

U. S. Bureau of Reclamation

Area immediately above the Hoover Dam site, seen from Monument Pass, Nevada, that will form part of the vast reservoir which is to hold more than 30,000,000 acre-feet of water.

America's Wonder River—the Colorado

*Work on the Hoover Dam Now Underway After the Disposal of Many Puzzling Questions**

By R. G. SKERRETT

IN curbing the Colorado by means of the Hoover Dam, the Federal Government is essaying the greatest task in hydraulic engineering that it has taken upon itself since digging the Panama Canal. In beginning this momentous undertaking, both engineers and constructors have joined battle with inexhaustible nature; and they have willed to bring under subjection a stream with a violently riotous record that reaches unbrokenly into the dim past. The work in hand is not only superlatively big in the matter of dimensions but vast in its economic potentialities and significance.

The mere start of the Hoover Dam crystallizes agitation for the control of the Colorado that dates back more than a quarter of a century. And that we may have a fair conception of the undertaking and the steps by which it has been brought to its present pass, it might be well to summarize the preliminaries that smoothed out difficulties of various sorts and that provided a firm basis for the consummation of a long-desired relief.

The Hoover Dam project as now planned calls for the ultimate expenditure of $165,000,000, including the construction of an appurtenant undertaking known as the All-American Canal. The total sum will be made up of the following four items:

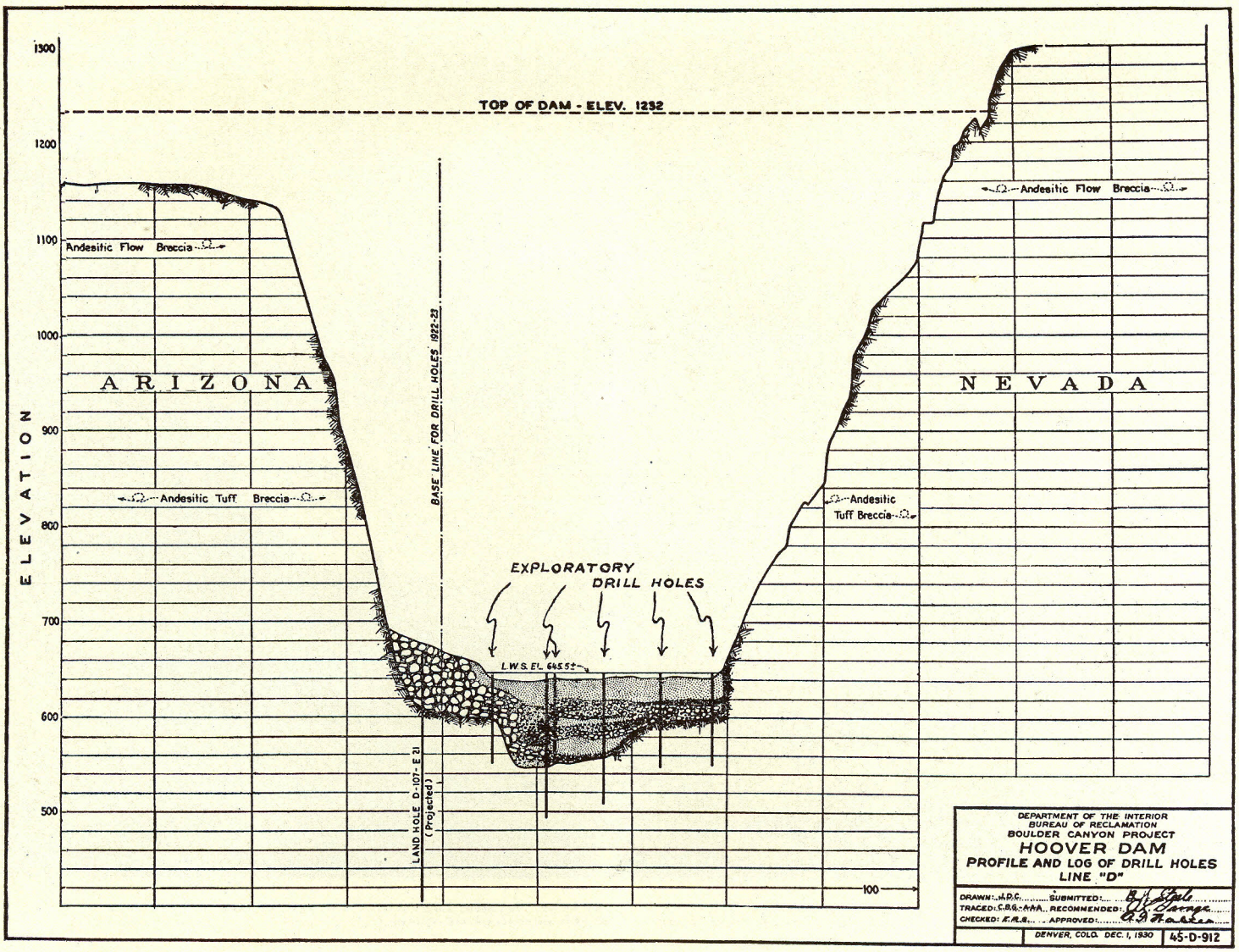
Dam and reservoir	$70,600,000
1,000,000-hp. development	38,200,000
All-American Canal	38,500,000
Interest during construction	17,700,000
Total	$165,000,000

