valley. The idea is reflected in several writings of the fifties. However, it was not until the nineties that actual development took place.

The California Development Co., a privately owned enterprise, undertook construction of irrigation canals in 1896. In 1901 the first Colorado River water reached Imperial Valley fields, flowing through a canal which looped through Mexico for about 60 miles and followed for much of its way the course of the old Alamo River, one of the Colorado's overflow channels. But the problem of a stable water supply for the valley's irrigated lands was far from solved.

Flood . . . and Drought

Like other western desert streams, the lower 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 inundated flood-plain areas for miles around. Following these high-water periods, the flow might diminish until it ran only 3,000 or 4,000 cubic feet per second. Large flash floods from such tributaries as the San Juan, the Little Colorado, the Bill Williams, or the Gila Rivers infrequently punctuated the periods of low flow.

The river in times of flood carried immense quantities of sediment which deposited in irrigation canals and created serious problems of water delivery and maintenance. In the arid Southwest, growing crops rapidly wither and die if irrigation water is withheld. So the clogging of headworks and canals with sediment, preventing water deliveries to the fields awaiting them, constituted a major irrigation problem along the lower Colorado River in the early 1900's.

Irregularities of river flow presented additional difficulties. Flood flows increased the expense required for headworks and levees. Low flows in the river called for special measures for diversion and set an eventual limit to the irrigated area which was undergoing such rapid expansion in the early part of this century.

The Colorado River's spectacular break-through into the Imperial Valley in 1905 was due to a combination of sediment difficulties, off-season flash floods, and regular seasonal high water in the spring and early summer.

The fertile Imperial Valley can be likened to a deep saucer whose lowest point, the Salton Sink, was in 1900 about 280 feet below sea level. The saucer's southeastern rim, along which the Colorado River flowed for a certain distance, was roughly 100 feet above sea level near the international boundary in California. The descent from the rim of the saucer to the Salton Sink, if once established on a uniform grade, would be much steeper than the descent in the other direction to the Gulf of California.

The headgate to the Imperial Canal, which in those early days transported

Colorado River water to the Imperial Valley, was located in California about 100 yards north of the international boundary line. Thence the canal ran south, paralleling the Colorado River for 4 miles. Next it turned west, away from the river, and followed the Alamo River channel, an old river course which made its way to the Salton Sink.

The spring flood of 1904 left the upper 4 miles of the Imperial Canal—the stretch paralleling the river—badly silted. When the high water receded, the irrigators below would have been short of water had not the canal company, by October 26, 1904, dredged a bypass leading directly from the river to the point where the canal made its westward turn.

No regulating gate was provided in the bypass—the company intended to close the opening well before another year's regular spring and summer floods were due. Floods during the winter season had been so rare for more than two decades past that no particular concern was felt on that score. But the winter of 1904–5 proved an exception, and by March 1905 three heavy floods had already come down the river. Following the third off-season flood prompt measures were taken to close the bypass, but it was too late. A fourth and then a fifth flash flood came along, destroying the dams intended to plug the cut from the river to the canal.

The flow through the bypass started cutting away the sand and soft alluvial soil. As the Colorado deepened the canal, it swung into a new course, utilizing the bypass, the canal, and the Alamo and New River channels, and began discharging its entire flow into the Salton Sink. The river was out of control until November 4, 1906, when a first closure of the canal was effected. Then on December 5 a second flood, originating on the upper Gila, came down the Colorado, breached the levees, and rediverted the river into the Salton Sea via the Imperial Canal. By this time, however, the technique of handling the unruly river was better developed. This break was closed February 10, 1907.

For about 16 months the river had created havoc in the Imperial Valley, threatening lives, ruining farms and agricultural land, destroying highways, homes, and improvements. The Southern Pacific Railroad, which had been forced to move its tracks to higher ground, ultimately threw its resources and engineering skill into the battle and, at a cost of nearly $3 million, made the final closures.

One good did come from the bout with the river: the deeply excavated Alamo and New River channels through which the Colorado had poured its flood waters provided the start of a good drainage system for the Imperial Valley.

But the fight actually had only begun. The Colorado's natural regimen through the delta had been upset during the time it was flooding Imperial Valley. Overbank flow of the river to the south of the main canal during the summer floods of 1907 and 1908 started erosion fingers cutting back from the low area to the west. The river, it became apparent, could take a new course if one of these fingers should cut back to the main channel—

and that is exactly what happened during the summer flood of 1909. After the flood passed, the entire flow went down the Bee River—another of the Colorado's old overflow channels—to Volcano Lake. Thence, fortunately, it drained off through the Hardy's Colorado channel and eventually reached the gulf—fortunately, because it certainly would have been a physical possibility for the flow from Volcano Lake to follow New River into the Imperial Valley.

So the fight with the river went on, calling for more and more levees and piling up expense. The Government appropriated a million dollars in 1910 for the Ockerson levee, along the west side of the river, to put the Colorado in its old channel and keep it there. That levee failed. Other levees, elsewhere, had to be built. The continual deposit of sediment at critical places made high and then still higher embankments necessary. Expense to combat sediment and floods mounted to over half a million dollars a year, yet the threat was not abated.

Any lowering of the river, such as that following the break into the Bee River, meant diversion difficulties and shortages during periods of low flow. And when the river was low, junior appropriators upstream dipped into the short water supply.

For the Imperial irrigation project it was a continuous, harassing fight, come high water or low. Without greater control over the Colorado, the situation was going to become intolerable.

And the Imperial Valley was not the only area along the lower Colorado suffering from the vagaries of the river and its tributaries. There was the Yuma Valley where the growing city of Yuma and the Bureau of Reclamation's Yuma project, undertaken in 1902, were located. These lowlands, too, felt the punishing effects of both Colorado and Gila River floods.

As early as 1893 a levee less than a mile long, costing $10,000, was built along Yuma's eastern boundary to protect the town from Gila River rampages. Between 1905 and 1908 the Government built a levee south from Yuma to the Mexican border, and from 1909 to 1912 it spent $240,000 on levee construction to safeguard the project. Yet, when 200,000 second-feet of flood water came down the Gila in January 1916, the levees were breached, water stood 4 feet deep in the streets of the town, and project lands were inundated.

The Bold Decision

Faced with constantly recurring cycles of flood and drought, the people of the Southwest appealed to their Government for help. Reclamation engineers saw clearly the solution to the problem—harness the untamed river and control its flow so that the low-lying valleys would be protected against floods and assured a stabilized, year-round water supply.

Uncontrolled and unregulated, the Colorado had limited value. The yearly spring runoff followed by rainless months made large irrigation or power developments uncertain and unprofitable unless control measures could be established. The undependable, silt-laden flow of the stream was not at all suitable for municipal water supplies. Nor did it allow for any expansion of lands under cultivation—already more land had been reclaimed by irrigation than could be sustained by the river's natural flow.

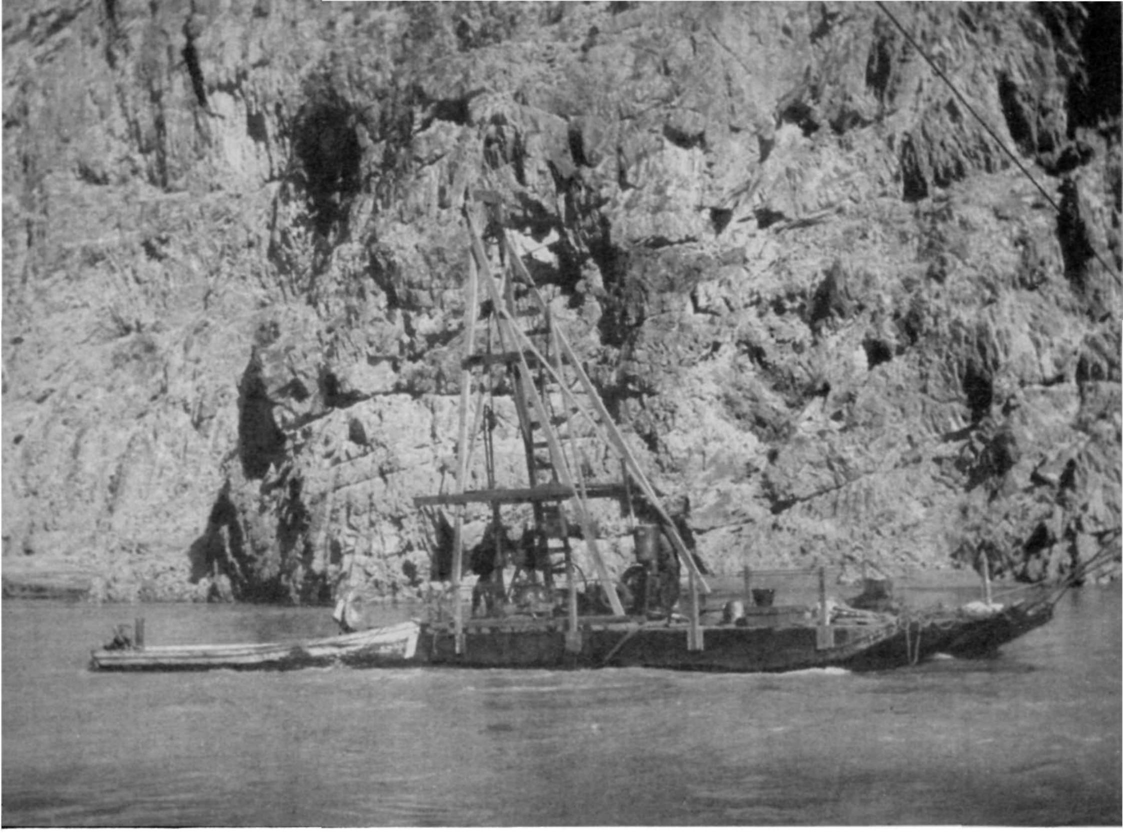
With the river dammed and under control, the danger of recurring floods or droughts would be ended. And there were many possible damsites along the course of the Colorado.

The area tributary to the Colorado is, by nature, roughly divided into an upper and a lower basin. To simplify negotiations over the water of the Colorado River, advantage was taken of this natural geographical subdivision of the river basin. The "upper basin," it was agreed, should include the drainage area above Lee Ferry, a point 1 mile downstream from the mouth of the Paria River; and the "lower basin" should include all the drainage area downstream from Lee Ferry.

The two basins are about equal in area. Just below Lee Ferry is the lower basin's canyon region—a 350-mile bottleneck through which the Colorado has battered its way for countless eons of time. The major gorges begin at Lee Ferry and end with Black Canyon.

A comprehensive plan of development required detailed data from both upper and lower basins. Reclamation and United States Geological Survey engineers investigated a total of 70 dam and reservoir sites along the entire course of the river.

Looking upstream through Black Canyon toward Boulder dam site before construction activities were begun.



Boulder Canyon. New 36' x 15' drill barge at work on Hole U200N120.

The upper basin sites at that time considered to be the most suitable were: the Flaming Gorge site on the Green River in northern Utah, with 4,000,000 acre-feet in potential reservoir capacity; the Juniper site on the Yampa River in Colorado, with 1,500,000 acre-feet; and the Dewey site on the Colorado in eastern Utah, with 2,370,000 acre-feet.

From the standpoint of lower river regulation, all of these sites left much to be desired. In the first place, none of them offered sufficient storage capacity for adequate river regulation. They were too far from the places where regulation was most needed. Hundreds of miles separated them from the irrigable fields of Arizona and California. Also, there were too many tributaries below these sites capable of causing destructive floods.

In the lower basin two excellent sites were found—Boulder Canyon and Black Canyon. Each offered potential reservoir capacity of over 30,000,000 acre-feet. However, each site posed engineering problems of unprecedented proportions.

The Black Canyon Site

Reclamation engineers, with control of the lower river as their primary concern, recogized that the lower basin sites were obviously the ones to study. Their intensified investigations, including geologic and topographic surveys starting in 1919, revealed the superiority of Black Canyon over Boulder Canyon in several respects. The depth to bedrock was less in Black Canyon, the geologic structure was better, and a dam of lesser height would give the same reservoir capacity.

From 1920 to 1923 men lived in Black Canyon, diamond drilling and testing the rock. The rock had to guarantee an unquestionably sound foundation—it was going to support the highest dam that the world had ever seen.

The proposed dam would be so high that its reservoir could store the entire flow of the Colorado River—including all average floods—for 2 whole years. Furthermore, it would be located below the large tributaries and thus would provide for their control. The dam would create a power head within transmission distance of the power markets of southern California. And it would be in the midst of a heavily mineralized region in Nevada and Arizona where low-cost power could be a boon to strategic metal production.

The engineering problems were formidable, and even the elements of nature seemed to conspire against those pioneers of river control. But in spite of summer temperatures of 125° in the canyon, cloudbursts, high winds, and sudden floods, the work of surveying the dam site went forward steadily.

In 1918 the United States Department of the Interior and the Imperial Irrigation District, successor to the California Development Co. in the Imperial Valley, entered into an agreement providing for investigations, surveys, and cost estimates on the construction of a canal extending from the Colorado River to the Imperial Valley and lying wholly within the boundaries of this country. The surveys were to follow a general plan agreed upon by a joint board consisting of one representative each of the Government, the District, and the University of California.

The All-American Canal Board, appointed under this agreement, submitted its report during the summer of 1919. On the basis of its findings it recommended construction of an all-American canal and provision of large storage reservoirs on the Colorado River by the United States Government.

The first All-American Canal bill—often spoken of as the first Kettner bill—was introduced in Congress about the time the All-American Canal Board submitted its report, but the bill never came to a vote as the Congress was not satisfied with available data.

The Kinkaid Act authorizing and directing the Secretary of the Interior to make an examination and report on the condition and possible irrigation development of the Imperial Valley was passed in May 1920. Approximately one-half of the cost of this examination and investigation was paid by the United States and the other half by local interests.

In 1921 Arthur P. Davis, then director of Reclamation, reported to Secretary of the Interior Fall on the results of the Colorado River investigations. Shortly thereafter in February 1922 the "Fall-Davis report," recommending that the Government undertake construction of the All-American Canal and a high dam at or near Boulder Canyon on the Colorado, was transmitted to the United States Senate.

In 1924 Reclamation's chief engineer, F. E. Weymouth, submitted eight volumes of precise data to the Secretary. This "Weymouth report," which represented 2 additional years' work under the Kinkaid Act, emphasized the feasibility of a dam at Boulder or Black Canyon (also known as Lower Boulder Canyon) in the lower basin.

Then the Senate Committee on Irrigation and Reclamation, in its report of March 1928, agreed that "The overwhelming weight of opinion favors the Boulder or Black Canyon site . . . Natural conditions at this site are extremely favorable for the construction of a great dam at a minimum cost."

A board of consulting engineers also reviewed the feasibilities of the two sites in the lower basin. This board agreed with the Bureau of Reclamation that Black Canyon was the bettter choice.

Thus, the site of this projected dam—to become one of the major engineering accomplishments of all time—was settled. However, the engineering technique was but one phase of the overall problem of river control. Another phase—the legislative—also had to be solved.

The most difficult legislative aspect had to do with equitable division of the water of the Colorado, for the people who lived in the basin were dependent 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 upon which they resided.

Rights to Water

The prospective building of a large dam in the lower Colorado River basin led to an understandable apprehension on the part of basin States other than California.

The basic doctrine of water law recognized in all the basin States excepting California was that of prior appropriation and use. In other words, the person or agency complying with the required preliminary legal formalities and first appropriating water for beneficial use thereby secured a first right to its use.

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 the water flowing past his property. Other basin States had abrogated the riparian doctrine within their borders and held to the appropriation doctrine to which—to that extent—they were committed.

The building of a large dam would place California in a position to put a large amount of Colorado River water to beneficial use. The State seemed to have the financial resources and, obviously, she had the inclination to proceed with a large irrigation development.

There would not be enough water for all potential developments in the basin. Under the doctrine of appropriation, what was to prevent California from getting the lion's share of the Colorado's flow by being first with water development?

All of the States involved could see, theoretically, the advantage of a great dam in the lower basin; but in all cases, they were concerned about its effect on their individual fortunes. They were haunted by the bad dream of seeing "their" water leave their borders, committed to a State whose better fortunes had enabled her to make first use of the water.

The ideal solution, it appeared, would be for all the basin States to agree in advance upon their respective rights. Certainly, without some sort of agreement any large-scale development on the Colorado would be hopelessly deadlocked.

In 1920 a meeting of representatives of the governors of the basin States endorsed the proposal for an interstate compact. The Wyoming Legislature authorized the appointment of a compact commissioner in February 1921. Arizona followed, and before the middle of the year all of the States had provided for such appointments. Following authorization by an act of Congress, President Harding on December 17, 1921, appointed a Federal representative on the commission—Herbert Hoover, then Secretary of Commerce. A little over a month later, on January 26, 1922, the Colorado River Commission held its first meeting in Washington, D. C., and elected Mr. Hoover as its presiding officer.

The first idea was to devise a compact that would divide the water among the individual States, but agreement on this proposition was impossible. Delph E. Carpenter, of Colorado, is given credit for proposing a big forward step—a step that did clear the way to agreement. Water would be apportioned to two groups, the upper and the lower basin States; and the division of water between the individual States would be left to future agreement.

The compact was signed by the members of the commission on November 24, 1922, at Santa Fe, N. Mex., and is often referred to as the Santa Fe Compact. Ratification by the legislatures of the basin States and the United States followed over a period of years.

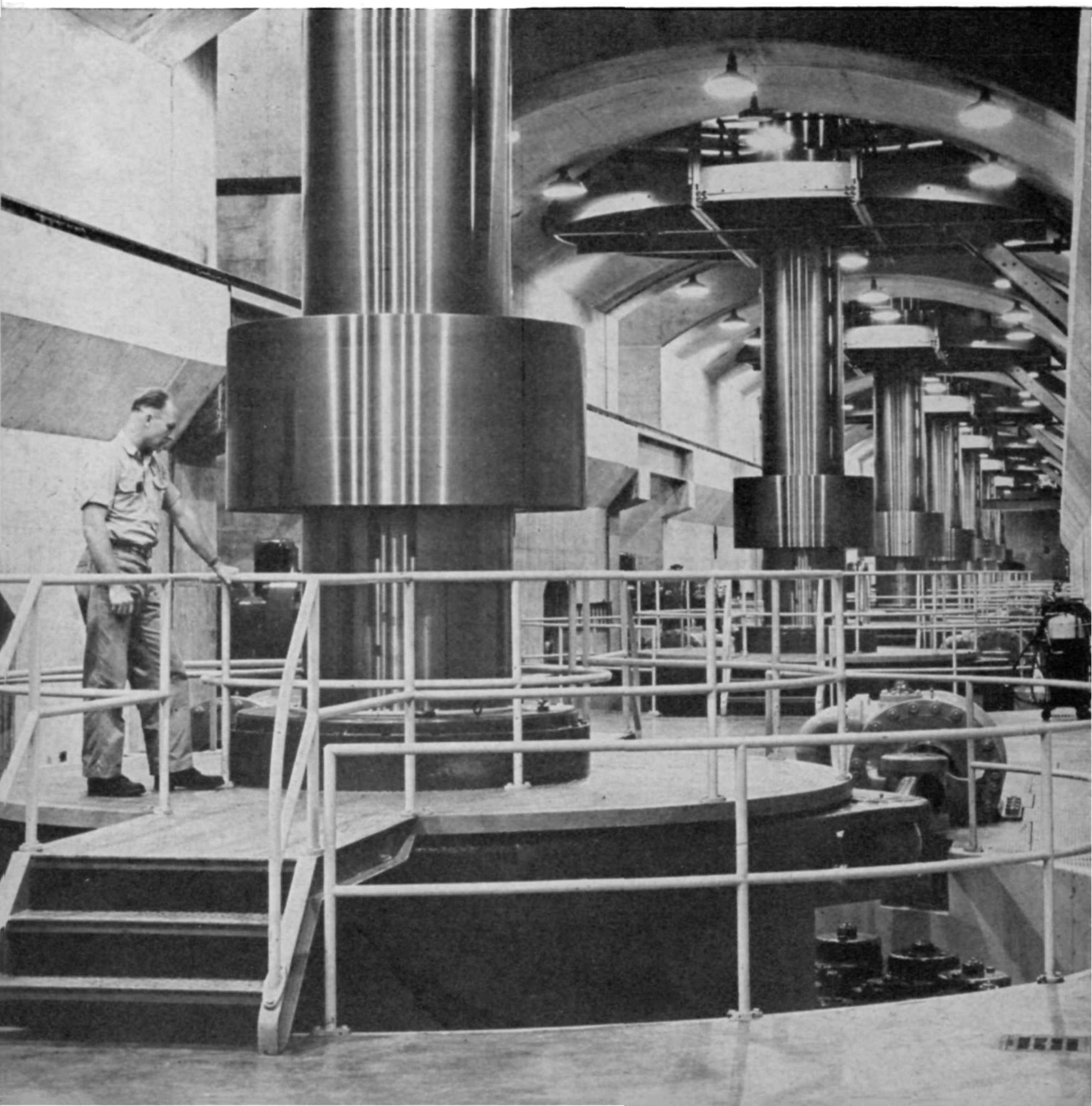
The Colorado River Compact divided the Colorado River Basin into the Upper Basin and the Lower Basin. The division is at Lee Ferry, a point in the main stream of the Colorado River 1 mile below the mouth of the Paria River and a few miles south of the boundary common to Utah and Arizona. The term "Upper Basin" means those parts of the States of Arizona, Colorado, New Mexico, Utah, and Wyoming within and from which waters naturally drain into the Colorado River system above Lee Ferry, and also all parts of said States located without the drainage area of the Colorado River system which are now or shall hereafter be beneficially served by waters diverted from the system above Lee Ferry.