The All-American Canal will, when completed, take water from the Colorado at a point above the Mexican boundary, and is designed to supply the needs of the Imperial Valley and the Yuma project. It will be 75 miles in length, and will be notable for a number of reasons. We shall not now touch upon this phase of the control of the Colorado River—the matter of immediate interest is the Hoover Dam and its associate features.

Colorado River Compact

The building of the Hoover Dam might still be something for future decision had not the Colorado River Commission been called into existence in 1921. That commission was made up of representatives from Arizona, California, Colorado, Nevada, New Mexico, Utah, and Wyoming. Herbert Hoover, then Secretary of Commerce, was the chairman of the commission. The commission was brought into being when the several states immediately concerned had advanced numerous sincere but very conflicting claims; and it was manifest that some representative body would have to take all these claims under consideration

**Third of a series of articles on the Colorado River and the building of Hoover Dam.*





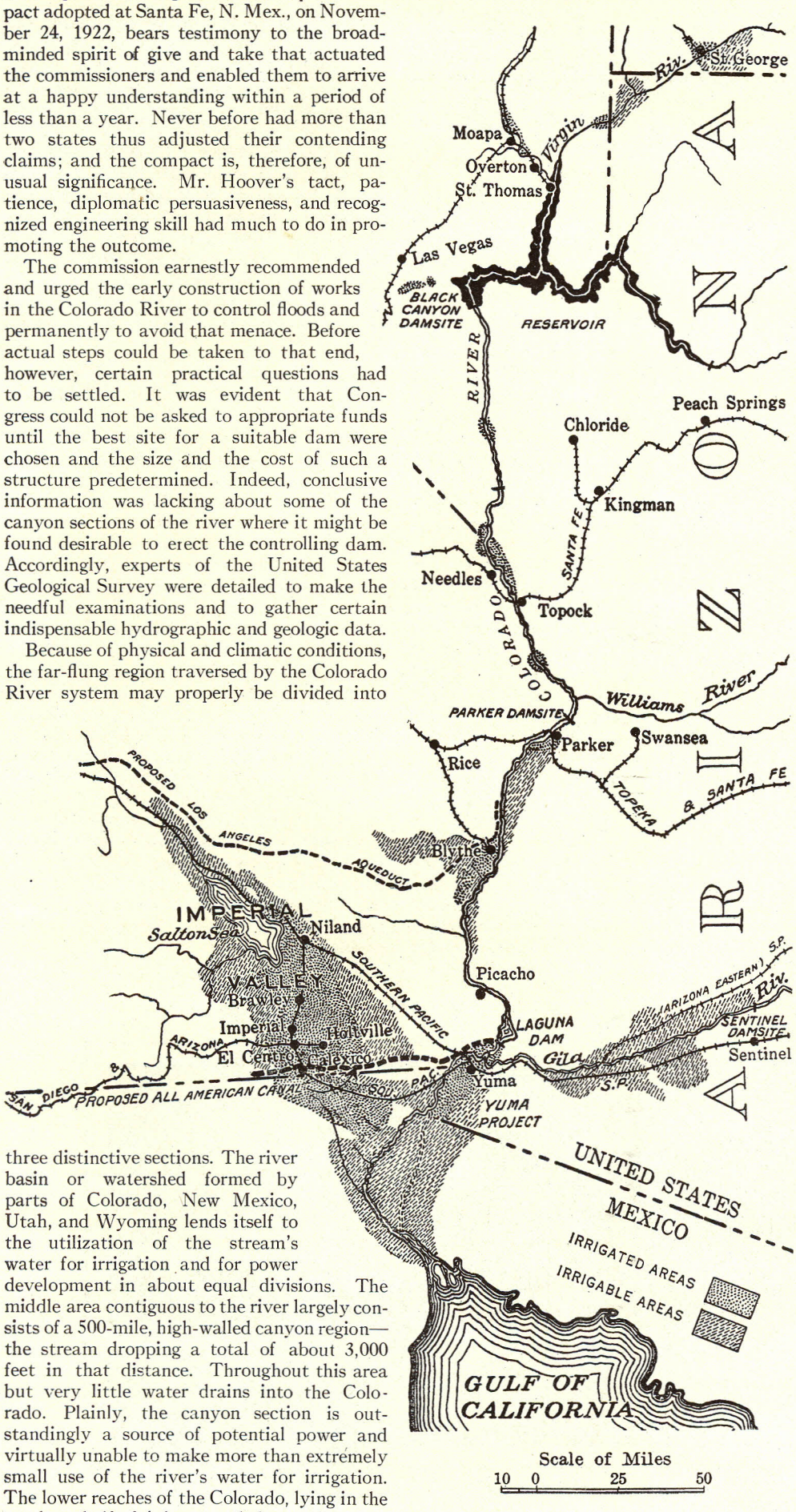
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Black Canyon before work was started on the Hoover Dam project. The site is just at the far bend in the river and was chosen only after extensive investigation had revealed its outstanding advantages.

and, if possible, bring about accord. The compact adopted at Santa Fe, N. Mex., on November 24, 1922, bears testimony to the broad-minded spirit of give and take that actuated the commissioners and enabled them to arrive at a happy understanding within a period of less than a year. Never before had more than two states thus adjusted their contending claims; and the compact is, therefore, of unusual significance. Mr. Hoover's tact, patience, diplomatic persuasiveness, and recognized engineering skill had much to do in promoting the outcome.

The commission earnestly recommended and urged the early construction of works in the Colorado River to control floods and permanently to avoid that menace. Before actual steps could be taken to that end, however, certain practical questions had to be settled. It was evident that Congress could not be asked to appropriate funds until the best site for a suitable dam were chosen and the size and the cost of such a structure predetermined. Indeed, conclusive information was lacking about some of the canyon sections of the river where it might be found desirable to erect the controlling dam. Accordingly, experts of the United States Geological Survey were detailed to make the needful examinations and to gather certain indispensable hydrographic and geologic data.

Because of physical and climatic conditions, the far-flung region traversed by the Colorado River system may properly be divided into three distinctive sections. The river basin or watershed formed by parts of Colorado, New Mexico, Utah, and Wyoming lends itself to the utilization of the stream's water for irrigation and for power development in about equal divisions. The middle area contiguous to the river largely consists of a 500-mile, high-walled canyon region—the stream dropping a total of about 3,000 feet in that distance. Throughout this area but very little water drains into the Colorado. Plainly, the canyon section is outstandingly a source of potential power and virtually unable to make more than extremely small use of the river's water for irrigation. The lower reaches of the Colorado, lying in the southern half of Arizona and the southeastern part of California, constitute an area of 69,000 square miles; and while the river throughout this region drops about 500 feet in 300 miles still it is preëminently suited to agricultural operations. Thus, it is manifest that the Colorado River Commission did wisely in dividing the whole watershed into two main divisions or basins. The Upper Basin embraces parts of Arizona, Colorado, New Mexico, Utah, and Wyoming lying above Lees Ferry, while the lower Basin is composed of those parts of Arizona, California, Nevada, New Mexico, and Utah below Lees Ferry.