The term "Lower Basin" means those parts of the States of Arizona, California, Nevada, New Mexico, and Utah within and from which waters naturally drain into the Colorado River system below Lee Ferry, and also all parts of said States located without the drainage area of the Colorado River system which are now or shall hereafter be beneficially served by 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 annum, and, in addition to such apportionment, gave to the Lower Basin the right to increase its beneficial consumptive use of such water by 1,000,000 acre-feet per annum.

The Colorado River Compact made no apportionment of water to any State. On October 11, 1948, the States of the Upper Basin entered into the Upper Colorado River Basin Compact for the apportionment of the

Turbine gallery in the Hoover Dam powerplant.



use of the waters of the Upper Basin. Although the Boulder Canyon Project Act authorized the States of Arizona, California, and Nevada to enter into an agreement relating to the waters of the Lower Basin, such an agreement has not been entered into and the claims asserted by the States with respect to the waters of the Lower Basin are in conflict and dispute.

The Boulder Canyon Project Act

On December 21, 1928, the Boulder Canyon Project Act, presented to the Congress in the fourth Swing-Johnson bill, became law.

As passed, the Boulder Canyon Project Act—

Approved the Colorado River Compact and provided that in the event only six States should ratify, the compact should become effective as a six-State compact, provided that California should agree to limit her use of water for the benefit of the other six States;

Authorized the construction of a dam at Black Canyon or Boulder Canyon;

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

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

Six of the States immediately ratified the compact. Arizona withheld ratification until February 1944.

Authorization of the great dam listed the following purposes:

Flood control;

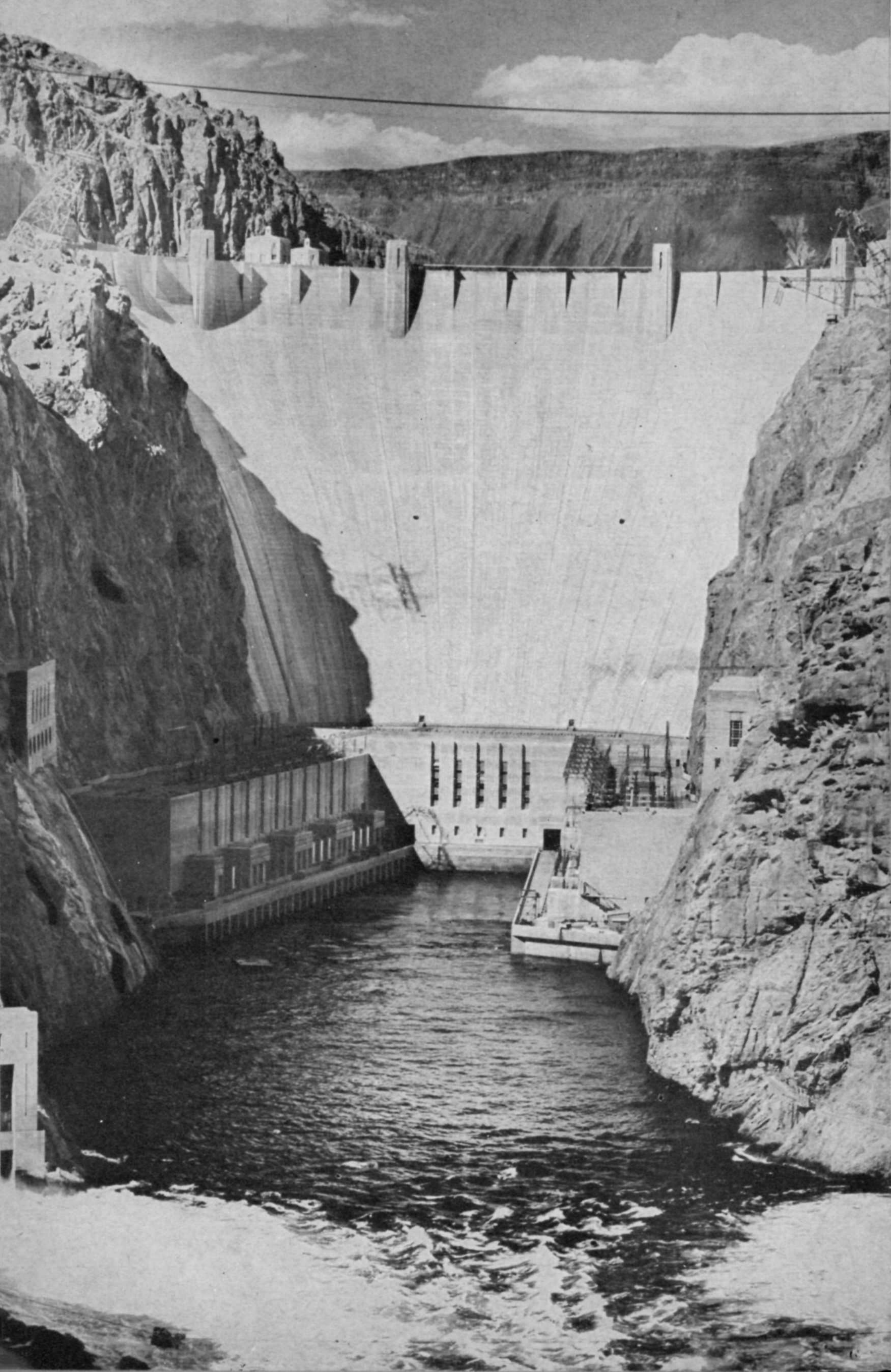
Improvement of navigation and regulation of the flow of the Colorado River;

Storage and delivery of stored waters of the Colorado River for reclamation of public lands and other beneficial uses exclusively within the United States; and

Generation of electrical energy.

The act established a special fund—the "Colorado River Dam fund"—for financing construction and authorized the transfer to it from the Treasury of $165 million. A condition precedent to the construction of the dam was that the Secretary of the Interior should provide for revenues adequate to insure operation, maintenance, and amortization. These revenues were to repay, within 50 years, all advances for the construction of Hoover Dam and powerplant with interest, except for $25 million allocated to flood control, repayment of which—without interest—could be deferred until after the interest-bearing portion of the debt was paid. Revenues were to come mainly from the sale of electrical energy generated at the dam. The necessary contracts to cover the sale of energy for the payment of the dam's construction costs were speedily negotiated.

The stage for the drama of actual construction was set. Work could begin. The Bureau had a job which would draw to the uttermost on its quarter of a century of experience and skill.



the dam

THIS booklet does not attempt to present, in minute detail, engineering techniques or technical data. Rather, it tries to outline in broad terms the varied ramifications of the Boulder Canyon project. Therefore, description of construction procedures has not been undertaken. For those interested in the technical features of design and construction, a full treatment is available in the Boulder Canyon project reports. Several of the bulletins included in these reports have already been published and may be obtained from the office of the Assistant Commissioner and Chief Engineer, Bureau of Reclamation, United States Department of the Interior, Denver Federal Center, Denver, Colo., Attention: 841.

The Fundamental Problem

After legislation authorizing the Boulder Canyon project had been passed, the problem of construction was placed squarely before the Reclamation engineers. To achieve the purposes set forth in the legislation, the low-lying valleys of Arizona and southern California must be protected from yearly threat of flood. The annual spring runoff must be stored for later use. The sediment problem of the river had to be solved. And a powerplant large enough to use economically the full flow of the river ought to be provided.

A huge dam, obviously, would be the key to the whole problem. To harness the river effectively and obtain the desired objective, this dam would have to be the highest in the world—726.4 feet from bedrock to crest. A structure of this height would create a reservoir large enough to store safely

Hoover Dam and powerplant as seen from the downstream side.

the normal flow of the river for 2 years. Measured by volume, such a 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—water enough to cover the entire State of New York 1 foot deep. And the lake would store more than water: it would trap the millions of tons of sediment which the Colorado carried downstream every year. Therefore, it had to be large enough to hold the sediment without seriously impairing its efficiency as a reservoir or interfering with the generation of power.

The dam which the engineers proposed to build would, they were sure, create the necessary reservoir and make possible the construction of a powerplant capable of producing 6 billion kilowatt-hours of energy annually.

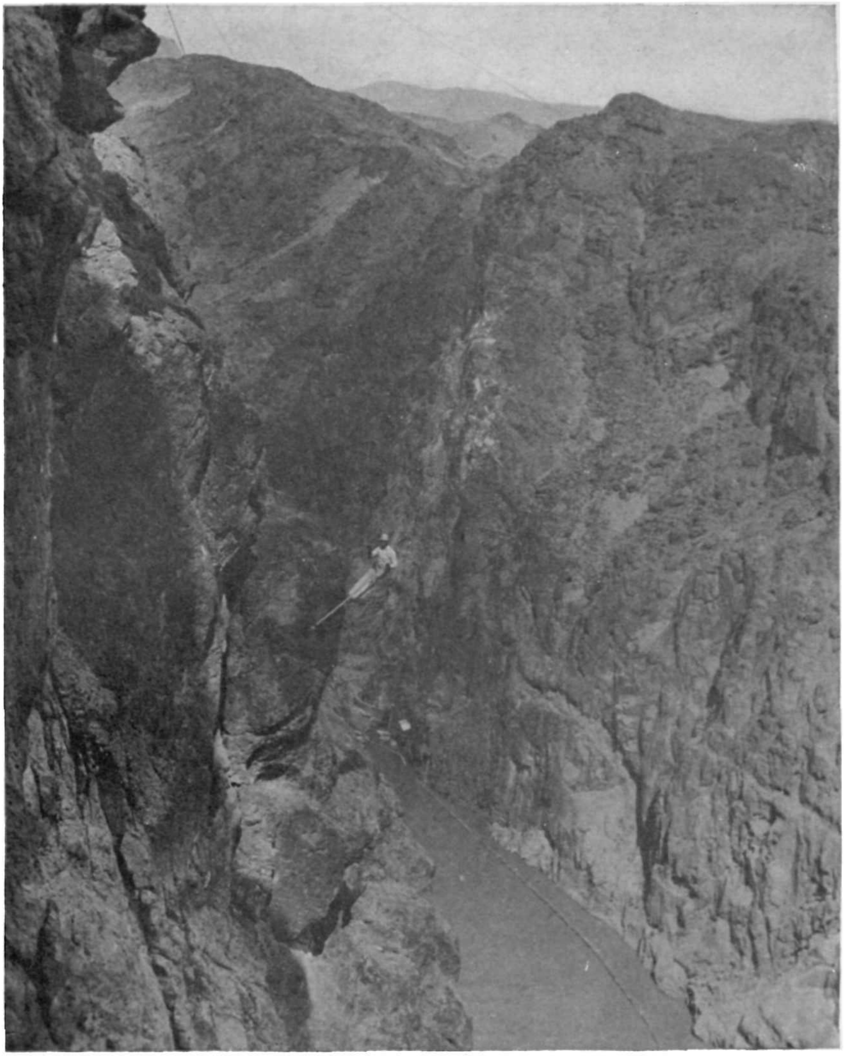
As is so often the case in new undertakings that go beyond precedent, there was opposition. Some of it was clearly biased or irresponsible, but some of it was obviously sincere and came from engineers and others of recognized standing. Of the more responsible critics, there were those who looked on the dam as a potential white elephant, financially speaking—they believed that many years would elapse before the power market would absorb the energy produced. Others pointed out the possibility that the fluctuating reservoir, loading and unloading the earth's crust, would set up earthquakes of destructive magnitude. The difficulty of controlling the river during construction was magnified to seem insuperable. Filling of the reservoir with sediment so that its useful life would be insignificant was predicted. The question was raised as to whether unknown and unpredictable factors cast so much doubt upon feasibility that the whole idea should be abandoned. And in the minds of some lay the thought of what would happen if the dam should fail after it was built—the whole area below Black Canyon would face utter destruction.

Serious problems had to be solved. What contractor, for instance, would dare undertake such a mammoth job? The proposed dam site was in a desolate region where there were no transportation facilities or living quarters, and where there was nothing to afford protection from harsh and unfriendly natural elements.

All of these questions and problems raised and compounded real worries, but the Bureau of Reclamation went steadily forward with its exploration and preliminary work. Geologic examinations revealed good foundation rock. Former geologic faults that went through the block of rock on which the dam was to rest had long since healed—the block was sound. Challenges there were, but none that could not be met. The job could, and would, go on.

Specifications and drawings for the dam and appurtenant structures were being prepared in the Bureau's main design office in Denver, Colo. They were prepared at no leisurely pace. Washington had flashed word to push the design and specification work so that actual construction could start as soon as possible to create employment—the trying year of 1930 was upon the land.

The specifications were rushed to completion 6 months ahead of schedule.



Rigger-rodman with topography survey party in Black Canyon on Nevada side. Rodman is lowered over Black Canyon rim on rope and gives points which are recorded with both horizontal and vertical angle by two transit parties.

On March 11, 1931, the Secretary of the Interior awarded the labor contract for construction of Hoover Dam to Six Companies, Inc., of San Francisco, Calif., the lowest bidder. 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 was $48,890,995.50—the largest labor contract let by the United States Government up to that time.

Steps Preliminary to Construction

Before actual construction of the dam could begin, much preliminary work had to be done to insure successful completion of the gigantic task. Ways and means had to be devised to cope with the rigors of a forbidding desert. Facilities had to be provided for transporting material and equipment over miles of burning sand and onto the construction site 800 feet below the rim of the canyon.

It must be emphasized that all essentials for existing and working in the desert had to be planned and created, for the section in which the dam was to be built was utterly devoid of any provisions for modern living. Therefore, faulty planning would mean delays in construction, if not total failure, of the project. And it was the responsibility of the engineers and the contractor to plan so well that nothing of the slightest importance would be overlooked.

Facilities for transportation were needed first. The Union Pacific Railroad contracted to lay a branch line from Las Vegas to the site of Boulder City. From that point the Bureau of Reclamation would build its own railroad to the dam site. Highways were required. Machine shops, air-compressor plants, garages, and warehouses must be erected. The canyon had to be spanned, first by bridges and later by aerial cables. A great gravel-screening plant and two huge concrete-mixing plants had to be designed and constructed; and power draglines and power shovels, trucks, cars, derricks and cranes must be acquired in great numbers. Electric power for construction had to be brought 222 miles across the desert from San Bernardino, Calif.

The problem of living quarters required particularly earnest thought. There was no "labor pool" in the area, and construction workers had to be recruited from all parts of the Nation. Homes had to be provided—no ordinary construction camp would do. Nor could the workers be expected to live in the immediate vicinity of the dam site. There, temperatures in summer often reached 125°, with heat waves rising from the canyon as from a blast furnace.

After studying climatic and soil conditions in the area, Reclamation engineers agreed upon a location 7 miles southwest of the dam site. There, on a high plateau, a complete town was erected. Modern homes were built; lawns and parks were planted; streets were laid out and paved; schools, churches, and stores were erected. A sewerage system was installed, and Colorado River water was piped into the town. In short, a modern desert oasis was brought into being.

To assure the procurement and delivery of materials as needed called for further careful planning. Materials were going to be required in quantities never before shipped to a single construction job in so short a time—5 million barrels of cement, 18 million pounds of structural steel, 21 million pounds of gates and valves, and 840 miles of pipe were actually hauled over the railroad to the dam site during the first 4 years of construction.

The amassing of specialized machinery in quantities greater than ever before assembled demanded the most meticulous attention.

Huge trucks were procured to haul men, materials, and equipment—some of 16-cubic-yard capacity, others of 50-ton capacity, and still others for operations as 100- and 150-man transports.

Air compressor plants of 14,500 cubic feet per minute capacity were built near the dam site.

The sand and gravel screening and washing plant to provide the aggregate was the largest of its type. It could screen, wash, and place aggregate in readiness for mixture with cement and water at the rate of more than 16½ tons per minute.

Finally, recruiting an army of laborers for the job presented special problems in spite of the fact that the business depression of the early thirties had resulted in large numbers of unemployed workers. It was imperative that methods be devised to select men of proper type to do the work at hand.

The Government and the contractors together employed 5,250 men at construction peak, with a gross monthly payroll of more than $750,000. The workmen ate at a mess hall with a capacity of handling 1,300 men at one time. Single men were charged $1.60 a day each for meals, rooms, and transportation to and from the canyon. Married men rented houses, unfurnished, from the contractor for $15 to $50 a month.

The dispatch with which the job was ultimately accomplished bears lasting testimony to the efficiency of the men who planned it so carefully and executed it so effectively.

Plan of Attack

The general plan of attack in building Hoover Dam was to drive tunnels through the canyon walls around the site, divert the Colorado through the tunnels, build cofferdams to block off the river from the dam site, excavate the site, and build the dam and powerplant.

The narrowness 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 Colorado a ticklish one.

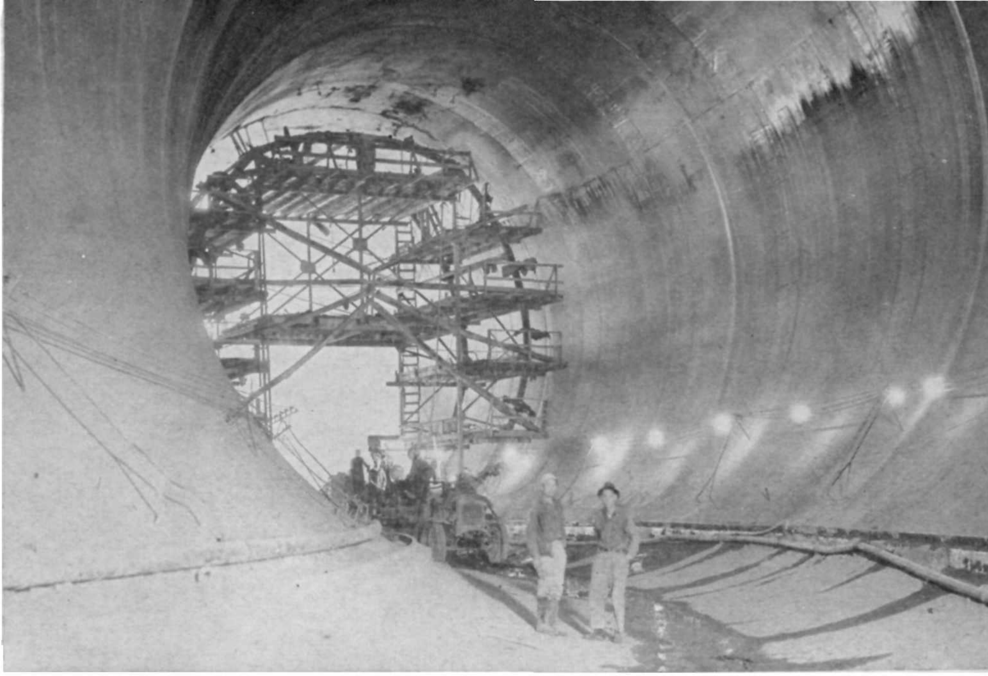
It had been decided to drive four diversion tunnels (two on each side of the river) around the dam site through the solid rock of the canyon walls. Two temporary cofferdams would then be built—one would be upstream, above the site but just below the tunnel inlets; the other would be downstream, below the site but upstream from the tunnel outlets. These cofferdams would block off the river so that the site could be pumped dry and excavated to foundation bedrock.

The four tunnels would serve another purpose when their use as diversion tunnels was completed. The two outer tunnels would become outlets for the huge spillways. The inner tunnels would be utilized for installation of penstocks to convey water from the intake towers in the reservoir to the powerplant or to the outlet valves below the dam.

The dispatch with which the diversion tunnels were driven by the contractor's forces forecast the efficiency and speed which was to characterize the whole construction schedule. Tunnel excavation was started in June 1931 and completed in November 1933.

An average blasting round broke 1,000 cubic yards of rock and advanced the heading 17 feet. A total length of 256 feet of tunnel was driven during one 24-hour period, and 6,848 feet were completed in a single month. Removal of the million and a half yards of rock in the 4 tunnels required 3,561,000 pounds of dynamite, or 2.38 pounds per cubic yard.

Blasting on the road being constructed by the Six Companies about half a mile downstream from Hoover dam site.



Completed tunnel lining at intake portal of diversion tunnel No. 4, looking toward entrance. Pressure for grouting jumbo seen in operation.

Each of the 4 tunnels was holed out to 56-foot diameter and then lined with a 3-foot thickness of concrete. The combined length of the 4 tunnels was approximately 3 miles.

In tunnel construction, the tunnel headings were attacked first by batteries of compressed-air drills. When the drills had bitten 10 to 20 feet into solid rock, a ton of dynamite was loaded into the holes. The electrically fired blast shook the walls of the canyon. The resulting loose rock and debris was loaded into trucks. The trucks roared away to dump their loads in side canyons.

The River Is Turned

With the completion of the two tunnels on the Arizona side of the river, steps were taken to begin actual diversion of the river's flow.

A temporary dam of earth and rock was thrown across the river just below the inlets of the two tunnels. Within 24 hours after starting this work, a dam of sufficient height to block the channel and force the water through the tunnels had been formed.

Meanwhile, downstream below the dam site, another cofferdam was pushed across the river's channel just above the tunnel outlets. This prevented the river from backing into the construction area.

The Colorado River had been diverted. With the cofferdams in place and the water diverted around the construction site, excavation for the foundation of the dam and powerplant proceeded swiftly. Manning huge power shovels, draglines, and other equipment, men labored 24 hours a day digging down through the mud and silt of the channel before reaching solid rock. More than half a million cubic yards of muck were removed.

Work also went ahead on the removal of loose and projecting rock from the canyon walls. To reach the desired spots, the "high scalers" either climbed up ropes or were suspended from anchors sunk in the canyon walls. They swung in safety belts or "bosun" chairs, pendulum fashion, hundreds of feet above the river and gouged at weak spots or drilled blasting holes. Nearly a million cubic yards of rock were dislodged from the walls of the canyon.

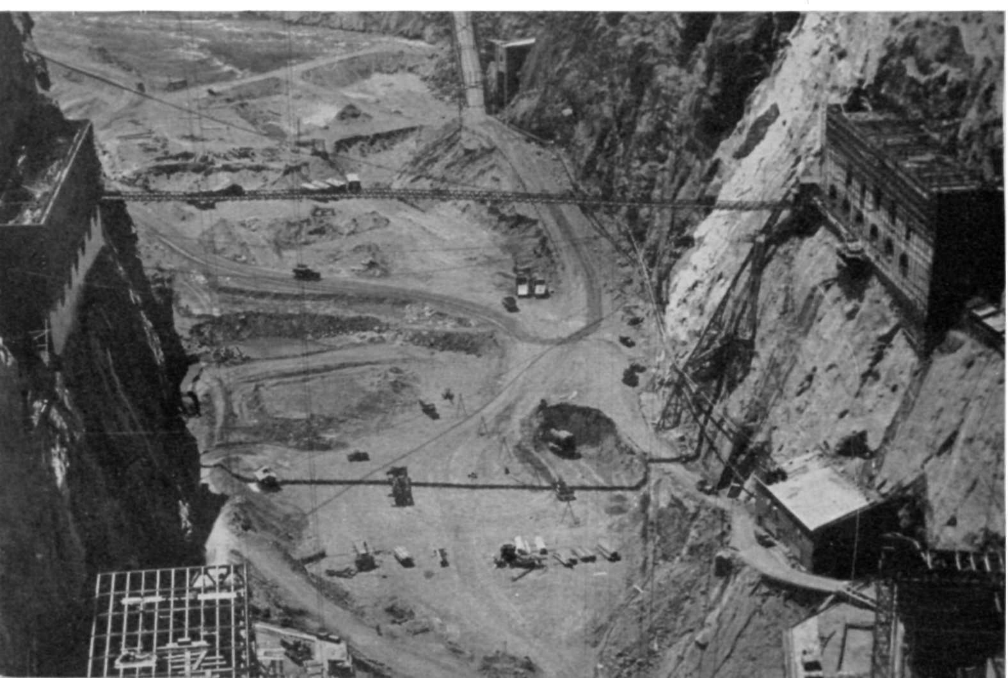
A Plate Steel Fabricating Plant Erected at the Dam Site

A major problem confronted the engineers when it came to procuring steel pipe for the penstock system. Penstock designs called for 2¾ miles of nearly 3-inch-thick plate-steel pipe, exceeding 44,000 tons in gross weight.

Standard railroad cars were not designed to carry so much weight. Nor would loads of such dimension pass through a normal railroad tunnel. It was obvious that the fabricated pipe sections could not be shipped from eastern plants.

The mountain would not come to Mahomet; neither could Mahomet come to the mountain. Here indeed was a problem for the engineers and fabricators. But they hit upon the solution. They would construct a plant at the dam site and fabricate the great pipe on the spot.

View looking downstream from crest of dam showing downstream section of powerplant, canyon wall outlet works and downstream cofferdam excavation.



Boulder Canyon. Eight cubic yard capacity bucket discharging load into dam forms at upstream face of dam.

Babcock & Wilcox, the contractor, erected a plant along the construction railroad a mile and a half from the top of the dam on the Nevada side of the canyon. Flat plates of steel were shipped to the plant and there fabricated into the required sections.

Special equipment was required for both fabricating and transporting the finished pipe sections to the dam site. Planers, rollers, presses, electrical equipment for welding the plates, and X-ray equipment for examining the welds were installed in the plant. A 200-ton trailer, pulled and controlled by two 60-horsepower caterpillar tractors, transported the heavier pipe sections from the plant to the canyon rim. From the rim of the canyon the pipe was transferred to a 150-ton cableway and lowered to the portal of one of the construction adits. Here, a specially constructed car received each section and conveyed it through the adit to the penstock header tunnel. Finally, it was pulled into position by winches and hoists.

Except for the 8½-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 were 3 inches in diameter. In welding, the weld and pipe near it were stress-relieved by heating with gas rings.

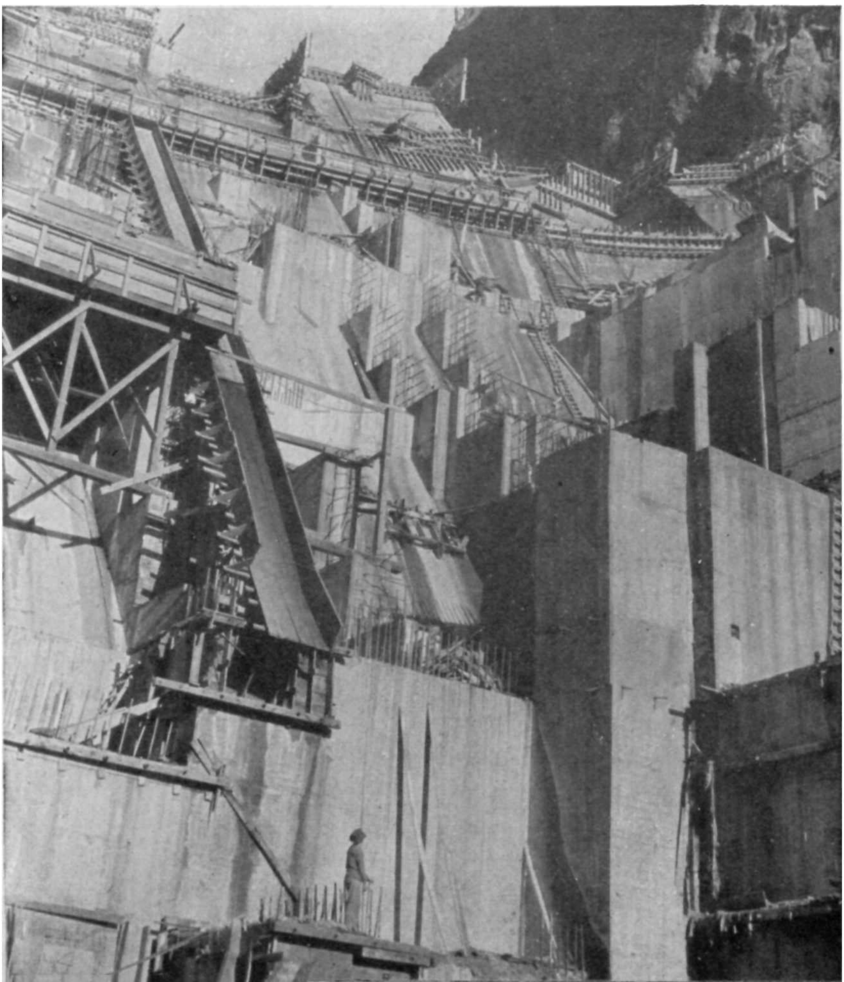
While the engineers were surmounting the difficulties of making and installing the great penstock pipes, the main job of concrete placement for the huge structure of the dam was being carried out swiftly. On June 6, 1933, the first bucket of concrete was placed. Six months later a million yards were in place. Another million was placed in the following half year, and the third million by December 6, 1934, only 18 months after starting placement.

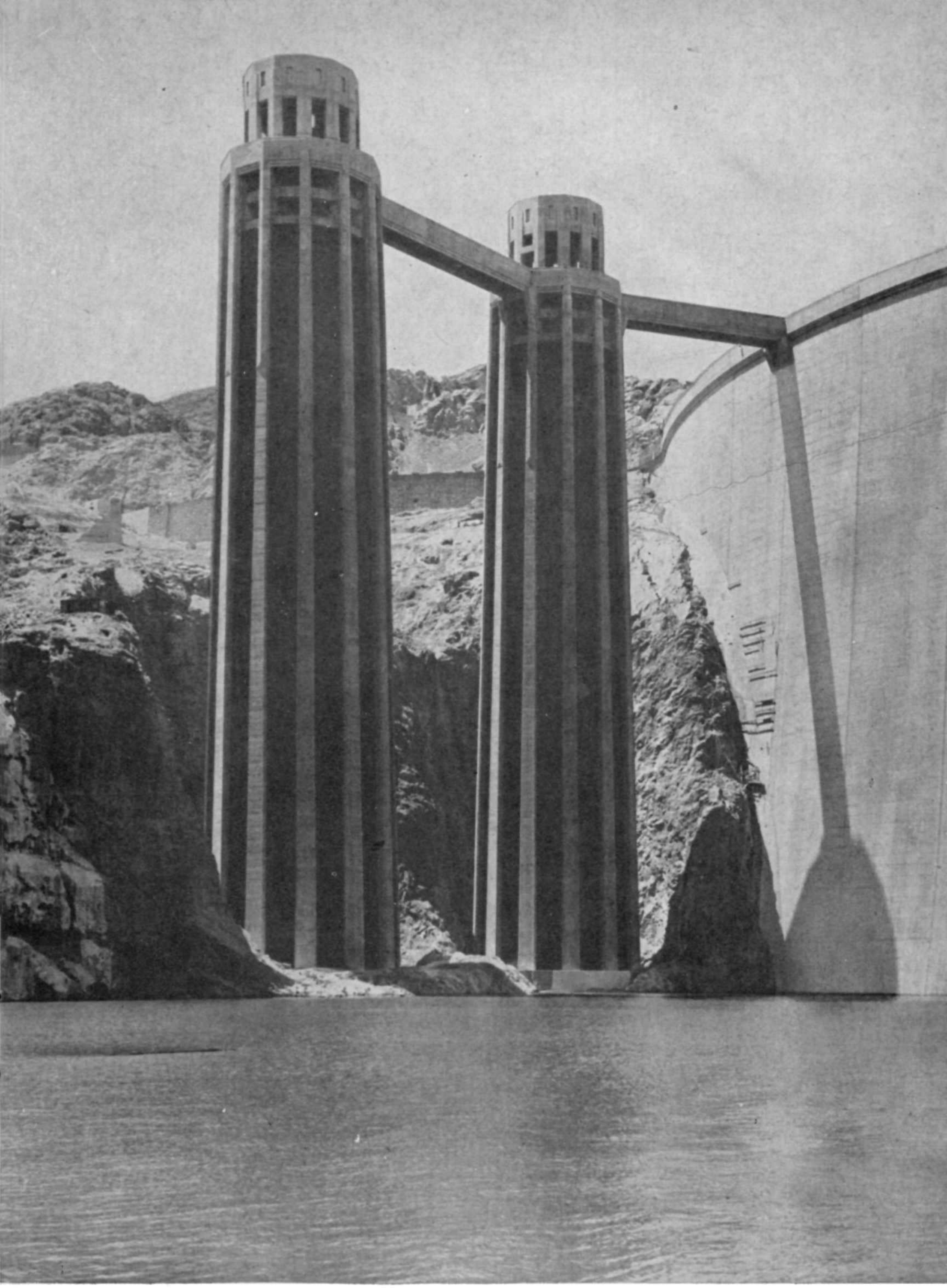
As soon as construction of the dam, intake towers, and outlet works was sufficiently advanced, and the upstream portions of the two inner diversion tunnels plugged with concrete, a steel bulkhead gate was lowered at the inlet of the outer diversion tunnel on the Arizona side of the river.

The River Harnessed at Last

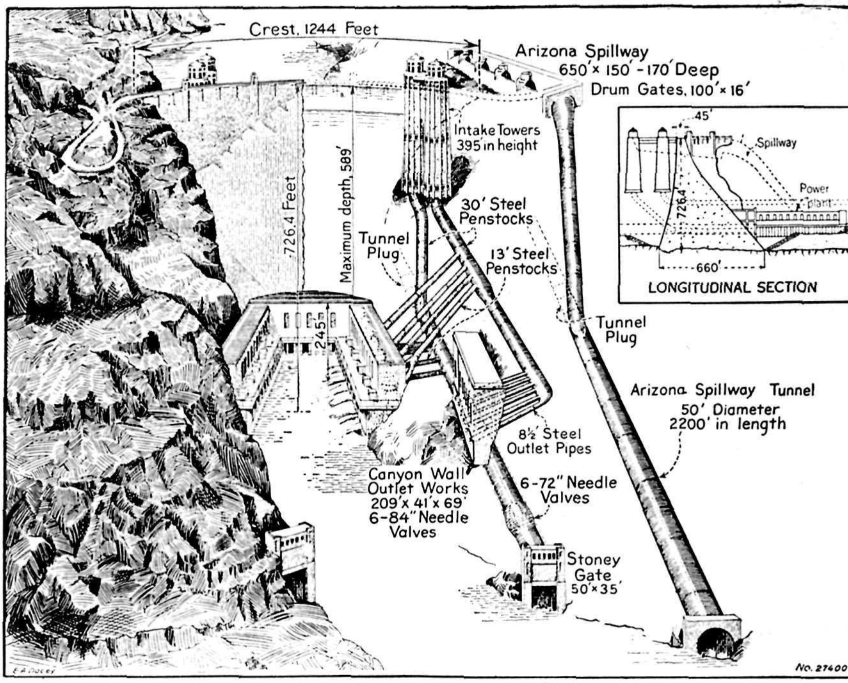
This was on February 1, 1935. Back of the unfinished dam, water started to rise. By midsummer the new reservoir held more than 3 million acre-feet of water having a maximum depth of 271 feet. And the formerly muddy Colorado, dropping its sediment in the reservoir, was transformed into a lake of clear blue water sparkling in the brilliant sun.

Arizona side of downstream face of the dam. View shows powerplant footings and foundation.





Arizona intake towers as seen from surface of reservoir. Water surface at elevation 884. Bottom of intake towers at elevation 894.



This drawing illustrates the manner in which Hoover Dam works. The Nevada wall of Black Canyon is shown as solid, whereas the Arizona wall is cut away to reveal the intake towers, the spillway, the penstock pipes, and outlet works. Inside the Nevada wall of the canyon a similar set of diversion works has been placed. Principal dimensions are shown.

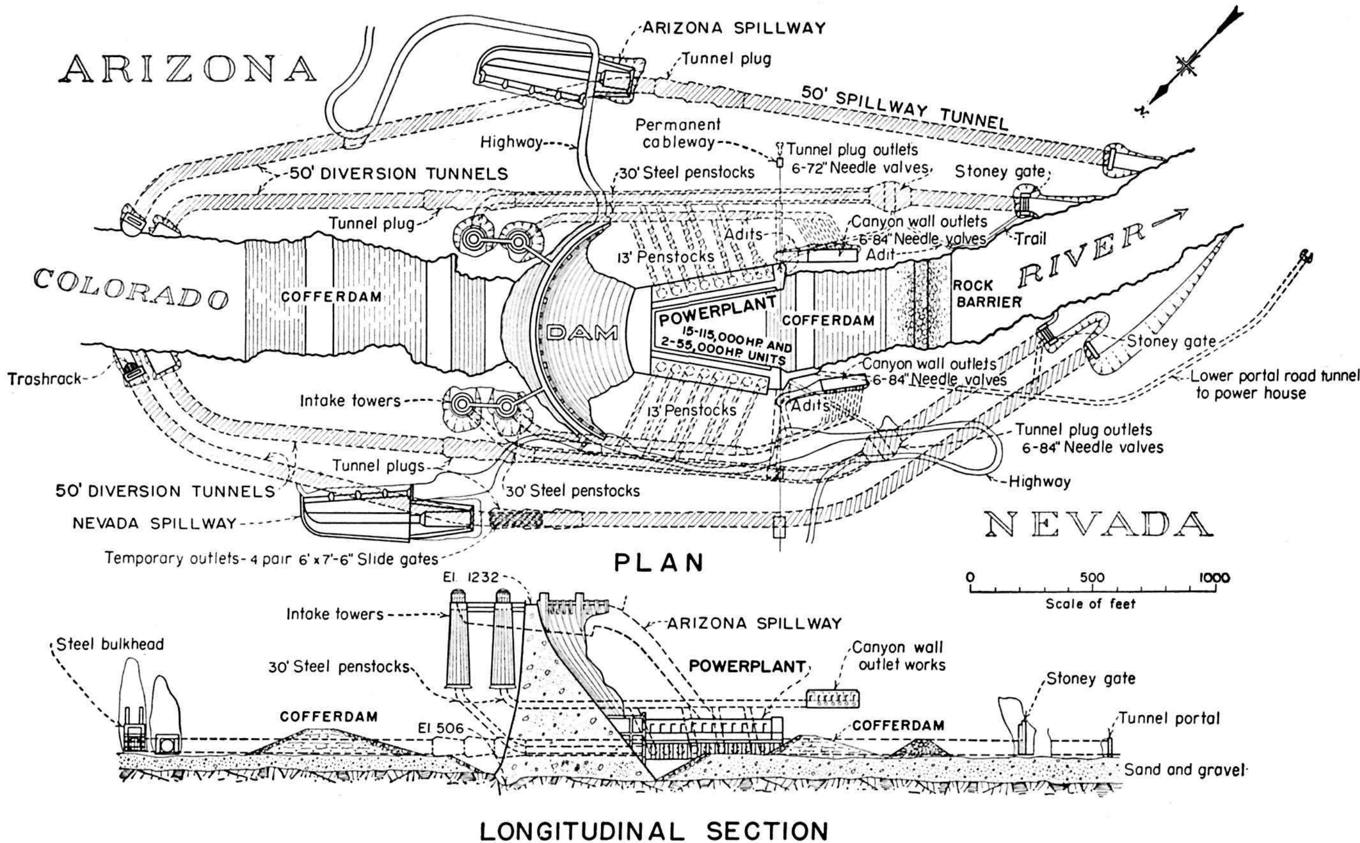
When the waters of Lake Mead had risen to the base of the intake towers. 260 feet above the river bed, the one remaining opening—in the outer diversion tunnel on the Nevada side—was closed. From that time the Colorado had to respond to rein. For the first time in history, the river had been harnessed.

Concrete placing continued, and the crest height of the dam was reached March 23, 1935. By the following summer all the concrete—3,250,335 cubic yards, 6,900,000 tons of it—was in place.

In 21 months 5,000 men with modern equipment had built a structure greater in volume than the largest pyramid in Egypt—a pyramid which, according to Herodotus, required 100,000 men working 20 years to build.

The dam towered 726.4 feet above bedrock—a distance equivalent to the height of a 60-story skyscraper. It had a base thickness of 660 feet—equal to the length of two ordinary residential blocks; a crest thickness of 45 feet; and a crest length of 1,244 feet—nearly a quarter of a mile.

The Government's contract had allowed Six Companies, Inc., 7 years to finish the job. But with efficient personnel and the finest of equipment, the company completed the contract 2 years ahead of schedule.



HOOVER DAM AND APPURTENANT WORKS

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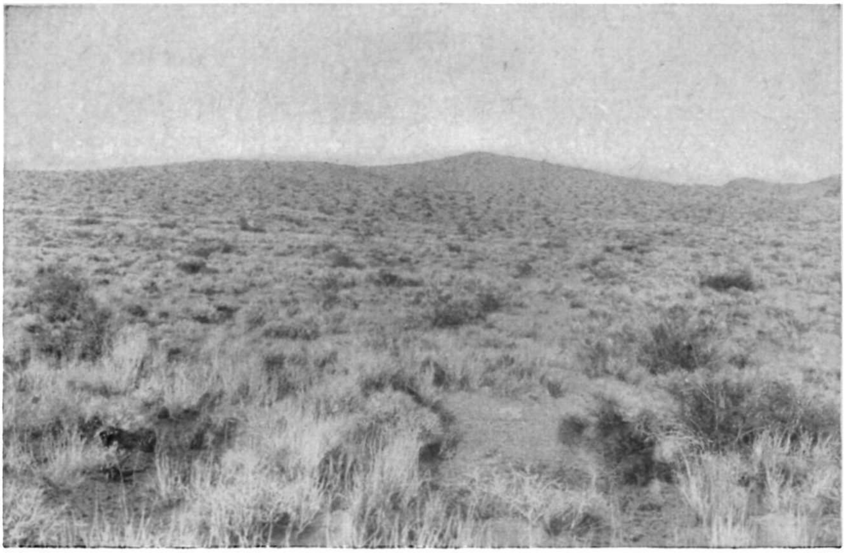


Panorama of north part of site of Boulder City, Nev.

The speed with which Hoover Dam was completed bears testimony to the ability and experience of a combination of grand old construction men.

One of the master strokes in the construction of Hoover Dam was the cooling of the concrete. Left to itself, the vast bulk of the dam would have taken more than a century to lose the heat created by the setting of the cement. It would have shrunk as it cooled, and cracked as it shrank. The solution, the engineers determined, was to build the dam in pier-like blocks and to cool the placed concrete by running ice-cold water through pipes imbedded 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.