The natural flow of the Colorado River averages annually 20,000,000 acre-feet; and about one-third of this flow is now utilized. Present users in the Lower Basin take about 3,700,000 acre-feet. By the compact, this region is awarded a total yearly flow of 8,500,000 acre-feet—more than double existing needs. The Upper Basin was awarded 7,500,000 acre-feet, also more than double its present needs and ample to serve quite 3,000,000 acres of additional cultivated land. Besides these allotments, there remains an unapportioned measure of 4,000,000 acre-feet of water for future division as unforeseen demands may arise. So much for the wise and equitable apportionment of the water made by the commission.

Choice of Dam Site

The steep gradient of the Colorado in the canyon section made logical the building of a control dam therein. The problem then was to find the place within that section where physical conditions would lend themselves best to the rearing of such a structure and where such a structure would be able to impound the largest volume of water. Furthermore, the dam had to be so situated that the associate power plants would be within relatively easy reach of markets for the electricity generated there. Consideration had to be given to the distances within which current could be transmitted without encountering prohibitive losses. The importance of this phase of the problem becomes apparent when it is realized that the sale of power is counted upon to repay the outlays incident to the building of the Hoover Dam. Indeed, the undertaking would probably not have been started had this method of refunding not been assured by contracts made with prospective users.

The responsibility for the choice of the dam site was placed upon the Colorado River Board on the Boulder Dam Project. The board was called into being agreeably to a joint resolution of Congress approved May 29, 1928. It was composed of eminent engineers and geologists; and its report was made towards the end of November following. Two sites were considered—one in Boulder Canyon and one in the upper part of Black Canyon; and the Black Canyon site was chosen. The reasons for the selection are thus summed up by that body:

"In general, geologic conditions at Black Canyon are superior to those at Boulder Canyon. The Black Canyon site is more accessible, the canyon is narrower, the gorge is shallower below water level, the walls are steeper, and a dam of the same height here

would cost less and would have a somewhat greater reservoir capacity. The rock formation is less jointed, stands up in sheer cliffs better, exhibits fewer open fractures, is better healed where formerly broken, and is less pervious in mass than is the rock of the other site. The Black Canyon rock is not so hard to drill as that of Boulder Canyon; and it will stand better in large tunnel excavations with less danger to the workmen.

"There is no doubt whatever but that the rock formations of this site are competent to carry safely the heavy load and abutment thrusts contemplated. It is well adapted to making a tight seal and for opposing water seepage and circulation under and around the ends of the dam. It insures successful tunneling, and, so far as the rock is concerned, the general safety and permanence of the proposed structures." Exploratory drilling, carried to a depth of 557 feet below the low-water surface of the rock, did not penetrate any other formation.

While the foundation rock upon which the dam will rest is a volcanic breccia or tuff, derived from probably repeated eruptions, still time has worked a transformation that has cemented the breccia into a tough, durable mass of rock capable of withstanding the weather and of resisting erosion exceptionally well. There is every indication that volcanic action ceased thousands of years ago; and the district, today, is virtually free from the effects of recurrent earth movements in that part of the country.

The board realized that the dam then contemplated would have to be much higher than any other dam built or projected, and was keenly alive to the fact that the structure would have to be correspondingly strong. Failure would let loose suddenly an enormous body of water which, sweeping unimpeded down the river channel, would probably destroy Needles, Topock, Parker, Blythe, Yuma, and obliterate the levees of the Imperial district—creating a channel into the Salton Sea that would in all likelihood be so deep that it would be impracticable to turn the Colorado River again into its normal course. As the board expressed it: "To avoid such possibilities the proposed dam should be constructed on conservative if not ultraconservative lines." That recommendation has been observed in every phase of the design of the Hoover Dam.