Hoover Dam was done. A permanent asset had been added to the Nation's productive 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 its designers expected, Hoover Dam amply demonstrated its economic and social worth to the Southwest and to the Nation at large.

Boulder City, Nev.

A major argument against construction of a dam in Black Canyon was the complete absence of facilities to house the workers who would be employed on the project. None knew better than the engineers who had

Boulder City today, as seen from the air.

conducted the preliminary surveys that the provision of suitable living quarters would be vital to construction progress.

A camp in the vicinity of the dam was out of question. In summer, heat waves swept over the gorge like blasts from an inferno, and living conditions anywhere nearby would be unbearable. So the search began for a townsite that would provide the most in the way of advantages.

The site ultimately chosen for Boulder City was on a high plateau about 7 miles southwest of the dam. Several factors figured in the final choice, including temperature differentials and topography of the site. With an elevation of about 2,500 feet above sea level, Boulder City is more than 1,800 feet above the Colorado River; it is more than 1,200 feet higher than the crest of Hoover Dam; and it is nearly 500 feet higher than the neighboring city of Las Vegas, Nev. Temperature recordings prior to selection of the site confirmed expectations that temperatures would be more moderate there than at other locations which were considered.

The city was laid out in a triangle, with the apex pointing north. Here, the Bureau of Reclamation's administration building was erected. Fanning out from this apex are the principal streets of the city.

The townsite was located on Government-owned land, and title to all land was retained by the Bureau of Reclamation. Private citizens who were granted land leases were permitted to erect buildings. No land taxes were levied, but the lessee was charged a ground rental, payable to the Government.

With the site selected, the town began to rise from the desert early in 1931. Streets were surveyed and paved. Trees and lawns were planted. Spacious parks were laid out. The Bureau of Reclamation, as well as the contractors engaged in building the dam, began constructing dwellings and other structures. Private businesses were licensed and were soon in operation. Sewer and water systems and electrical facilities were provided. By mid-1932 more than 2,500 persons resided in Boulder City, and in 1934, with a population of slightly more than 6,000 the town was the third largest in Nevada.

As the dam neared completion, the contractors and a large portion of their personnel began moving to other jobs. Decline in population was gradual for the next few years, and by 1940 the town held fewer than 3,000 persons. Some believed that the decline would continue until the only remaining residents would be those concerned directly with project operation and maintenance.

Then came World War II, and America began to prepare for the impending crisis.

Although the 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. Workmen were needed to install these units and; with other industries moving into the area, once more Boulder City began to grow.

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

When Boulder City was laid out, only such requirements as were foreseen during the construction of the dam were taken into account. A large number of buildings were erected as temporary structures. The Government buildings and some dwellings were built with a view to permanency, but most of the structures were designed to serve during the construction period only. All the original leases negotiated in 1931 were made for a period of 10 years.

With the city facing a housing shortage in 1940 and with the original leases expiring, there was urgent need for additional housing as well as for the extension of leases then in effect. For the most part, all leases were renewed for another 10-year period. And as it became apparent that new structures would be permanent in nature, some leases for a 20-year period were issued. Still another type of lease was needed. There were those who sought to finance building through the Federal Housing Administration; and in order to meet the requirements set forth by the FHA, some leases were granted for a 53-year period.

Since 1941 Boulder City has shown steady though not phenomenal growth. To provide needed housing, the Bureau of Reclamation built 100 temporary houses and 40 semipermanent housing units in 1941–42. The Defense Plant

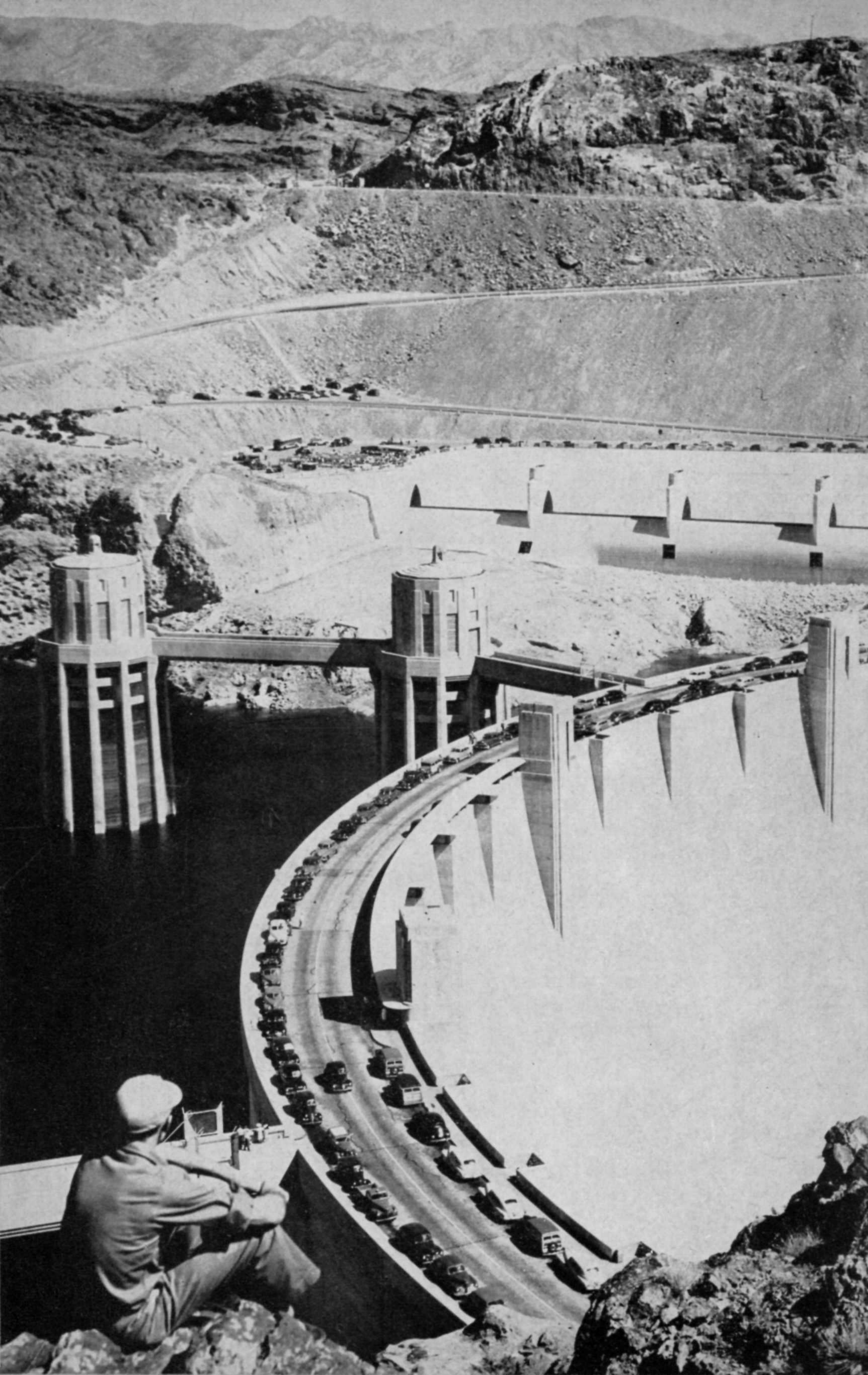
Corporation erected 60 houses and 26 apartment units to house some of the personnel engaged in operating the magnesium plant, and considerable building was undertaken by individuals. Prior to this, in 1936–37, the City of Los Angeles Department of Water and Power and the Southern California Edison Co., the agencies which operate the Hoover powerplant under contract with the Government, constructed offices and dwellings to provide facilities for their operations and personnel.

As time went on, it became clear that Boulder City's development was not temporary in character, for with growth and expansion there came an air of permanency and stability.

Since the end of the World War II all municipal facilities have been expanded. The town's original water system has been doubled in capacity. Additional streets have been laid out. A modern school plant has been built, and hundreds of houses have been constructed by private owners. Business firms have increased in number as the years passed. The National Park Service, which has jurisdiction over the Lake Mead national recreation area, has maintained offices in Boulder City since 1936. The Bureau of Mines began operating a pilot plant here in 1938, and in 1943 the city became headquarters for the Bureau of Reclamation's Region 3.

With a permanent community established, it became evident that the original status of the town could not be maintained indefinitely. In 1951 the Secretary of the Interior ordered that steps be taken to separate the administrative functions of the city from those of the Boulder Canyon project. Pursuant to that order, a city manager was appointed in the spring of 1952, and the city is undergoing changes which are directed toward its complete separation from Federal Government control.

Thus, a town which began primarily as a construction camp has become a stable and permanent community. Boulder City today is symbolic of the benefits accruing from reclamation. Like this small oasis in the midst of desert barrens, other and larger arid regions throughout the West are made to bloom and flourish as water supplies are assured and low-cost power is made available. The importance of water conservation and utilization of waste lands could scarcely be more dramatically emphasized.



the benefits

A Significant Prophecy Now Being Realized

On SEPTEMBER 30, 1935, less than 5 years after actual construction started, in dedication ceremonies at the dam site, President Franklin D. Roosevelt said:

"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 created Boulder Dam [1] *and on behalf of the Nation say to you 'Well done'."*

The great structure, an outstanding feat of modern engineering technique and construction skill, was an accomplished fact. And so it stands today—an enduring monument to man's ingenuity.

But Hoover Dam is significant not only because of its physical proportions and the skills and techniques it represents. Its significance is even greater in terms of the benefits it confers upon the entire region of the lower Colorado River Basin—benefits which manifest themselves in every phase of the Nation's economy. It was the prospect of these benefits, now being realized, that provided the driving incentive for those whose concerted action made construction of the project possible.

When the Committee on Irrigation and Reclamation of the United States Senate in March 1928 endorsed the construction of the multibenefit dam, it made this significant prophecy:

> A mighty river, now a source of destruction, is to be curbed and put to work in the interests of society.

[1] Renamed Hoover Dam in 1947 by the 80th Congress.

Typical scene at Hoover Dam.

The fulfillment of this prophecy has brought about the following major benefits:

First, flood control. Protection is provided for lives and property that were formerly at the mercy of the unbridled river.

Second, water for irrigating more than a million acres of rich land. More than half of this acreage was under cultivation when Hoover Dam was built, but crop success or failure was dictated largely by the vagaries of the river.

Third, water for domestic, industrial, and municipal use by the rapidly expanding population of the southern California coastal region.

Fourth, elimination of the damaging, clogging sediment deposits which formerly cost more than a million dollars yearly to remove from canals and irrigation ditches.

Fifth, improvement of navigation.

Sixth, a national playground and recreational area.

Seventh, dividends in fish and wildlife conservation.

Eighth—last, but by no means least—the generation of low-cost hydroelectric power.

Each of these benefits makes a story in itself and deserves individual consideration.

Lake Mead Swallows the Floods

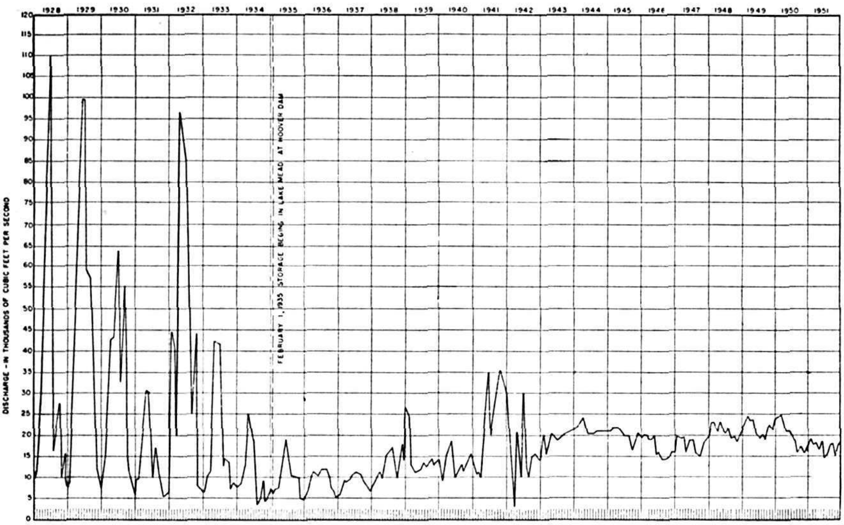
Set in the midst of the deep mauve and russet tones of the surrounding mountains and mesas, shining in the bright western sun, a clear blue lake has come into being behind Hoover Dam. It is called Lake Mead in honor of the late Dr. Elwood Mead, commissioner of the Bureau of Reclamation from 1924 to 1936. Measured by volume, it is the largest artificial lake in the world.

This inland sea is as useful as it is beautiful. Gathering to itself the wild, muddy waters of the Colorado, once so destructive to life and property, it stills them in its calm and placid depths. The lake has a total content at elevation 1221.4 of 29,827,000 acre-feet—enough to store more than 2 years of the Colorado's average flow—enough to flood the entire State of New York with water 1 foot deep.

When filled to capacity, Lake Mead has a depth of 589 feet, a shoreline of 550 miles, and a surface area of 255 square miles. It extends upstream 120 miles above the dam.

With its great reservoir, the dam controls not only the flashy, lesser floods which may occur at any time throughout the year, but also the great flood-tide runoff occurring each spring and summer.

Regulations governing the seasonal use of the upper portion of Lake Mead for flood-control purposes have been negotiated jointly by the Bureau of Reclamation and the U. S. Army Corps of Engineers (see Federal Register for February 18, 1954). Fulfillment of the flood-control function, together with the requirement for seasonal use of stored water for irrigation and



MAXIMUM MEAN DAILY DISCHARGE OF COLORADO RIVER AT HOOVER DAM

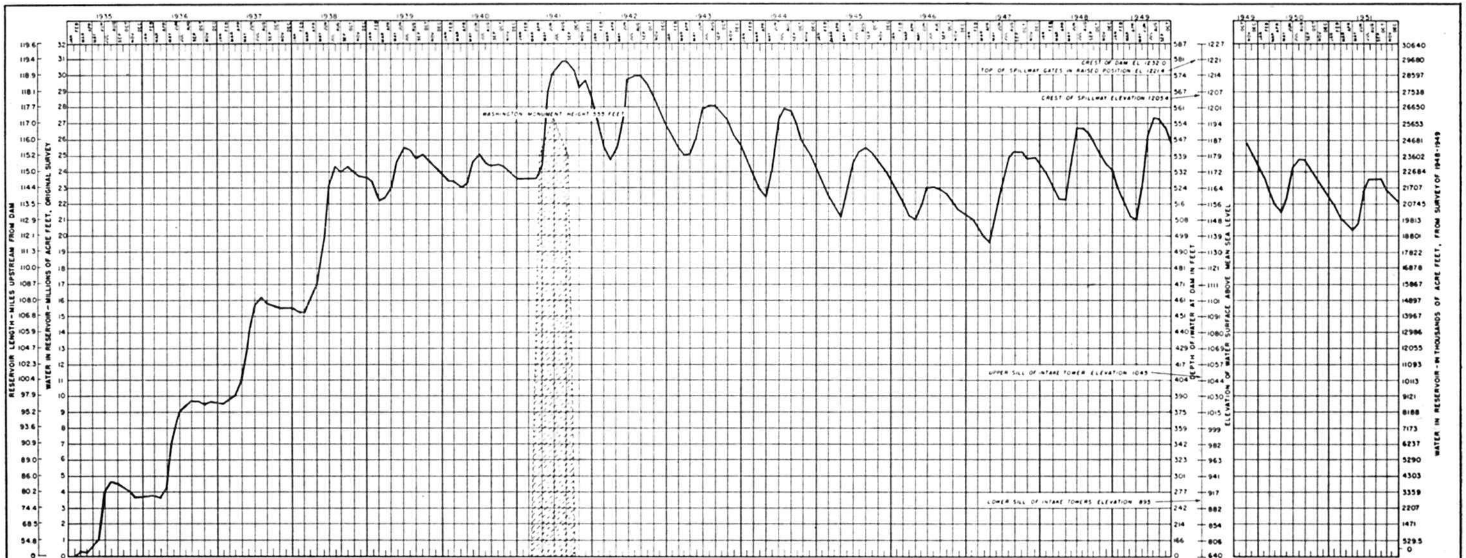
power production, results in a constantly changing level of the lake. In the spring and early summer the lake level rises; and then, during the fall and winter, the level is drawn down to make room for the next flood.

No longer at the mercy of the Colorado are the homes and the highly productive lands in the low, flat valleys of southern California and southwestern Arizona. These farms, carved out of the desert by the early pioneers, represent property values of hundreds of millions of dollars.

With Lake Mead functioning, the large floods entering the lake can be reduced from magnitudes up to 200,000 cubic feet per second to releases past Hoover Dam of less than 40,000 cubic feet per second. The extremely rare floods with magnitudes approaching 300,000 cubic feet per second can be reduced to about 75,000 cubic feet per second. In 1941 a flow of 122,000 cubic feet per second was reduced to 35,000 with no resulting damage below Hoover Dam. Again, in 1952, in anticipation of one of the greatest spring floods of record, the lake level was drawn down by increasing power generation schedules to the point where it was possible to reduce a flow of 122,000 cubic feet per second to less than 31,000 cubic feet per second.

And so today, when discharges can be adjusted to conditions, residents of the valleys below Hoover Dam need no longer fear the fury of the untamed river so long as the channels and levees are maintained.

A pilot's view of Hoover Dam. ☛



STORAGE IN LAKE MEAD

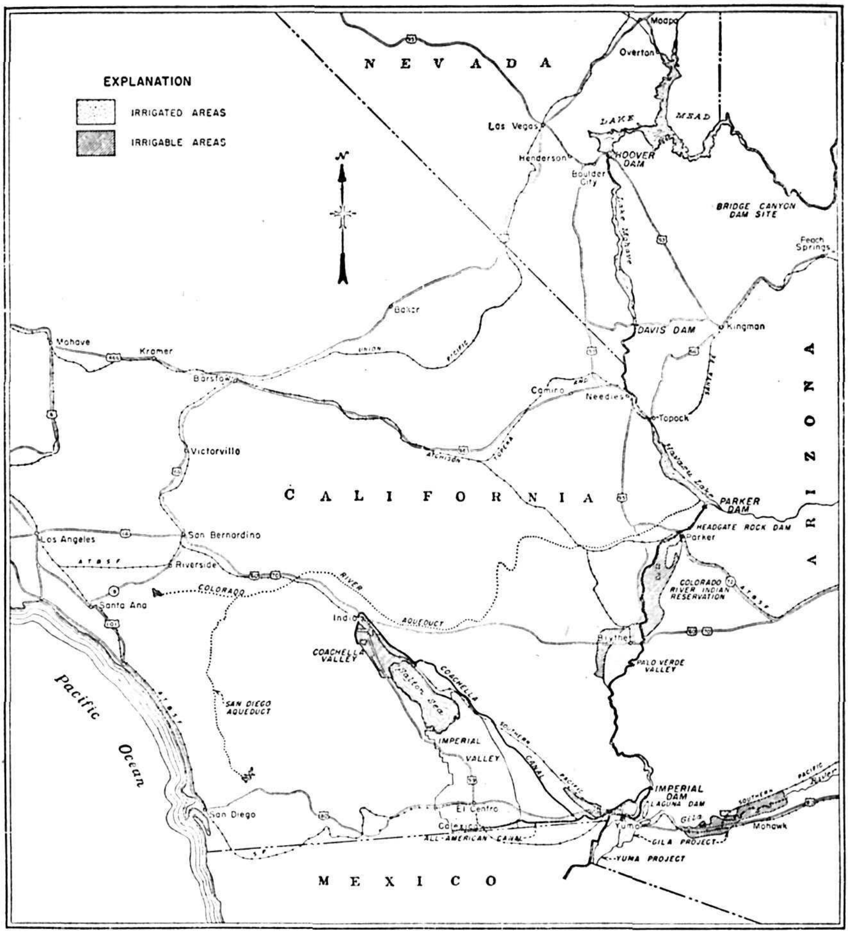
BEGINNING OF OPERATIONS FEBRUARY 1935, TO DATE

No More Drought

The second great benefit from Hoover Dam is the provision of a stable supply of water for irrigation. No more is the Colorado's water—precious as the gold that lured the 49'ers westward a century ago—wasted into the sea during the flood seasons.

The irrigated lands of the Southwest provide an all-year-round vegetable and fruit basket for the rest of the Nation. With an adequate and dependable supply of water for artificial application, the rich soils and warm climate have united to make the valleys of the lower Colorado River Basin veritable Gardens of Eden. From their sunny acres, in the dead of winter and in early spring, come lettuce, carrots, cauliflower, tomatoes, okra, asparagus, green peas, and other vegetables for the American table. Cantaloups, watermelons, citrus fruit, grapes, dates, and pecans add to the record of lavish production. General field crops such as alfalfa hay and seed, cotton, flax, small grains, sorghums, and sugar beets are all produced in some sections of the region. A flourishing seed industry has come into existence. Winter pasturing of cattle and sheep, finishing of beef cattle on locally grown feeds, and poultry and milk production are also important features of southwestern agriculture.

Harvesting head lettuce on irrigated land.