What the Dam Must Do

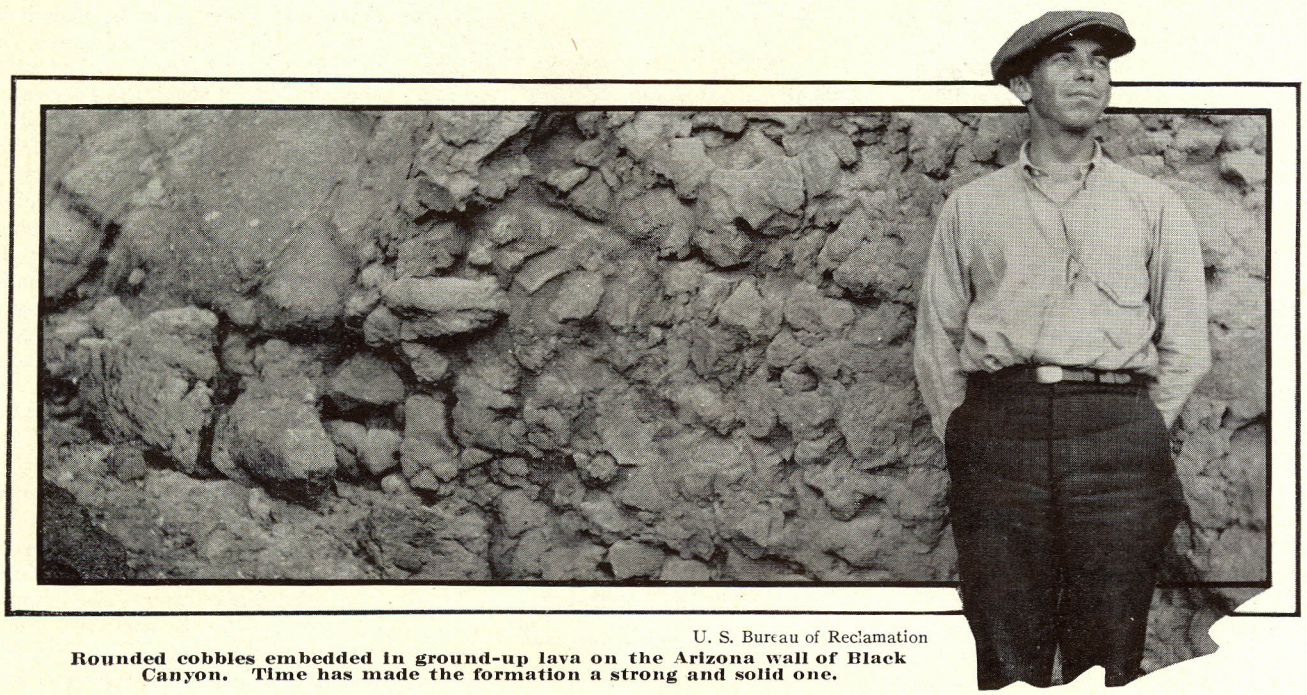
The Hoover Dam may best be described as a titanic wedge of concrete that will be rigidly secured to the rock underlying the normal water bed and anchored to the towering flanking walls of the relatively narrow gorge. From base to crest the structure will have a height of 730 feet; and up and down stream the base will have a spread of 650 feet. Along the crest the dam will have a width of 45 feet and a length of about 1,180 feet; and it will be made up of substantially 3,500,000 cubic yards of concrete. The foundation will be bound to the supporting bedrock at a depth of 150 feet below the low-water level of the river. Expressed otherwise, the dam will replace rock worn away by the Colorado in its age-old rush seaward.

The function of the dam is a fourfold one: It is to serve for flood control; for the regulation of irrigation flow; for the development of power; and for the storage of silt. The basin created by the Hoover Dam will have a capacity of 30,500,000 acre-feet of water, or water enough to cover to a depth of 1 foot the combined land areas of Maine, New Hampshire, and Vermont. The lake above the dam will extend upstream for a distance of 115 miles and at its widest point have a breadth of eight miles. It will be the biggest of man-made reservoirs, and will be able to store nearly seven times as much water as the world-famous Assuan reservoir, on the Nile, after the heightening of the Assuan Dam has been completed. Expressed in another way, the Hoover Dam basin will have sufficient capacity to hold substantially a two years' flow of the Colorado!

Annual Flow of River

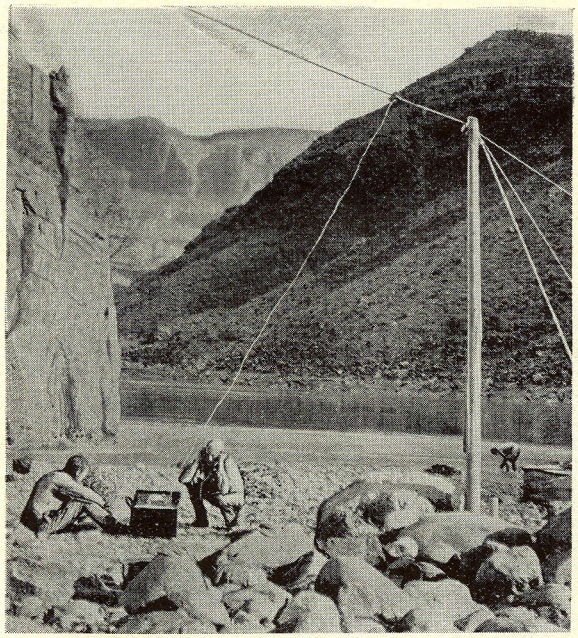
Averages are difficult to arrive at in the case of the Colorado's flow. At times the discharge is less than 3,000 second-feet, while on one recorded occasion the outpouring mounted as high as 300,000 second-feet! Careful records made over a period of some years have given an average annual flow of 17,300,000 acre-feet. The point to be emphasized is that the Colorado in any of its flood periods presents a problem for the hydraulic engineer; and the Hoover Dam has been so designed that it can stand rigidly, with a very large factor of safety, against on-rushing torrents when the river is in a tempestuous mood. When the water is at its maximum height in the lake it will have a depth of 580 feet.

Next to controlling the flood flow of the Colorado, the reservoir created by the Hoover Dam will, because of its stupendous capacity, make it feasible to release continually into the river channel a volume of water ample enough to meet the irrigation needs of the farmlands on the Yuma project, in the Imperial Valley, and on those lesser areas in the lower reaches of this variable stream. So much stress has been laid upon flood control and the ravages wrought by the river when on its annual rampages that most people unfamiliar with the Colorado assume that it always is of sufficient volume to meet the demands of dependent agriculturists. This is not true; and there are years when there is an actual deficiency in vitally necessary water. Therefore, the conservation and control which will be made possible by the completion of the Hoover Dam will prevent these serious fluctuations and assure, from season to season, the water that may be required for the growing of crops and other essential purposes. The foregoing services are the primary ones of this magnificent project. Now let us consider briefly the two remaining objects of the undertaking—one of which is to make the venture a self-paying proposition.



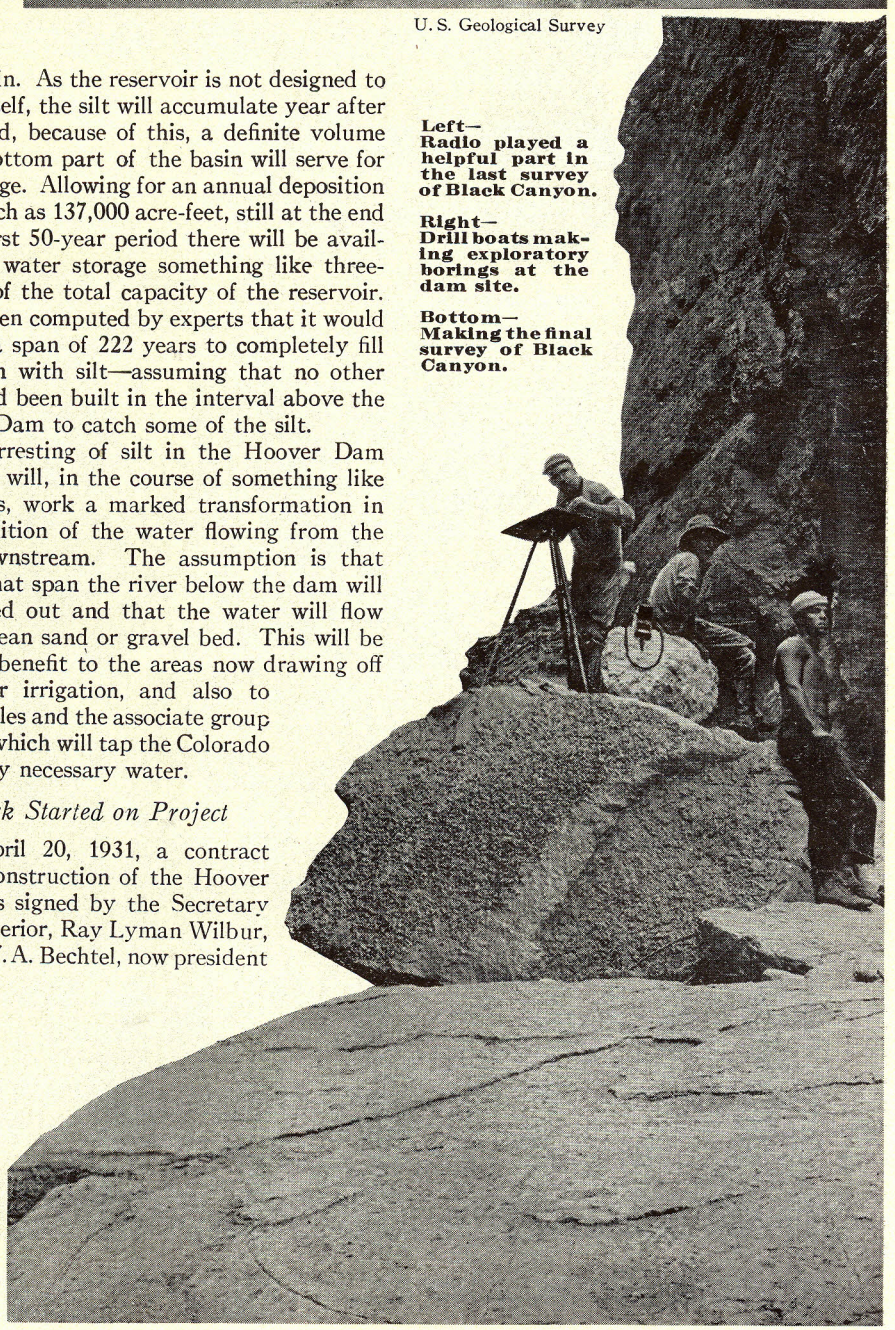
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Rounded cobbles embedded in ground-up lava on the Arizona wall of Black Canyon. Time has made the formation a strong and solid one.