A million acres of irrigable lands are located along the Colorado River below Hoover Dam and in the nearby valleys. Only a little more than half of this acreage had been brought under irrigation by the 1930's, but any further extension of the irrigated areas was already out of the question without Hoover Dam. The natural flow of the river was already overtaxed during the peak of the irrigation season, and in years when the river flow was less than normal, there were serious water shortages.

In the Imperial Valley of southern California there are more than 500,000 acres of irrigable land. About 425,000 acres have been farmed annually by irrigation in recent years. During 1934, when the Colorado River discharge was only slightly over 4 million acre-feet, a crop value of $10 million was lost. Entire communities were jeopardized. In contrast, a decade later, with Hoover Dam to regulate the flow of the river and the All-American

Canal to deliver irrigation water—the farmers of the area produced crops valued at nearly $70 million. Since that time the annual crop production has equaled or bettered the 1944 figure. In 1953 crops valued at more than $86 million were produced in the Imperial Valley.

The Coachella Canal, a branch of the All-American Canal, was transferred to the Coachella Valley County Water District on March 25, 1949. With an overall length of 123 miles, this canal carries water from the All-American Canal northwestward into the rich Coachella Valley where some 75,000 acres will eventually receive Colorado River water. For many years prior to the completion of the Coachella Canal, about 20,000 acres of land in the valley had been irrigated by pumping from underground water supplies. However, the water table was being lowered dangerously, and the irrigated lands were in jeopardy because of water shortages. Now, Coachella water deliveries assure the farmers on these fertile lands adequate water for full crop production.

Imperial and Coachella Valley lands are not the only acreages benefited by control of the Colorado River. The Yuma project, which has 54,903 acres of Colorado River bottom land in Arizona and 14,853 acres across the river in California, now receives a stable and assured water supply from the All-American Canal. On the Gila project south and east of the city of Yuma, 115,000 acres of Arizona mesa and valley lands will, when fully developed, receive a dependable flow of irrigation water as a direct result of the river control afforded by Hoover Dam. Upstream from Yuma, 62,850 acres of land in the Palo Verde Irrigation District, near Blythe, Calif., and 33,000 acres on the Colorado River Indian Reservation, at Parker, Ariz., are in flourishing fields irrigated with water impounded in Lake Mead.

A Vital Metropolitan Water Supply

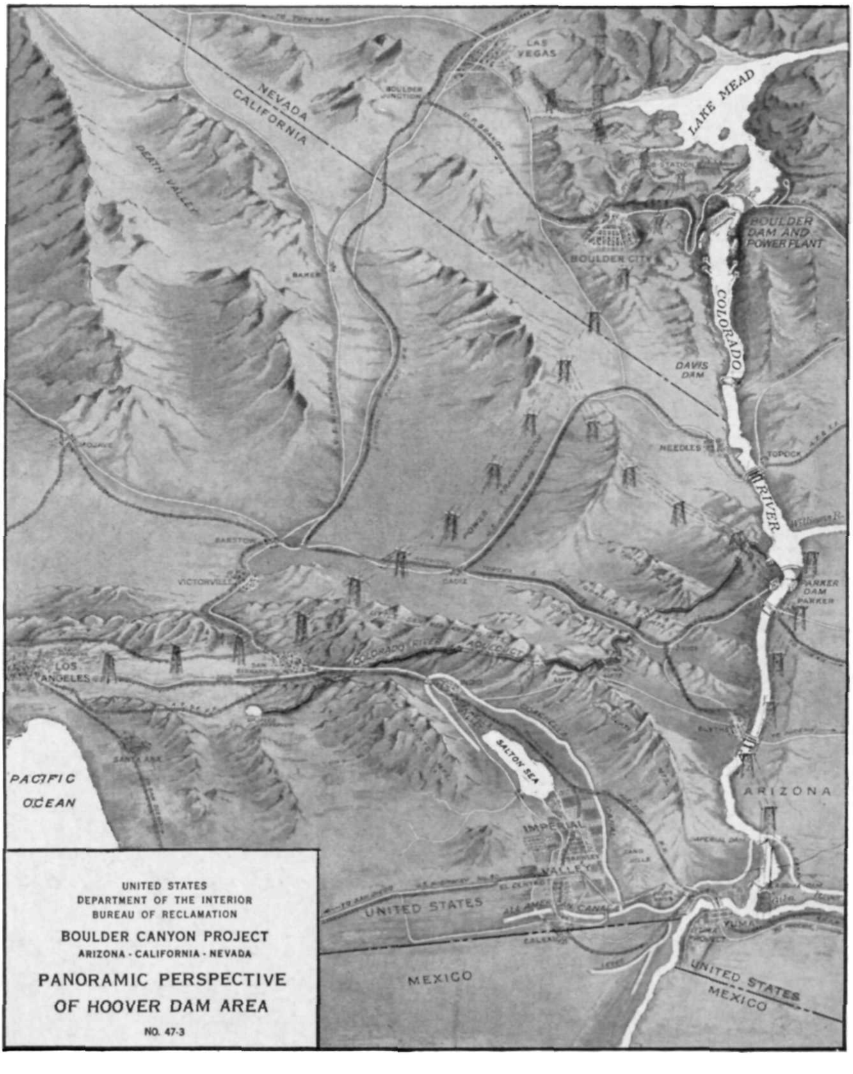
A third important benefit deriving from Hoover Dam's construction is the dependable supply of domestic, industrial, and irrigation water furnished to the urban and—to some extent—highly developed rural areas of the southern California coastal plain.

Southern California is a semiarid region. Average rainfall near the coast is about 15 inches annually—far less than is required for dependable agricultural development, to say nothing of the needs of modern industrial cities. In the interior valleys the average rainfall shades down to around 3 inches.

Metropolitan Los Angeles recognized many years ago that the provision of domestic water was one of its most pressing problems. By 1906 it had become apparent that the Los Angeles River was an inadequate source of supply, even though the population at that time numbered only 160,000. It was then that the city undertook to provide for the importation of water.

Looking northward, it first constructed the Los Angeles aqueduct, which brings water from the Sierra Nevada Mountains 250 miles away. Although this aqueduct was constructed to supply enough water for some 2 million persons, the city with its surrounding area grew so rapidly that by 1920 it was again face to face with impending shortages in its domestic water supply. If another source of water could not be found, the expansion of the entire coastal area of southern California would be seriously impeded.

The only obvious source was the Colorado River. But the river in its natural state did not offer a reliable supply. In order to assure water for domestic use, just as for irrigation use, the river had to be controlled and regulated.



Construction of Hoover Dam would provide the necessary regulation of the river. So from the inception of the project in the early 1920's, the southern California area was directly interested—the proposed construction would mean a solution to the pressing problem of domestic water supply.

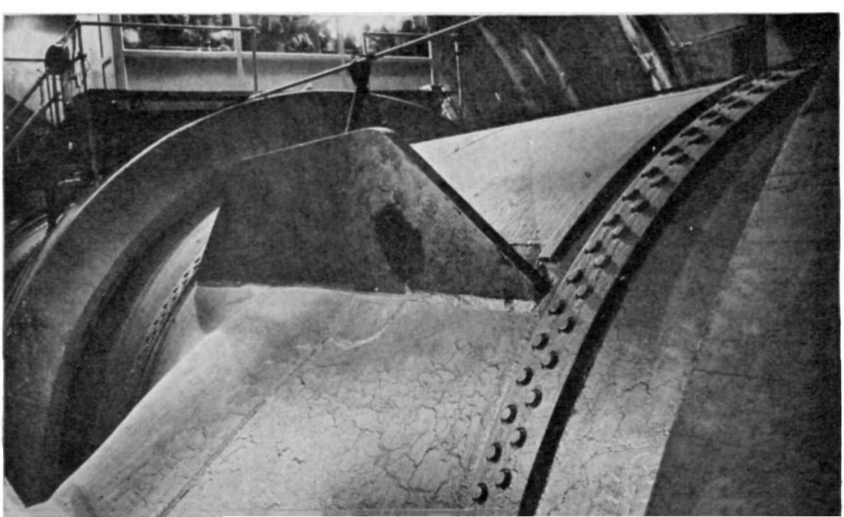
Eleven southern California coastal cities—Beverly Hills, Burbank, Glendale, Los Angeles, Pasadena, San Marino, Santa Monica, Anaheim, Santa Ana, Colton, and San Bernardino—in 1928 formed the Metropolitan Water District of Southern California in order to cooperate in the acquisition of the water they needed. The first meeting of the newly formed district's board of directors was held in December, immediately following the passage of the Boulder Canyon Project Act. In 1931 Long Beach, Torrance, Fullerton, and Compton were annexed, while Colton and San Bernardino withdrew. Thus, there were 13 cities in the original group that, later the same year, approved a $220,000,000 construction bond issue to finance the construction necessary to bring Colorado River water to the Pacific coast.

Through the years, other cities and municipal and county water districts, county water authorities, and utility districts have been annexed until, by the end of 1952, the Metropolitan Water District included 47 incorporated cities located in southern California's 5 coastal counties, together with large and populous unincorporated territory.

With Hoover Dam in control of the Colorado River, Parker Dam could be constructed 155 miles downstream to form a forebay from which an aqueduct could draw off the needed water. The Bureau of Reclamation built Parker Dam with funds advanced by the district from its $220,000,000 bond issue, and the district built the Colorado River aqueduct.

The aqueduct was completed in 1941. Today it carries water across 242 miles of mountain and desert—through tunnels, conduits, canals, siphons and pumping plants—to distribute it to the homes and industries of more than 4 million people in southern California.

Section of 30-foot penstock, showing visitor's gallery in background.



The Sediment Menace Reduced

A fourth benefit of Hoover Dam is the elimination of hundreds of millions of tons of sediment from the waters released at Hoover Dam.

The Colorado gets its name from its reddish-brown color, and the reddish-brown color comes from the sediment carried in its turbulent waters. Engineers have estimated that the average flow of the river carries 330 tons of sediment and sand past the Bright Angel gaging station, in Grand Canyon, every single minute of the day and night.

This sediment, untrapped, not only obstructed the diversion works, canals, and ditches of those who wished to use the water, but its deposition created a dangerous situation in the lower Colorado River. A committee of the United States Senate in 1928 reported as follows:

> The river has an annual discharge at Yuma of more than 100,000 acre-feet of silt. This silt greatly aggravates the flood menace. No temporary works can be built to hold it. It was the silt deposit that built the deltaic ridge on which the river now flows. It was the silt deposit that filled Bee River and Volcano Lake, so that the river could no longer be held at that point, and the same silt deposit will quickly fill the depression where the river now flows.
>
> The gradient to the north into Imperial Valley is much greater than that to the south into the gulf, and when the depression is filled there is no means known which, at any cost within reason, can prevent the river from again flowing into the Imperial Valley.
>
> The dam proposed in this bill will catch and hold the silt. Most of the silt finding its way onto the delta is from and above the canyon section. If no other dams were provided on the river, the one proposed in this bill would retain all of the silt finding its way into the reservoir for a period of 300 years, and for more than 100 years before its storage capacity and usefulness would be seriously interfered with. As other dams are constructed on the river they will catch and retain the silt, thereby further extending the usefulness of the Boulder Canyon reservoir.

Reclamation engineers set aside approximately 3 million acre-feet of Hoover Dam's reservoir capacity for the job of settling out sediment. The deep reservoir forms a natural trap—the river's flow slackens as it enters the lake and the sediment, heavier than water, sinks to the bottom. As it settles, the clear blue waters of Lake Mead bear witness that the reservoir's task of silt retention is well performed.

Navigation on the Colorado

A fifth benefit from Hoover Dam's construction is the improvement of navigation on those sections of the Colorado River below Grand Canyon.

Technically, the Colorado always was considered a navigable stream. Actually, under natural conditions of unregulated stream flow, navigation of the river was extremely hazardous and decidedly impracticable. Now craft ranging in size from small boats powered by outboard motors to luxurious cabin cruisers ply the waters of 120-mile-long Lake Mead which Hoover Dam has created.

After the flow of the river was regulated by Hoover Dam, construction of Parker Dam 155 miles downstream became feasible. Parker was completed

Majestic scenery awaits the vacationist in the upper reaches of Lake Mead.

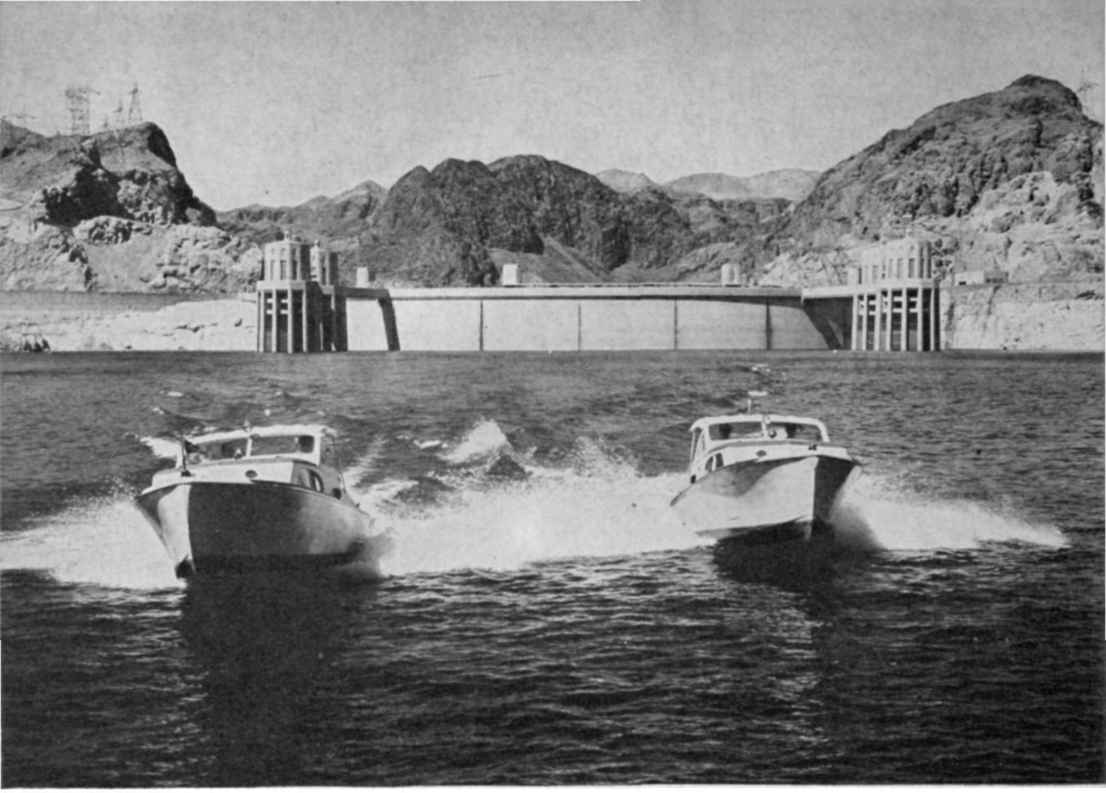
in 1938, and thereafter Havasu Lake was formed. A third reservoir, Lake Mohave, behind Davis Dam, is 67 miles below Hoover. This newest of the lakes along the lower Colorado came into existence in 1950, following completion of Davis Dam, and now extends up the river to the tailrace of the Hoover powerplant. Boats are operated on both Havasu Lake and Lake Mohave, under conditions very similar to those that exist on Lake Mead.

A Nation's Playground

A sixth benefit, the creation of a national playground, typifies the ultimate aim of Hoover Dam which, essentially, is to provide the people of this country with an instrument for promoting their further well-being and enjoyment.

Under an agreement between the Bureau of Reclamation and the National Park Service, effected in 1936, a recreational area was formed. The National Park Service was made responsible for developing the recreational facilities of Lake Mead, and through its efforts this great inland waterway has become one of the Nation's outstanding attractions.

The Lake Mead national recreation area, as originally established, included all the lands surrounding Lake Mead and extending downstream from



Speedboating in Black Canyon.

Hoover Dam on both sides of the Colorado River for about 40 miles. Late in 1947 the area was enlarged so that today it encircles Lake Mohave and continues down the Colorado for a short distance below the site of Davis Dam.

Visitors to the Lake Mead national recreation area in 1953 numbered 2,220,940, coming from all parts of this country and from many foreign lands.

Certainly, Lake Mead alone is worth traveling hundreds of miles to visit. Its 120-mile length reaches up into the lower end of Grand Canyon, penetrating colorful canyons and narrow gorges, opening up vistas and areas of nature's majestic handiwork that, through preceding centuries, have been inaccessible to other than the most intrepid explorers.

With their hundreds of miles of shoreline, Lake Mead and Lake Mohave afford wonderful possibilities for camping, swimming, boating, and fishing. Although temperatures are high during the summer months, the heat is not exhausting as the relative humidity is extremely low.

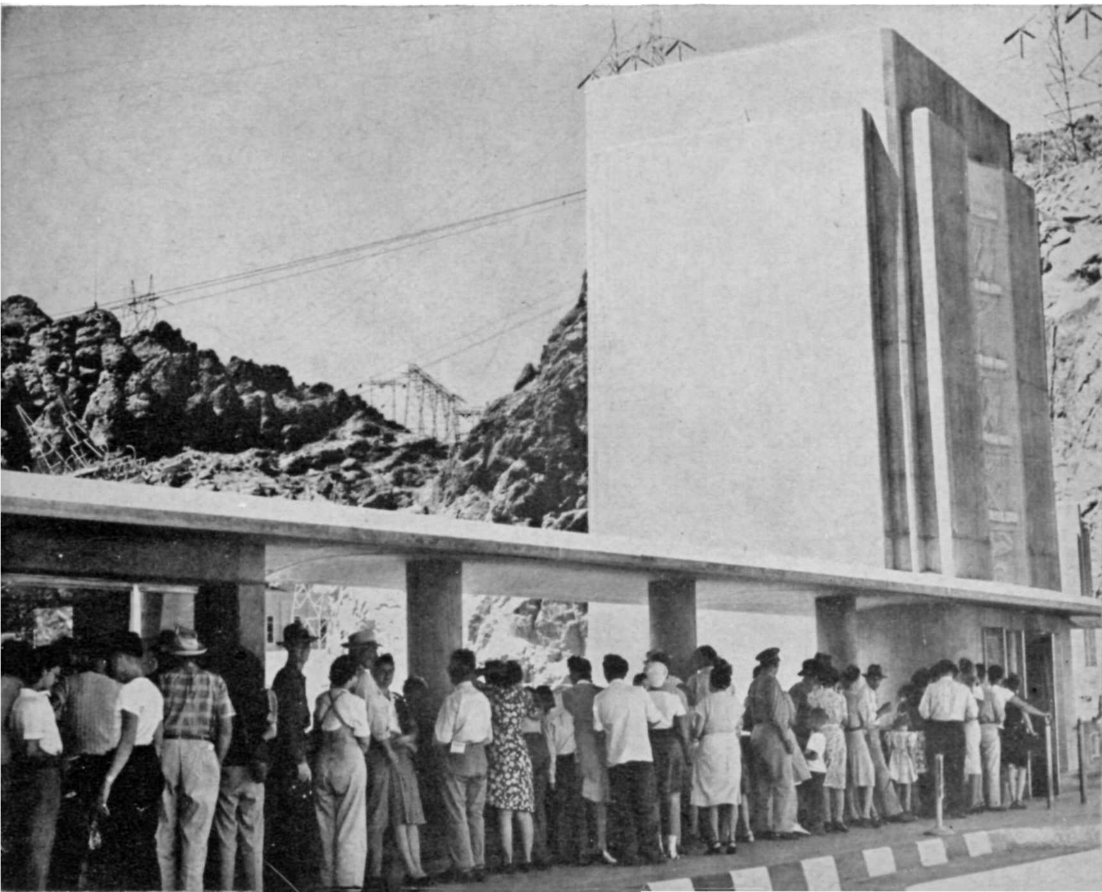
Although all types of water sports are popular, swimming and fishing are the prime attractions. Lake Mead abounds in black bass, bluegill, crappie, and catfish. There is no closed season imposed, and the fisherman may try his luck on this lake any day in the year.

The clear, cold waters pouring down from the deep recesses of Lake Mead into the upper reaches of Lake Mohave create a perfect habitat for rainbow trout, and thousands of these beauties have been planted there. Lake Mohave's lower reaches, where the waters are deep and still, abound in large numbers of black bass.

Except for a closed and posted area 2 miles below Hoover Dam, and where Arizona and Nevada State regulations may forbid fishing during the trout-spawning season in the winter, there are no restrictions on Lake Mohave fishing. At Willow Beach, 14 miles below Hoover Dam, excellent facilities are available for those who like to cast for trout. El Dorado Canyon, 27 miles below Hoover, offers good accommodations for both trout and bass fishermen.

Although the National Park Service has been designated the responsible agency for developing recreational facilities, the Bureau of Reclamation is by no means unmindful of its visitors and their interests. Bureau of Reclamation guards are on duty at Hoover Dam 24 hours a day, primarily for plant protection, but they also are present to assist travelers. The dam is open to the public every day in the year, and competent, well-trained guides

Visitors at Hoover Dam waiting to take the guided tour through the huge structure.



are on hand between the hours of 8 a. m., and 5 p. m., to conduct visitors through the famous structure and its powerplant.

Since guide service was established at Hoover Dam in 1937, more than 5 million persons have taken the guided tours. Visitors conducted through the dam and powerplant during 1953 numbered 448,081. From every State in the Union—from all over the world—they came to see and study this magnificent engineering achievement. Among the notable foreign visitors of recent times were the King of Iraq and the President of Turkey.

In addition to the guided tours, an exhibit building has been provided at the dam to further accommodate the traveling public. The topographic model of the entire Colorado River Basin and the operating scale-model of a generating unit which this building house are very enlightening and, together, give a clear exposition of Hoover Dam and its part in the life of the great Southwest.

A day's catch on Lake Mead.

Benefits to Wildlife

Advantages accruing to resident and migratory wildlife in the Lake Mead national recreation area and elsewhere along the lower Colorado River make the seventh entry on the list of benefits resulting from the construction of Hoover Dam.

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, they serve as huge waterholes for mountain sheep and other wild creatures inhabiting adjacent mountain and mesa uplands.

Also of considerable importance to conservation are the sanctuaries these man-made lakes afford for such waterfowl as the pintail, mallard, Canadian goose, and snow goose and for wading birds like the egret, the blue heron, and the many varieties of sandpipers that frequent these parts.

Nor are water-loving birds the only ones to profit. More than 250 species of birds have been counted within the boundaries of the Lake Mead national recreation area alone. This area, incidentally, is no longer designated a wildlife refuge and, according to National Park Service regulations promulgated July 4, 1952, hunting and trapping are subject to applicable Federal, State, and local laws.

Havasu Lake, above Parker Dam, is located on one of the flyways of migratory waterfowl and is an ideal haven during annual migrations. Davis Dam's Lake Mohave offers much the same attraction for ducks, geese, and other birds on their long migratory flights.

Power and Strength of the West

Another benefit accruing from the construction of Hoover Dam, and one of the most important to southwestern economy, is the generation of low-cost electrical energy.

From its earliest days the West has been the elbowroom of our Nation's expanding population. In the West growth and development have been more rapid than in any other part of our country. Nowhere has this trend been more pronounced than in the southern California coastal region. Los Angeles is an excellent example.

Los Angeles enjoyed its most rapid growth during the decade 1920–30, when its population rose from 500,000 to 1,200,000. But its expansion has continued. By 1940 its population had increased to 1,504,277, and the 1950 census gave the city's population as 1,970,358. In 1952 it was estimated that the city had reached the 2 million mark.

Nor is this trend confined to the city of Los Angeles. The entire Pacific coast reveals the same general condition of population increase. In fact, the Pacific Coast States, together with the States of Arizona and Nevada, have experienced an expanding population trend during the decade 1940–50 which has not been matched by any other section of the Nation. In many parts of the country, during this same decade, there were marked decreases in population.

This trend, begun in the 1920's, can continue only so long as water and power can be obtained to sustain expansion.

As before noted, intensive development of agriculture in southern California has been dependent wholly on water for irrigation of crops. Moreover, rapid increases in population have required an assured water supply for domestic and industrial purposes. Reliance solely on underground water resources could not sustain a continued trend of growth and expansion such as that established in 1920–30.

Power also was needed to assure continued progress. During the decade and a half preceding the passage of the Boulder Canyon Project Act, use of electrical energy in southern California increased three times as rapidly as in the rest of the United States.

Water, which also meant power, was within reach and obtainable; but it was being wasted annually in Colorado River floods. Instead of being allowed to deal destruction, the flood waters could be harnessed and thus turned into a vital asset of benefit to southwestern economy.

The consequences that were resulting from failure to conserve and utilize that great natural resource, the Colorado River, were recognized for a quarter of a century before any constructive action was taken, but the problem of how best to solve the difficulties of river control was a difficult one. Not the least perplexing phase of the entire problem was the question of how to finance so large an undertaking.

When plans for the construction of Hoover Dam began to take shape, it was recognized that the amount of energy which could be produced could be sold and the revenues thus realized could be returned to the United States Treasury. Moreover, it was adjudged that these revenues would be large enough to make the project self-liquidating. Power, then, made possible the construction of Hoover Dam.

The Endless Tune of Untold Wealth

Today the Hoover powerplant is capable of supplying whole cities with light and power. Transmission lines running from the dam carry electrical energy to homes and farms, stores and factories, mines and smelters, pumping plants and refineries. In the plant, sixteen giant generators hum an endless tune of untold wealth, the creative wealth of hydroelectric power.

In 1952 the Hoover powerplant reached an installed capacity of 1,249,800 kilowatts. For several years it was the largest hydroelectric powerplant in the world, but in 1949 it was surpassed in capacity by the Grand Coulee plant. Today it is the second largest in the world.

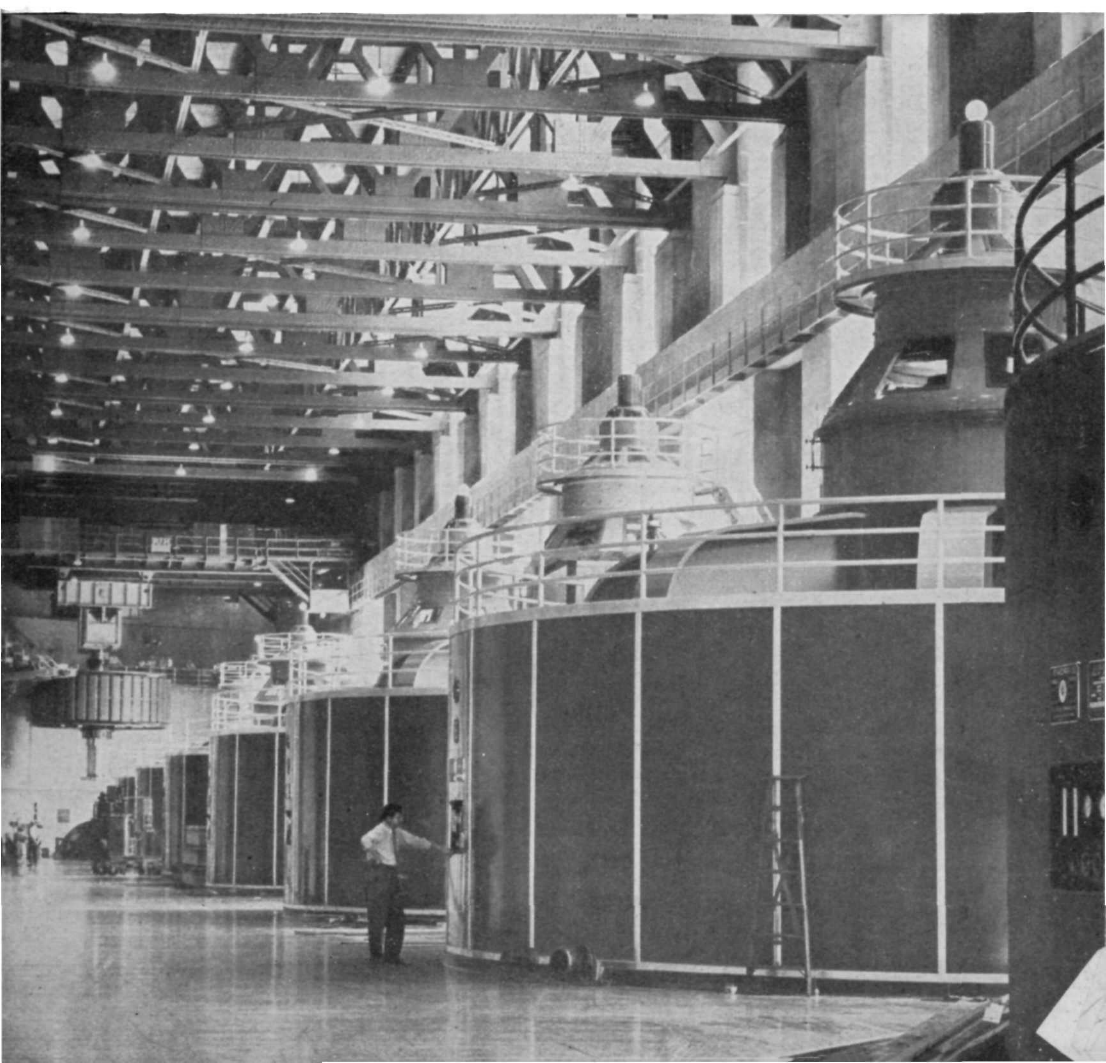
The powerplant can be depended upon in an average water year to generate 5.4 billion kilowatt-hours of electrical energy. It provides about a quarter of the electrical energy used in the Pacific Southwest area. In addition, power has been transmitted to northern and central Arizona and to southern Nevada within transmission distance.

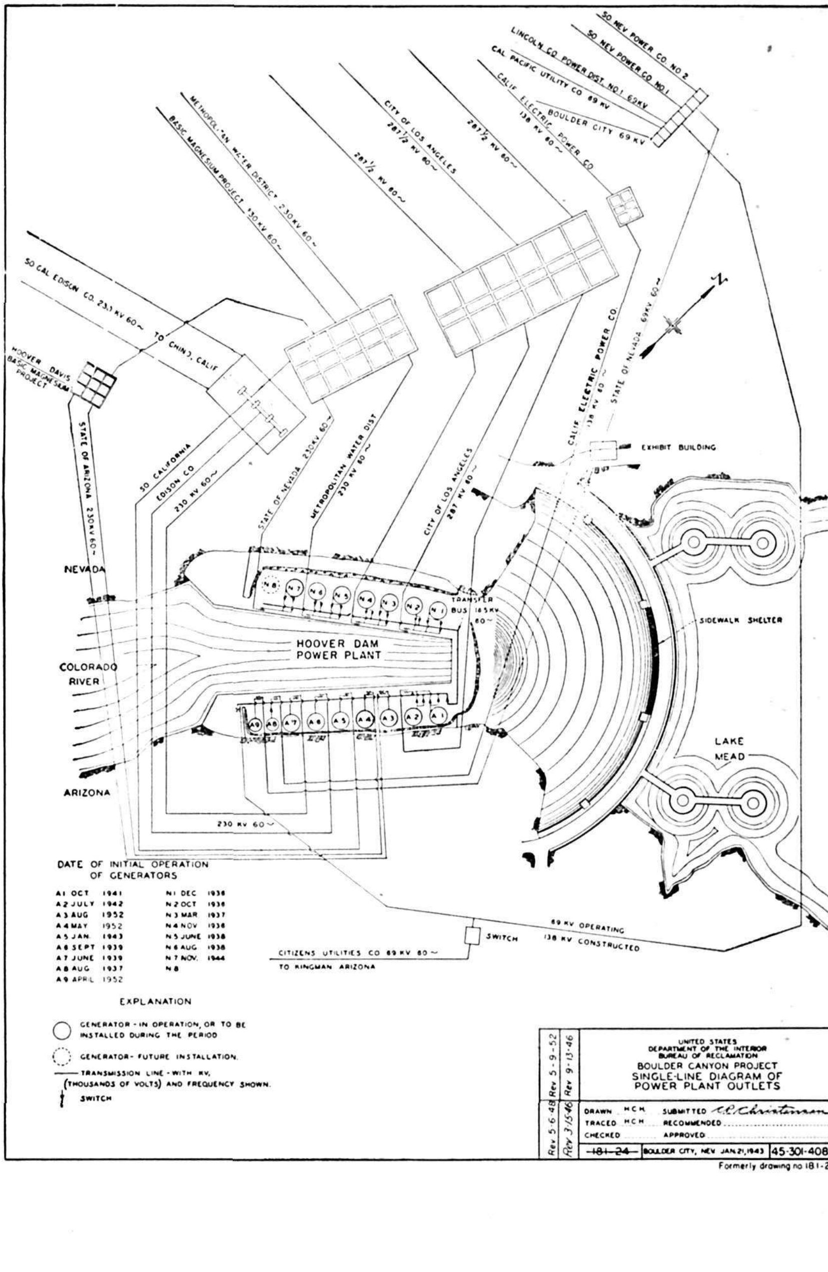
During the operating year 1952–53, the Hoover powerplant produced 6,397,270,000 kilowatt-hours of electrical energy.

Increasing Power Generation

Commercial power generation in the Hoover powerplant was begun on October 26, 1936, when N–2, the first of the four generating units then in process of installation, was placed in operation to serve the Los Angeles metropolitan area. Since then the installation of additional generating units has continued, and the significance of the Hoover plant to the expanding economy of the Pacific Southwest has increased materially.

Nevada wing of the Hoover Dam powerplant. Scene shows one of the huge rotors being moved by the giant cranes.





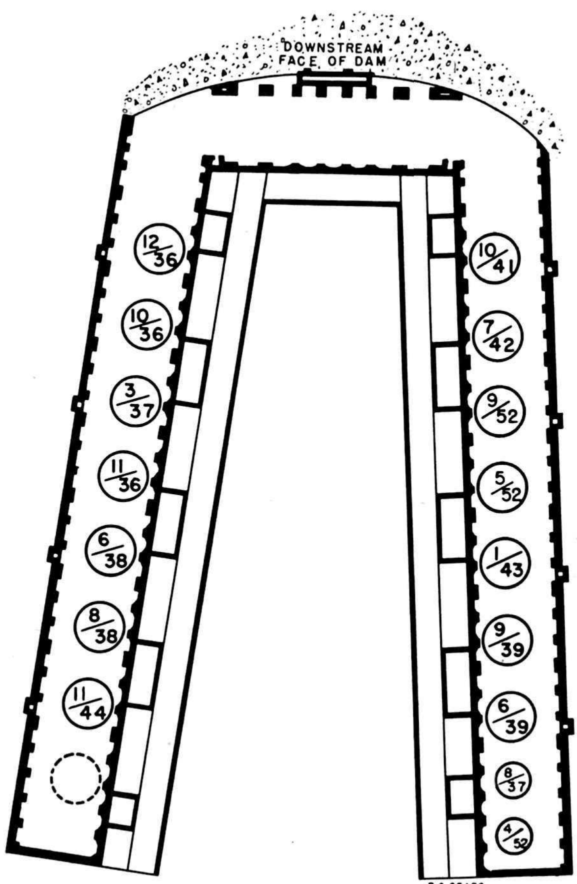
By the end of 1936, units N–2, N–4, and N–1 had been installed; unit N–3 was placed in operation early in 1937. These units served not only the city of Los Angeles, but the neighboring cities of Glendale, Burbank, and Pasadena. Las Vegas and Boulder City, both in Nevada, also obtain energy from these units.

In August 1937 unit A–8 went into operation for the California Electric

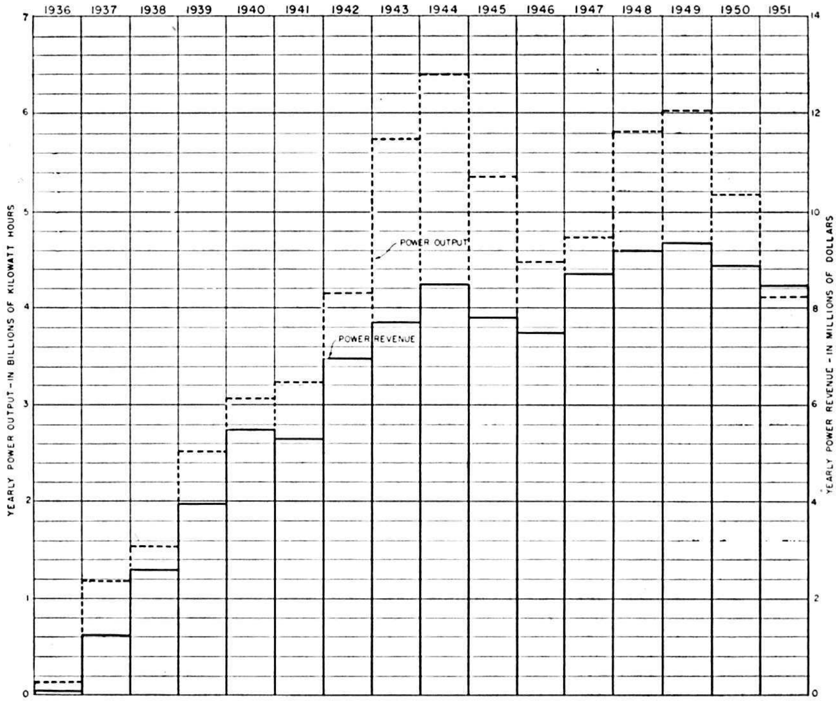
Power Co., a private utility supplying customers from central Nevada to the southernmost part of California.

In 1938 units N–5 and N–6 were completed. These were installed for the Metropolitan Water District of Southern California. Energy generated by these units is earmarked primarily for pumping Lake Havasu water at Parker Dam into and along the district's Colorado River aqueduct, after having been stored also at Lake Mead. Energy over and above the amounts required for pumping is sold to municipalities and utilities.

The Southern California Edison Co., which serves seven counties in southern California, exclusive of the city of Los Angeles, had a contract with the Government to begin taking power from the plant beginning June 1, 1940. But a power shortage in the area served by this company hastened installation, and by the end of 1939 units A–6 and A–7 were in operation supplying energy to the Edison Co.



PLAN OF POWER HOUSE
SHOWING DATES OF FIRST REGULAR OPERATION



GROSS OUTPUT AND REVENUE OF HOOVER POWER PLANT

At the close of 1939, with an installed capacity of 704,800 kilowatts, the Hoover powerplant was the world's largest hydroelectric plant.

The growing industries of the Pacific Southwest were given tremendous impetus with the outbreak of World War II. This increased tempo of industrial development accelerated installation of additional generating units at Hoover Dam. By October 1944 units A–1, A–2, A–5, and N–7 had been placed in operation. The capacity of the plant had reached 1,034,800 kilowatts by the time hostilities had come to an end.

Generating units A–1 and A–2 supply power mainly to the city of Los Angeles; some power from these units is used to supply the requirements of the United States, and some is used by the State of Nevada. Unit A–5 was installed for the Southern California Edison Co. Unit N–7, installed at the request of Defense Plant Corporation, was transferred by contract to the State of Nevada, which it now serves, on June 1, 1951.

One of the major users of electrical energy from the Hoover plant during World War II was the huge Basic Magnesium, Inc., plant northwest of Boulder City. Built by Defense Plant Corporation, this plant in 1943 consumed one-fourth of the total energy output of the Hoover powerplant. Magnesium produced here was used largely in the manufacture of incendiary bombs so vital to the successful prosecution of the war by the United States and her allies.

In 1952 generating units A–3, A–4, and A–9 were placed in production. Units A–3 and A–4 were installed for the State of Arizona, while unit A–9 serves Nevada with energy urgently needed by that State's growing economy. The latter units complete installation in the Arizona wing of the plant and bring the plant capacity to 1,249,800 kilowatts. Only one more unit remains to be installed. It will be located in the Nevada wing of the powerplant and will give the plant a total installed capacity of 1,354,300 kilowatts.

The income from the sale of Hoover Dam energy has risen steadily. The utility revenue from October 26, 1936, to May 31, 1941, was $15,655,086 and the revenues for the operating years 1942 and 1943 were between 6½ and 7½ million dollars and since 1943 the revenues have amounted to over $8 million annually.

Power and other revenues from June 1, 1937, to May 31, 1953, totaled $124,572,525. Up to May 31, 1953, the net operating income was $85,661,-360, of which $77,056,302 had been returned to the Treasury of the United States.

Fifteen high-voltage transmission lines connect Hoover Dam with its power-market area. Three lines terminate at Los Angeles, a line distance of 266 miles. Two lines extend directly to Chino, Calif., a distance of 233 miles, and another line leads to Chino via Hayfield, Calif. Another line extends to San Bernardino, Calif. Two lines extend to Las Vegas, Nev., and two lines lead to Henderson, Nev. One of the latter connects with the Davis Dam transmission system. Other lines extend to Kingman, Ariz.; Needles, Calif.; Pioche, Nev.; and to nearby Boulder City.

Davis Dam, 67 miles below Hoover Dam and latest addition to the series of structures controlling the lower Colorado River, has an installed powerplant capacity of 225,000 kilowatts. The Davis powerplant can be expected to generate an average annual output of 1,514,000,000 kilowatt-hours of energy.

Parker Dam, on the Colorado River 88 miles below Davis Dam, has an installed capacity of 120,000 kilowatts. The Parker plant produces about 786 million kilowatt-hours of energy annually.

The Hoover, Davis, and Parker powerplants are interconnected. Energy supplied by the Parker and Davis plants is delivered to load centers in Arizona and in southern California, as well as to the industries now in production at Henderson, Nev.

The Ramified Benefits

As the amount of energy generated at Hoover Dam has risen steadily, so also have the benefits ramified into the varied phases of the Pacific Southwestern economy.

As a direct result of the availability of Hoover-generated energy, power rates have been lowered throughout the whole area served by the project. Nowhere has this trend been more pronounced than in Las Vegas, Nev., where energy rates are very low. From a maximum of 8 cents a kilowatt-hour, energy rates in Las Vegas have been reduced to 3 cents. And the rate for energy over and above 500 kilowatt-hours is only 5 mills.

Likewise there has been a lowering of energy rates in Los Angeles. In the first year of operation, it has been estimated that Hoover energy resulted in a saving of $1,320,000 to the consumers in the Los Angeles metropolitan area.

In a recent survey of the 15 largest cities of the United States, Los Angeles was found to have the lowest energy rate of any on a basis of 30,000 kilowatt-hours at 150 kilowatt, or over, demand. This fact is of tremendous importance to the industrial consumer, and is one of the reasons for the rapid industrial growth of the southern California coastal region during recent years.