U. S. Geological Survey



Left—
Radio played a helpful part in the last survey of Black Canyon.

Right—
Drill boats making exploratory borings at the dam site.

Bottom—
Making the final survey of Black Canyon.

Generation of Power

Associated with the Hoover Dam will be power plants equipped with groups of great hydro-electric generators that will have a combined rated output of 1,000,000 hp.—one-fourth of all the power that might be developed by a series of stations placed at strategic points in the canyon section of the Colorado. The turbines will be operated under an average head of 520 feet, and they will have a firm or continuous output of about 660,000 hp. The price of this firm power will be at the rate of 1.63 mills per kilowatt-hour. During periods of high water, when the operating head may be as much as 582 feet, the dynamos will generate their full power; and this seasonal current will be sold for 0.5 of a mill for each kilowatt-hour. Cheap power will be a great boon to industrial activities of all sorts, and especially to mining enterprises in California, Arizona, and Nevada lying within a radius of economical distribution.

As Dr. Elwood Mead, Commissioner, Bureau of Reclamation, has pointed out: "The power and water income from the contracts already signed will, in 50 years, bring an income of $373,500,000. Of this, the United States will receive $228,260,000 to repay money advanced, with interest. Arizona and Nevada will each receive $31,235,000; operation and maintenance will absorb $16,120,000; and there will be a surplus of $66,650,000, which will be the net profit of the Government for going into this enterprise. This sum will be disposed of as Congress may hereafter direct." This statement will answer the questioning taxpayer.