The benefits of low-cost energy, however, have not been confined to industrial centers of the Pacific Southwest. Perhaps no phase of the area's economy has been more directly affected than its mining and mineral industries.

Directly, or through its interconnections, Hoover powerplant energy has figured in mineral production throughout the Southwest in the following places and industries: In California, tungsten at Bradensburg; saline deposits at Owens and Searles Lakes; steel at Fontana (the Kaiser plant); borax near Kramer; cement at Victorville, Colton, and Monolith; aluminum at Torrance; in Nevada, brucite and magnesite at Gabbs; silica sand near Overton; and manganese near Boulder City. In Arizona, in the Bagdad area, copper production is today a thriving industry that has been revitalized by low-cost energy.

The mines in the Pioche, Nev., area also have been benefited. This region, located 156 miles (transmission line distance) north of Hoover Dam in Lincoln County, Nev., was completely without electric service before Hoover Dam energy became available. Now the Lincoln County Power District No. 1 delivers Hoover energy to silver, lead, and zinc mines at 8.5 mills a kilowatt-hour.

Perhaps one of the most dramatic developments resulting from the construction of Hoover Dam is the growth of the light-metals industry in southern Nevada. First step in this process came with the construction of the magnesium plant at Henderson. The town of Henderson, located about 10 miles northwest of Boulder City, developed as a result of the construction of the plant.

The magnesium plant was started in 1941. The site was chosen because water was easily available from Lake Mead and power was within easy transmission distance from Hoover Dam—both water and power, in quantities, were needed to support this large wartime installation. The plant was completed in record time and contributed greatly to America's war effort.

Magnesium has not been processed at the Henderson plant since World War II hostilities came to an end, but the plant still stands. Following the termination of hostilities, possession of plant and townsite facilities passed to the War Assets Administration. In 1948 the State of Nevada, through its Colorado River Commission, purchased the plant, the town of Henderson, and all appurtenant facilities from the War Assets Administration.

To attract permanent industries to southern Nevada, the Colorado River Commission announced early in 1951 that it would sell the plant and all townsite facilities. Stauffer Chemical Co., Western Electro-Chemical Co., U. S. Lime Products Co., Titanium Metals Corp. of America, and others have purchased the plant buildings. On May 23, 1952, a sale of all residual assets, including housing facilities, the water system, and other public services, was completed. The purchaser was a holding company known as Basic Management, Inc. This concern will manage these various assets until sales to private individuals are effected.

While southwestern economy is being stimulated by the use of hydroelectric power from Hoover Dam, one of our most precious natural resources is being conserved. It is estimated that the Hoover Dam plant is saving the country, annually, about 10 million barrels of oil that otherwise would have to be used for the generation of electrical energy.

This record does not pretend to trace the ramifications of benefits deriving from the distribution of low-cost power. It only tries to point up the farflung effects of this great Colorado River dam upon the economy of the Southwest.

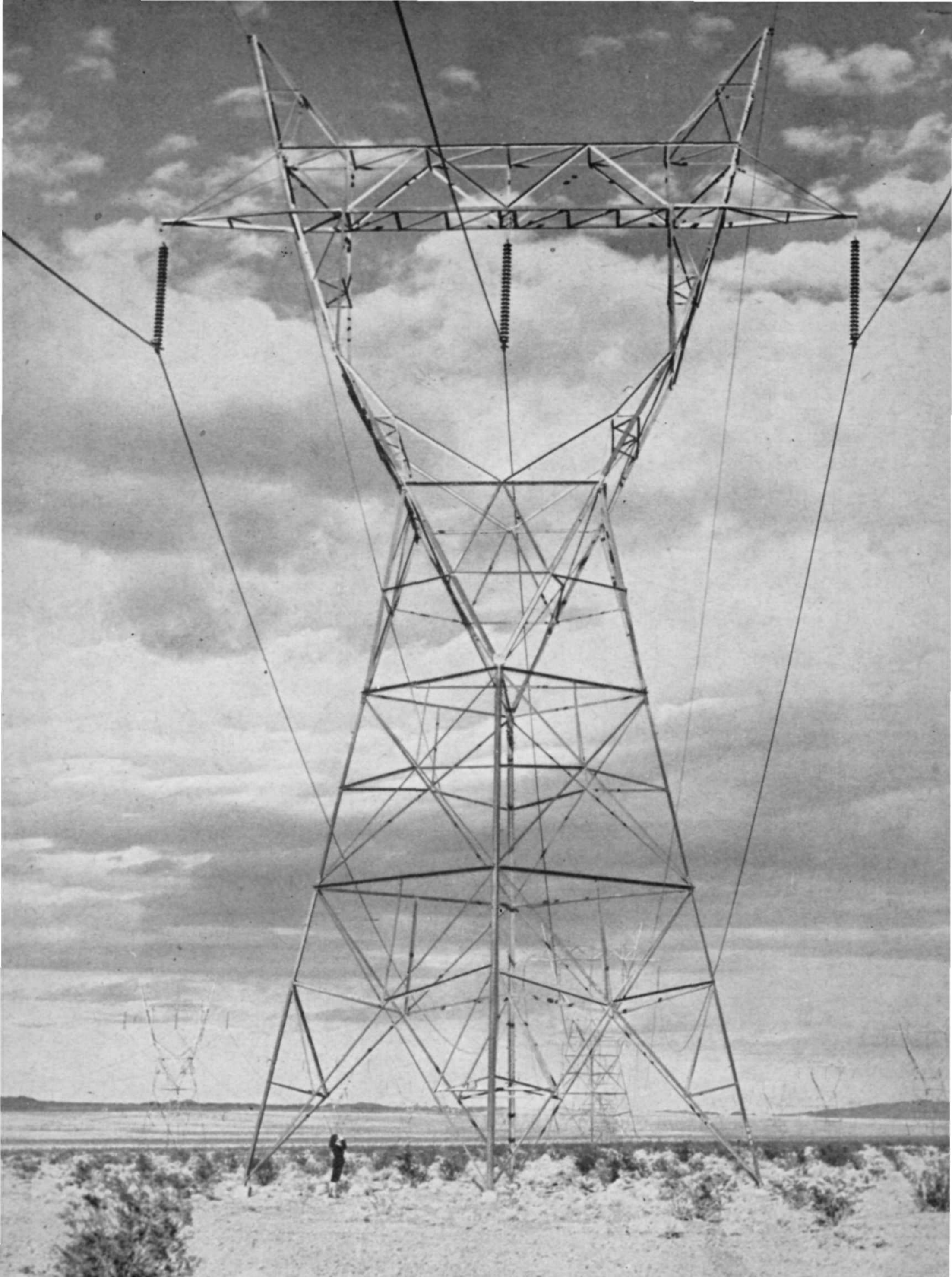
The Benefits Multiplied

The Boulder Canyon project has not resulted in full development of the Colorado River's resources. It has only cleared the way for future incalculable gains. And only the future can tell how benefits to southwestern economy will multiply as the river's possibilities are more completely realized.

The uncontestable feasibility and success of Hoover Dam, first of the great multiple-purpose Reclamation dams, gave impetus to the construction of other great Reclamation dams. Construction of Grand Coulee Dam, in Washington, Shasta Dam, in California, and Hungry Horse Dam, in Montana—all Bureau of Reclamation structures—followed the successful completion of Hoover. Today investigations are proceeding to the end that other projects may be undertaken to utilize the complete water resources of the United States.

The story of Hoover Dam and the Boulder Canyon project runs the entire gamut of river control—flood prevention, water conservation, sediment detention, increased facilities for recreation, wildlife preservation, and electrical power generation.

Countless Americans know that story. Millions of people have firsthand acquaintance with its full meaning. Others have heard it told by press and radio and have seen it written into the record of our times.



Like columns of marching soldiers, steel towers such as these carry electric energy over desert lands to industrial centers in the Southwest.

facts and figures

The Dam

Where is Hoover Dam located?

In Black Canyon, on the Colorado River. The dam is about 350 miles upstream from the Mexican border, along that stretch of river which forms the Arizona-Nevada boundary.

What does the Boulder Canyon project include?

Hoover Dam and powerplant in Black Canyon and the All-American Canal in southern California, together with appurtenant structures.

How high is Hoover Dam?

The maximum difference in elevation between the foundation rock and the roadway on the crest of the dam is 726.4 feet. The towers and ornaments on the parapet rise 40 feet above the crest.

How does this height compare with other dams?

Hoover Dam is still the highest dam in the world. Second is Shasta Dam in California, 602 feet high; third is Hungry Horse Dam in Montana, 564 feet high. All three dams were constructed by the Bureau of Reclamation. (Two concrete dams now building in Switzerland will, if completed as planned, exceed Hoover in height. They are Grand Dixence, to be 912 feet high, and Mauvoisin, to be 745 feet high.)

What type is Hoover Dam?

Concrete arch-gravity type, in which the water load is carried by both gravity action and horizontal arch action.

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

Forty-five thousand pounds per square foot.

What is the volume of concrete masonry?

Three and one-quarter million cubic yards in the dam alone, or 4,360,000 cubic yards in the dam, powerplant, and appurtenant works. This amount of concrete would build a monument 100 feet square and 2½ miles high; or, if placed on an ordinary city block, would rise to a height greater than that of the Empire State Building. It would pave a standard highway, 16 feet wide, from San Francisco to New York City. Mass concrete was placed in the dam at the rate of approximately 160,000 cubic yards a month, with a peak placement of 10,462 cubic yards a day (which includes some concrete placed in the intake towers and powerplant) and slightly over 275,000 cubic yards a month. The first concrete was placed on June 6, 1933, and the last concrete was placed in the dam on May 29, 1935.

What is the weight of Hoover Dam?

More than 6,900,000 tons.

How much cement was required?

More than 5 million barrels. The daily demand during construction of the dam was from 25 to 36 cars (7,500 to 10,800 barrels). The Bureau of Reclamation had used a total of 5,862,000 barrels in its 27 years of construction activities preceding June 30, 1932.

How was chemical heat, due to setting of the cement in the mass structure, dissipated?

By embedding in the concrete a system of pipes containing over 582 miles of 1-inch steel tubing, through which cooling water circulated from a cooling and refrigeration plant. The plant had sufficient capacity to produce 1,000 tons of ice from water at 32° F. in 24 hours. Cooling was completed in March 1935.

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

The dam was built in numerous blocks or vertical columns varying in size from sections approximately 60 feet square at the upstream face of the dam to sections 25 feet square at the downstream face. Adjacent columns were locked together by a system of vertical keys on the radial joints and horizontal keys on the circumferential joints. Specifications restricted the rate of placement in any one block to a maximum height of 5 feet in 72 hours. After the concrete was cooled, grout (cement and water) under pressure was forced into the spaces opened up between the columns by the contraction of the cooled cement to form a monolithic structure.

What were the principal items of work?

Excavation, all classes, diversional tunnels, 1,500,000 cubic yards; excavation, common, for foundation of the dam, powerplant, and cofferdams, 1,330,000 cubic yards; rock excavation for dam foundation, 430,000 cubic yards; excavation, all classes, for spillways and inclined tunnels, 750,000 cubic yards; earth and rock-fill for cofferdams, 1,000,000 cubic yards; excavation, all classes, valve houses and intake towers, 410,000 cubic yards; concrete, 4,400,000 cubic yards; drilling grout and drainage holes, 410,000 linear feet; pressure grouting, 422,000 cubic feet; all excavations, more than 5,500,000 cubic yards; total earth and rock-fill, more than 1,000,000 cubic yards.

How much reinforcement steel was used?

About 45 million pounds.

What were the quantities of other principal materials?

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; cement, 5,000,000 barrels.

Did the Government buy these materials?

Yes. The purchasing was handled by the Bureau of Reclamation, through its office in Denver, Colo.

What are the geologic conditions at the dam site?

The foundation and abutments are rock of volcanic origin geologically termed "andesite breccia," hard and very durable.

What was the depth from low-water surface of the river to foundation rock?

From 110 to 130 feet. The lowest point of excavation in the upstream cutoff trench was at elevation 506, or 139 feet below the low-water surface at elevation 645.

What are the canyon widths at the dam site?

From 290 to 370 feet at low-water level, and from 850 to 970 feet at elevation 1,232 feet, the crest of the dam.

What was the time required to build the dam, powerplant, and appurtenant works?

The contractors were allowed 7 years from April 20, 1931. Placing of concrete in the dam was completed May 29, 1935.

How many men were employed by the Government and contractors during the construction of the dam?

An average of 3,500 and a maximum of 5,218, which occurred in June 1934. The average monthly payroll was approximately $500,000.

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

(1) Construction of Boulder City to house both Government and contractors employees. (2) Construction of 7 miles of 22-foot, asphalt-surfaced highway from Boulder City to the dam site. (3) Building of 22.7 miles of standard-gage railroad from the Union Pacific main line to Boulder City, and of an additional 10 miles from Boulder City to the dam site. (4) Construction of a power transmission line 222 miles long, from San Bernardino, Calif., to the dam site to furnish energy for construction purposes.

What is the elevation of the reservoir's high-water line?

The high-water line is 1,229 feet above sea level. With the water surface at this elevation, over 7½ feet of water are flowing over the top of the raised spillway gates. With water-surface elevation at 1,221.4 feet, the water is at the top of the raised spillway gates. All lands below elevation 1,250 have been retained for reservoir purposes.

What is the area of the reservoir?

About 163,000 acres, or 255 square miles, with water level elevation at 1,229 feet. For comparison, Lake Tahoe along the California-Nevada border has an area of about 200 square miles.

What is the length and width of the reservoir?

Maximum water surface elevations have caused Lake Mead to extend approximately 120 miles upstream. It is a little more than 115 miles from Black Canyon to Bridge Canyon and, when Bridge Canyon Dam is constructed, backwater in the lake will be limited by that structure. The reservoir extends up the Virgin River about 35 miles. The width varies from several hundred feet in the canyons to a maximum of 8 miles.

How much water will the reservoir hold?

If filled to elevation 1,221.4 feet, it would contain 29,827,000 acre-feet. An acre-foot is the amount of water required to cover 1 acre 1 foot deep. The reservoir, which would store the entire average flow of the river for 2 years, holds enough water to cover the State of New York to a depth of 1 foot.

How will the reservoir capacity be utilized?

Below elevation 1,229, 9,500,000 acre-feet of storage capacity are reserved for flood control; about 2,620,000 acre-feet for sedimentation control; about 18,000,000 acre-feet for active or regulation storage.

Who operates the dam and reservoir?

The Bureau of Reclamation operates and maintains the dam, reservoir, penstock tunnels, intake and outlet works, and penstocks to, but not including, shutoff valves at the inlets to the turbine scroll case. The National Park Service administers the Lake Mead national recreation area.

How much sediment will be deposited in the reservoir?

A sedimentation survey shows that since 1935 sediment has been deposited in Lake Mead at an annual rate of 105,500 acre-feet. At the present rate of sedimentation and without considering compaction of the sediment, it would take 290 years, or until the year 2225, for Lake Mead to fill with sediment. Consolidation of sediment into a smaller volume, as tons of new sediment are deposited, will extend the life of the lake an additional 155 years, or until the year 2380. This, of course, makes no allowance for future upstream developments. In the event of construction of a dam or dams on the main stream above Hoover Dam, the time when Lake Mead becomes inoperative because of sediment deposits becomes indefinite.

What is the length of the shoreline?

About 550 miles.

What is the estimated annual evaporation on the reservoir?

Eight hundred and fifty thousand acre-feet.

How was the river diverted during dam construction?

By a temporary earth- and rock-fill coffer-dam, through four 50-foot-diameter tunnels, excavated to 56 feet and lined with 3 feet of concrete (300,000 cubic yards), and driven through the rock of the canyon walls, two on each side of the river. These tunnels could carry over 200,000 second-feet of water. The river was diverted through the two Arizona tunnels on November 13, 1932.

What was the length of these tunnels?

The 4 tunnels had a total length of 15,946 feet, or 3 miles.

After their use for river diversion, how were the tunnels used?

They were plugged with concrete at locations approximately one-third their length below the inlet ends of the inner tunnels and about midway in the outer tunnels. The two inner tunnels contain 30-foot diameter steel pipes connecting the intake towers in the reservoir with the penstocks to the powerplant and the canyon wall outlet works The lower portions of the two outer tunnels are used for spillway outlets.

What is the gate installation in the tunnels?

When river diversion through the tunnels was discontinued, the inlet ends of the two outer tunnels were 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 outlet ends of the two inner tunnels, 50- by 35-foot Stoney gates are installed, which may be closed when it is desired to unwater the tunnels for inspection or repairs.

What are the intake towers?

There are four reinforced-concrete towers located above the dam, two on each side of the river and about 165 feet apart in a direction parallel with the river. These towers average 75 feet in diameter (82 feet at the base, 63 feet 3 inches at the hoist house floor, and 29 feet 8 inches inside), each is 395 feet high from base to the top of the hoist house, and each controls one-quarter of the supply of water for the power-plant turbines. The four towers contain 93,674 cubic yards of concrete and 15,-299,604 pounds of steel.

How are these towers connected to the powerplant and outlet valves?

By 30-foot-diameter plate-steel pipes installed in 37- and 50-foot-diameter concrete-lined tunnels. Thirty-seven-foot inclined tunnels connect the upstream intake towers to the 50-foot-diameter inner diversion tunnels, and 37-foot-diameter tunnels lead from the downstream towers to the penstocks and outlet works at elevation 820, 180 feet above the diversion tunnels.

What method of control is used in the intake towers?

Two cylindrical gates, each 32 feet in diameter and 11 feet high, one near the bottom (elevation 895) and the other near midheight (elevation 1,045) of each tower, protected by trash racks located in front of the entrances to the tower. Total weight of the 8 gates is 5,892,000 pounds, and of the trash racks, 7,024,000 pounds.

What pipes are installed in the tunnels for reservoir outlets?

Four thousand seven hundred feet of 30-foot-diameter main headers, 1,900 feet of 25-foot-diameter pipes below the branch penstock tunnels to the powerplant, and 2,000 feet of 8½-foot-diameter pipes in 11-foot-diameter tunnels leading to the needle valve outlets. The maximum thickness of the largest pipe is almost 3 inches.

How are the 30-foot-diameter pipes connected to the powerplant turbines?

By sixteen 13-foot-diameter plate-steel penstock pipes totaling 5,800 feet in length installed in 18-foot-diameter concrete-lined tunnels.

What were the principal items in the contract for fabrication and installation of the steel penstock and outlet pipes?

Forty-four thousand tons of steel were formed and welded into 14,000 feet of pipe varying from 8½ feet to 30 feet in diameter. One length of the largest pipe, 12 feet long, 30 feet in diameter, and 2¾ inches thick, was made from 3 steel plates, of such weight that only 2 plates could be shipped from the steel mill to the fabrication plant on 1 railroad car. Two such lengths of pipe welded together comprised one erection section weighing approximately 135 tons and at intersections with the penstocks as much as 186 tons. For comparison, the weight on the drivers of the Consolidation type of steam locomotive on the project was 99 tons.

What outlets are used?

Six 72-inch needle valves in each inner diversion tunnel plug outlet, and six 84-inch needle valves in the Arizona canyon-wall valve house and five 84-inch needle valves in the Nevada canyon-wall valve house. The needle valves in the canyon walls are at elevation 820, which is about 180 feet above river level. Canyon-wall valves are not used except under emergency or flood conditions.

What is the total maximum capacity of these works?

About one hundred eighteen thousand cubic feet per second, of which about 32,000 cubic feet per second is for power generation and 86,000 cubic feet per second is valve discharge.

What are the Arizona and Nevada spillways?

Each spillway consists of a concrete-lined open channel, about 650 feet long, 150 feet wide, and 170 feet deep, with the side next to the river formed into an ogee-shaped crest. The 2 spillways required 601,419 cubic yards of rock excavation. There were 127,500 cubic yards of concrete placed, the walls being lined with 18 inches of concrete and the floors with 24 inches.

How is water discharged from the spillways?

Through inclined shafts, 50 feet in diameter and 600 feet long, into the outer diversion tunnels.

What will be the maximum water velocity in the spillway tunnels?

About 175 feet per second (120 miles per hour).

What gate installation was made at the spillways?

Four 100- by 16-foot drum gates on each spillway crest, controlled either automatically or manually. Each gate weighs 500,000 pounds.

What is the maximum capacity of the spillways, valves, and powerplant?

Five hundred and eighteen thousand cubic feet per second. Each spillway has a maximum discharge capacity of 200,000 cubic feet per second. Should a flood occur of sufficient volume to require the full capacity of the spillways, 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, and the total drop would be more than three times as great.

The Power Development

What was the installed capacity of the Hoover powerplant in 1953?

Its 16 main turbines gave the plant a rated capacity of 1,735,000 horsepower, and 7,000 horsepower in station-service units, as compared to an ultimate potential of 1,887,000 horsepower. In terms of kilowatts, the plant had a rated capacity of 1,249,800, which included 2 station-service generators of 2,400 kilowatts each. The ultimate potential in kilowatts is 1,354,300. In capacity the Hoover plant is surpassed only by the powerplant at Grand Coulee Dam.

What is horsepower in terms of falling water?

One cubic foot of water falling 8.81 feet equals 1 horsepower at 100 percent efficiency. A second-foot of water is 1 cubic foot, or nearly 7½ gallons, passing a given point in 1 second of time.

What is the ultimate continuous firm power output?

About 663,000 horsepower, based on 83 percent plant efficiency and 10 percent maximum shortage.

How much energy is produced on a yearly basis?

During the operating year ending May 31, 1953, 4,198,600 kilowatt-hours of firm energy were produced. Firm energy decreases each year an estimated 8,760,000 kilowatt-hours as a result of assumed upstream development and a consequent reduction in stream flow. The secondary energy produced in an average water year is estimated to be about 1,200,000 kilowatt-hours.

What is a kilowatt-hour?

The energy resulting from 1 kilowatt for 1 hour. A kilowatt is 1,000 watts. One horsepower equals 0.746 kilowatt. 663,000 (horsepower) × 0.746 (kilowatt) × 24 (hours) ×365 (days) =4,330,000,000 kilowatt-hours.

How is the income from the sale of energy used?

To pay all expenses of operation and maintenance of works incurred by the United States and to repay the major part of the cost of construction of the dam and powerplant, with interest not exceeding 3 percent, within a 50-year period. Repayment of $25,000,000 of the cost allocated to flood control is deferred beyond the 50-year period, when further action will be subject to congressional direction. Arizona and Nevada each are to receive $300,000 annually, paid from revenues, and $500,000 annually is set aside from revenues for further irrigation and power development of the Colorado River Basin.

Where is the powerplant located?

Just below the dam, forming a U-shaped structure built of steel and reinforced concrete. Each wing is 650 feet long, 150 feet high above normal tailrace water surface, and 229 feet (nearly 20 stories) above the powerplant foundation. In all of the galleries of the plant there are 10 acres of floor space.

How does the water reach the turbines?

Through four pressure penstocks, two on each side of the river, each provided with shutoff gates.

What were the power installations in 1953?

Installations as of 1953 were fourteen 115,000-horsepower, one 70,000-horsepower, and one 55,000-horsepower vertical hydraulic turbines. There were fourteen 82,500-kilovolt-ampere, one 62,500 kilovolt-ampere, and one 40,000-kilovolt-ampere generators. Some machines are rated at 50 cycles; however, all are operated at 60 cycles. There are also two 3,000-kilovolt-ampere station-service generators which provide electrical energy for lights and for the operation of cranes, pumps, motors, compressors, and other electrical equipment required for the operation and maintenance of the dam and powerplant.

What are the potential power installations?

Fourteen 115,000-horsepower, one 145,000-horsepower, one 70,000-horsepower, and one 55,000-horsepower vertical hydraulic turbines; fourteen 82,500-kilovolt-ampere, one 110,000-kilovolt-ampere, one 62,500-kilovolt-ampere, and one 40,000-kilovolt-ampere generators; also 2 station-service units rated at 3,500 horsepower, or 2,400 kilowatts, each. All generators are operated at 60 cycles.

What facilities were provided for transporting powerplant machinery from the canyon rim to the powerplant?

A permanent cableway of 150-tons rated capacity, electrically operated, with a span of 1,200 feet across the canyon, is used to lower all heavy and bulky equipment. The cableway is still in use and is brought into service whenever necessary.

Under what heads do the turbines operate?

Maximum head, 590 feet; minimum, 420 feet; average, 510 to 530 feet.

How is the firm energy generated at Hoover Dam allocated?

States of Arizona and Nevada, 17.6259 percent each; Metropolitan Water District of Southern California, 35.2517 percent; city of Burbank, 0.5773 percent; city of Glendale, 1.8475 percent; city of Pasadena, 1.5847 percent; city of Los Angeles, 17.5554 percent; Southern California Edison Co., 7.0503 percent; California Electric Power Co., 0.8813 percent.

Who operates and maintains the powerplant?

The powerplant is operated and maintained directly by the Bureau of Reclamation except for the generating machinery, which is operated and maintained indirectly through operating agents, the city of Los Angeles Department of Water and Power and the Southern California Edison Co. The city of Los Angeles generates for itself, other municipalities, the States of Arizona and Nevada, and the Metropolitan Water District of Southern California. The Southern California Edison Co. generates for itself and the California Electric Power Co.

Who are the principal contractors for energy?

The States of Arizona and Nevada, the city of Los Angeles Department of Water and Power, the Southern California Edison Co., the California Electric Power Co., the Metropolitan Water District of Southern California, and the cities of Glendale, Burbank, and Pasadena.

How is the power transmitted to market?

The contractors for energy provide for the transmission thereof at their own expense.

Colorado River Water Allocation

What States have beneficial interests in the Colorado River system?

The States which have beneficial interests in the Colorado River system are those lying within the Colorado River Basin, i. e., Arizona, California, Colorado, Nevada, New Mexico, Utah, and Wyoming. See map, page 4. Each of these States is a party to the Colorado River Compact entered into at Santa Fe, N. Mex., November 24, 1922. The compact has been ratified by acts of the legislatures of all the signatory States.

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 is at Lee Ferry, a point in the main stream of the Colorado River 1 mile below the mouth of the Paria River and a few miles south of the boundary common to Utah and Arizona. The term "Upper Basin" means those parts of the States of Arizona, Colorado, New Mexico, Utah, and Wyoming within and from which waters naturally drain into the Colorado River system above Lee Ferry, and also all parts of said States located without the drainage area of the Colorado River system which are now or shall hereafter be beneficially served by waters diverted from the system above Lee Ferry.

The term "Lower Basin" means those parts of the States of Arizona, California, Nevada, New Mexico, and Utah within and from which waters naturally drain into the Colorado River system below Lee Ferry, and also all parts of said States located without the drainage area of the Colorado River system which are now or shall hereafter be beneficially served by waters diverted from the system below Lee Ferry.

How is Colorado River water apportioned?

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 annum, and, in addition to such apportionment, gave to the Lower Basin the right to increase its beneficial consumptive use of such water by 1,000,000 acre-feet per annum.

How much water is apportioned to the individual States in the Colorado River Basin?

The Colorado River Compact made no apportionment of water to any State. On October 11, 1948, the States of the Upper Basin entered into the Upper Colorado River Basin Compact for the apportionment of the use of the waters of the Upper Basin. Although the Boulder Canyon Project Act authorized the States of Arizona, California, and Nevada to enter into an agreement relating to the waters of the Lower Basin, such an agreement has not been entered into and the claims asserted by the States with respect to the waters of the Lower Basin are in conflict and dispute. The United States has entered into contracts for the delivery of Colorado River water with the States of Arizona and Nevada and with various agencies in Arizona and California, but in all of those contracts the obligation of the United States to deliver water is made contingent upon the availability of water for use in the respective States under the Colorado River Compact and the Boulder Canyon Project Act.

What are the rights of Mexico in Colorado River water?

The United States and Mexico have entered into a treaty signed February 3, 1944, under which there is allotted to Mexico a guaranteed annual quantity of 1,500,000 acre-feet of Colorado River water. This annual entitlement is, however, subject to increase or reduction in certain circumstances provided for in the treaty.

Boulder City, Nevada

Where is Boulder City located?

The city is located on U. S. Highways 466 and 93, about 7 miles southwest of Hoover Dam.

What is the population of Boulder City?

In 1952 the city had approximately 4,000 residents.

What is the source of domestic water supply?

Water is taken from the penstocks at Hoover Dam and pumped to the city. The principal pumping stations are located in the powerplant and Nevada valve house. With a total pump lift of nearly 2,000 feet, "booster" pumping stations have been installed on the main water lines. At the city the water is delivered to a 100,000-gallon receiving tank. From there it flows to a filtration and purification plant and finally to 2 storage tanks, each holding 2 million gallons.

What improvements and facilities are provided?

A sewerage system, street and park lighting, paved streets, concrete sidewalks, and curbs are provided. Also, spacious parks and tree-lined parkways are maintained.

Did employees of the contractors live in the town during the construction period?

Yes. A portion of the town was set aside for the contractor's use during the construction period. In addition to dwellings erected for the contractor's convenience, service establishments, dormitories, mess halls, and club houses for the employees' use were also built. Moreover, the contractors built maintenance shops to service their own equipment.

What is the present status of Boulder City?

Today Boulder City is a pleasant and beautiful little city. Its well-kept homes, streets, and parks mark it as a man-made oasis. All structures erected as temporary quarters during the construction period have been removed or rebuilt. In addition to modern homes and stores, there are cultural and recreational facilities. The town has a motion-picture theater, several churches, a public library, excellent schools, and many social, fraternal, and civic organizations.

Who owns the land in the town site?

The Government owns the land, all of which is under first form withdrawal under the Reclamation law.

How is a town lot obtained for business purposes?

The land is leased to those awarded business permits. The Government thus far retains ownership and supervisory control. Continuation of the leases has been contingent upon compliance with the terms of the leases.

What provisions were made for erecting buildings suited to the climatic conditions in that section?

All permanent buildings were built to provide protection from the extreme summer temperatures insofar as possible. Even so, the earliest residents endured anything but soft living. Five years after the construction of housing facilities in Boulder City, the desert type of airconditioner was adopted, and now all buildings are cooled. Such climatic conditions as were encountered in the southern Nevada area were not unknown to the Bureau of Reclamation. Similar conditions had been met during the construction of the Yuma and Salt River projects in Arizona.

What is the form of town government?

Originally designed as an integral part of the Boulder Canyon project, Boulder City, during construction of the dam was administered by a city manager, appointed by the Secretary of the Interior and responsible to the Bureau of Reclamation construction engineer. In 1941 the city manager retired, and the administration of the city was placed under the project's director of power. He in turn delegated authority to an engineer in charge of city management. As time passed the changing nature of the town became apparent. It ceased to be a mere construction camp. With the change came an air of permanency. Taking notice of this trend, the Secretary of the Interior, in 1951, ordered steps to be taken to separate project and city administrative functions. In 1952, a city manager was appointed who is responsible to the regional director. An advisory city council is elected by the residents, and the ultimate aim is to bring about a fully incorporated city.

What is the temperature range in the locality?

Temperature extremes range from 20° to 110° F. Such extremes are rare, however. The winters are usually mild, with a few light frosts. Although the summers are hot, the extremely low humidity acts as a compensatory factor. The net result is a hot, dry climate which is not nearly as exhausting as lower temperatures with higher relative humidity recordings.

What is the elevation of the town?

The city is about 2,500 feet above sea level.

All-American Canal System

Is the All-American Canal system a part of the Boulder Canyon project?

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

Why the name "All-American"?

Because the canal is built entirely within the United States. The old Alamo Canal, which formerly served Imperial Valley, ran part way in Mexico.

Will users of water in Imperial and Coachella Valleys have to pay for water?

Imperial and Coachella Valley water users do not pay for the use, storage, or delivery of water for irrigation or for potable purposes. They are obliged to assume costs of construction, operation, and maintenance of the Imperial Dam, the All-American Canal to the Imperial and Coachella Valleys and of other works built under repayment contracts with the United States executed by the Imperial Irrigation District and the Coachella Valley County Water District on December 1, 1932, and October 15, 1934, respectively.

Where is the intake for the All-American Canal?

At the Imperial diversion dam and the All-American Canal desilting works, about 18 miles northeast of Yuma, Ariz.

What type of structure is Imperial Dam?

It is a concrete-slab-and-buttress overflow structure raising the water surface about 23 feet. At its west abutment is located the headworks structure for the All-American Canal in California, and at its east abutment the headworks structure for the Gila Canal in Arizona. Below the headworks on the California side is located the All-American Canal desilting works, consisting of three large desilting basins, each 540 feet wide and 770 feet long, designed to remove the silt picked up by the river on its 300-mile journey from Hoover Dam.

How much water will the canal carry?

A maximum diversion of 15,155 cubic feet per second.

What are the dimensions of the canal?

The maximum section is about 232 feet in width at the water surface, 160 feet in width at the bottom, and 20.6 feet in depth.

What is the length of the All-American?

The canal extends westward for 80 miles through Imperial Valley. The Coachella branch takes off from the All-American about 20 miles west of Yuma and runs northwest to a point just north of Indio, Calif., where it makes a loop to the south. It is 123 miles long.

What structures are built along the canals?

The usual irrigation canal checks, wasteways and turnouts, also, siphons or culverts are used to carry the canals under many washes; at other places, discharge from washes is carried over the canal in concrete overchute-type structures. Because normal operating elevation of the water surface in the Colorado River above Imperial Dam is 179.5 feet above sea level while many of the lands to be served are below sea level, construction of six drop structures have been required on this canal. Four of these drop structures provide possibilities for power generation. Both canals are spanned by highway and railroad bridges at certain points. Flood protection works have been constructed in the Coachella Valley.

Is there opportunity for power development?

Yes. However, under the terms of the All-American Canal contract of 1932, the Imperial Irrigation District was given all rights to power developments on the All-American Canal system, which includes both the All-American and Coachella Canals. To date developments have been confined to the All-American Canal, where the status of installations is as follows: Drop 3, one unit of 4,800-kilowatt capacity; Drop 4, two units of 9,600-kilowatt capacity each; Drop 2, two units of 10,000-kilowatt capacity each. The drop at Pilot Knob between the canal and river is being considered for immediate development. There are no provisions for power generation at Drop 1 and no plans are underway for installations at Drop 5 or for a second unit at Drop 3.

What are the principal areas benefited by the All-American Canal System?

The Imperial Valley (where the water users are organized as the Imperial Irrigation District); the Coachella Valley (where the water users are organized as the Coachella Valley County Water District); and the Yuma Project, Arizona-California, near Yuma, Ariz.

What is the Salton Sea?

An inland sea in a depression, formerly called the Salton Sink, to the north of Imperial Valley. It was created in 1905, when the Colorado broke through temporary diversion canal headworks and poured its entire flow into the valley and the Salton Sink for 16 months. At the present time the sea is about 42 miles long, with a maximum depth of about 40 feet. It covers an area of approximately 215,000 acres and has a water surface elevation of about 237 feet below sea level.

Imperial Valley

Where is the Imperial Valley located?

In the extreme southern part of California, bordering Mexico.

What is the irrigable area of the Imperial Valley?

Five hundred and seventeen thousand acres.

How much land is now irrigated in the valley?

About 430,000 acres in 1953.

What is the present irrigated area in Mexico (Lower California) served by the Colorado River?

About 400,000 acres.

What are the principal crops grown in Imperial Valley?

Alfalfa, cotton, sugar beets, winter vegetables, flax, cantaloupes, barley, milo maize, and fruits.

How much is the rainfall on the Imperial division?

About 3 inches a year.

How long is the growing season?

Three hundred and sixty-five days.

What is the elevation of the Imperial Valley?

From 250 feet below sea level at the Salton Sea to 50 feet above sea level.

Coachella Valley

Where is the Coachella Valley located?

North of the Salton Sea, which separates it from the Imperial Valley.

What is the irrigable acreage in the Coachella Valley?

About 75,000 acres will ultimately be irrigated with Colorado River water. Prior to the building of the Coachella Canal, about 20,000 acres had been developed by pumping water from underground sources.

What is the elevation of the Coachella Valley?

From about 220 feet below sea level near the Salton Sea to about 220 feet above sea level at the northern end of the valley.

What are the principal crops grown in the Coachella Valley?

Dates, grapes, citrus, winter vegetables, cotton, and alfalfa. About 90 percent of the Nation's domestic dates supply comes from the Coachella Valley.

What is the rainfall?

Around 3 inches a year.

How long is the growing season?

Three hundred and sixty-five days.

Yuma Project

Where is the Yuma project?

In southwestern Arizona and southeastern California, on the flood plains of the Colorado River, adjacent to the city of Yuma, Ariz.

How many acres does it contain?

About 65,000—approximately 50,000 acres on the Valley division in Arizona and 15,000 acres on the Reservation division in California.

What are its principal crops?

Flaxseed, alfalfa hay and seed, melons, winter vegetables, cotton, sorghums and small grains, pasture crops, a little citrus, some dates and pecans.

What is the annual rainfall?

A little over 3 inches a year.

How long is the growing season?

Three hundred and sixty-five days.

Colorado River Aqueduct

Is the Colorado River aqueduct a part of the Boulder Canyon project?

No. The aqueduct was built by the Metropolitan Water District of Southern California to transport water diverted from the Colorado River near Parker Dam to the district members generally in the vicinity of Los Angeles. The water thus diverted was released from storage in the reservoir back of Hoover Dam.

What is the Metropolitan Water District?

A public corporation formed for the purpose of securing additional domestic water for the southern California coastal region. When it was organized in 1928, the district was made up of Los Angeles and 10 neighboring municipalities. The Metropolitan Water District now comprises 47 incorporated cities located in southern California's 5 coastal counties, together with large and populous unincorporated territory.

What portion of the Colorado River's water is the district to receive?

The district has a contract with the Government for delivery each year from the reservoir up to but not exceeding 1,212,000 acre-feet of water. This corresponds to the flow of about 1,500 cubic feet per second, or about 1,000,000,000 gallons daily from the river. The district pays the United States a storage charge of 25 cents per acre-foot for the actual amount diverted from the river.

How is diversion into the aqueduct effected?

By pumping from Havasu Lake, back of Parker Dam. The dam is located 155 miles below Hoover Dam and about 18 miles upstream from the town of Parker, Ariz.

What type of structure is Parker Dam?

Parker Dam is a concrete arch structure, superimposed by five 50- by 50-foot Stoney gates for river control. It is 320 feet high, but only 85 feet extend above the river bed. The dam and its reservoir, Havasu Lake, were constructed by the Bureau of Reclamation with funds advanced by the Metropolitan Water District.

What is the total length of the aqueduct?

About 242 miles.

What is the pumping lift to cross the mountains?

One thousand six hundred and seventeen feet. Five pumping stations are required.

Where does the district obtain electrical energy for pumping and other operational needs?

From the Hoover and Parker Dam powerplants.

How much energy does the Hoover powerplant supply?

The Metropolitan Water District allocation is 35.2517 percent of the firm energy produced, with a preferential right to the use of dump or secondary energy. This energy is transmitted over lines built by the district.

How large is the Parker Dam powerplant and how is its production allocated?

Four hydroelectric generating units, each with a capacity of 30,000 kilowatts, give the powerplant an installed capacity of 120,000 kilowatts. Costs of powerplant construction were shared equally by the United States and the Metropolitan Water District. The United States retains one-half of the power privileges and responsibility for the operation of the plant, as well as control of all water passing over the dam. Ownership of the dam, powerplant, and appurtenant works is vested in the United States, and the portion of costs chargeable to the Government is being repaid by power revenues.

Davis Dam

Is Davis Dam a part of the Boulder Canyon project?

No; but it furthers the work of harnessing the Colorado begun by Hoover Dam and must be included to give a well-rounded picture of lower Colorado River basin development.

What are the purposes of Davis Dam?

The Davis Dam project helps to relieve a critical power shortage in the area served, plays a part in regulating the river, services provisions of the Mexican water treaty of 1945, and contributes to flood control, reduction of silt pollution, recreation, wild waterfowl protection, and related purposes.

What type of structure is Davis Dam?

Davis Dam, rising 200 feet above the lowest point of the foundation and about 138 feet above the level of the river, is an earth- and rock-fill embankment with concrete spillway, intake structure, and powerplant. It has a crest length of 1,600 feet, and a top width of 50 feet.

How much storage capacity is provided?

The Davis Dam reservoir, Lake Mohave, has a total capacity of 1,818,300 acre-feet of water. It extends 67 miles upstream to the tailrace of the Hoover powerplant.

How much power is developed?

Located on the Arizona side of the Colorado River, the Davis powerplant has an installed capacity of 225,000 kilowatts provided by five 45,000-kilowatt semioutdoor-type generators. The power output is over 1,000,000,000 kilowatt-hours a year.

What power-market areas are served?

High-voltage switchyards near the powerplant provide the takeoff point for a system of transmission lines and substations which interconnect the Davis, Hoover, and Parker powerplants and extend to load centers in Arizona, southern Nevada, and southern California.

Where is Davis Dam located?

Davis Dam is in Pyramid Canyon, 67 river miles below Hoover Dam and about 10 miles north of the point where Arizona, Nevada, and California meet. The dam is 32 miles west of Kingman, Ariz., and may be reached by east-west asphalt highways Arizona 68 and Nevada 77, which cross the river on the crest of the dam.

How did Davis Dam get its name?

The project originally was named Bullshead after a rock formation in the river near the dam site which was said to resemble the head of a bull. In 1941 it was renamed in honor of the late Arthur Powell Davis, director of Reclamation from 1914 to 1923, whose courage, foresight, and vision helped to spark the beginning of Colorado River development.

When did the construction of Davis Dam begin?

The Davis Dam project was authorized in April 1941, and actual construction began in August 1942. Some excavation was undertaken, but the exigencies of World War II brought the work to a halt in December of the same year. Work was resumed in March 1946 under a contract awarded to the Utah Construction Co.

When was Davis Dam completed?

The main dam embankment was completed in April 1949. The intake and spillway structures were substantially completed the same month. The six temporary diversion openings of the spillway structure were closed with concrete stop logs in January 1950, and first storage of water in the reservoir began. The powerhouse was completed in October 1950, the first unit went on the line in January 1951, and all five units were in operation by the middle of June 1951. The dam and powerplant were dedicated in December 1952 at a colorful ceremony attended by high Government officials, governors of five of the Western States and Alaska, representatives of the Government of Mexico, and other notables.

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