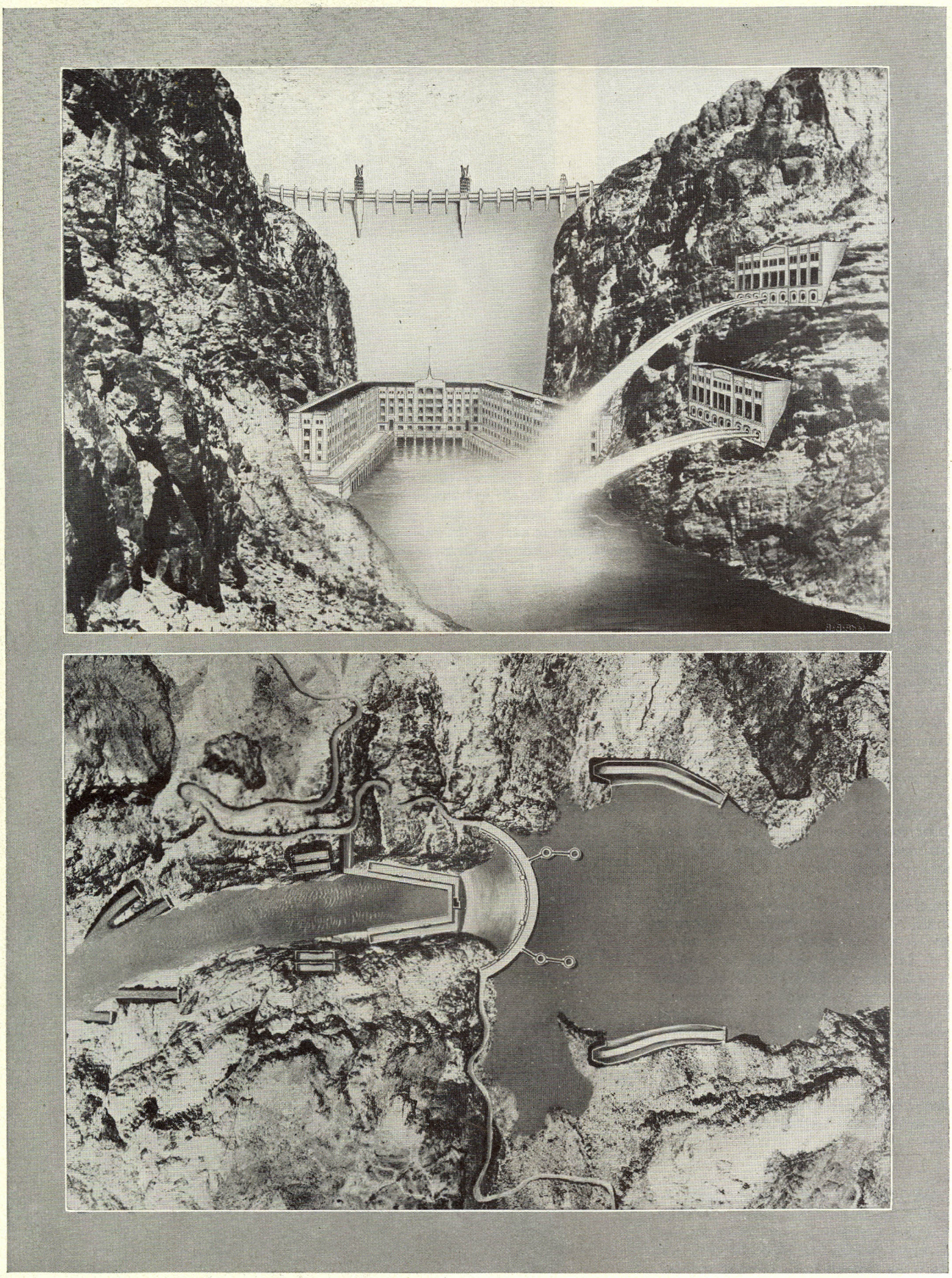
Storage of Silt

As had been well and wittingly said, the Colorado when in flood is a stream too thick to drink and too thin to plow. This description is based on the fact that the river will pour into the Hoover Dam reservoir approximately 100,000 acre-feet of mud every twelvemonth; and the major part of this alluvium will find a resting place on the bottom of the vast basin. As the reservoir is not designed to purge itself, the silt will accumulate year after year; and, because of this, a definite volume of the bottom part of the basin will serve for silt storage. Allowing for an annual deposition of as much as 137,000 acre-feet, still at the end of the first 50-year period there will be available for water storage something like three-fourths of the total capacity of the reservoir. It has been computed by experts that it would require a span of 222 years to completely fill the basin with silt—assuming that no other dams had been built in the interval above the Hoover Dam to catch some of the silt.

The arresting of silt in the Hoover Dam reservoir will, in the course of something like ten years, work a marked transformation in the condition of the water flowing from the dam downstream. The assumption is that within that span the river below the dam will be cleared out and that the water will flow over a clean sand or gravel bed. This will be of great benefit to the areas now drawing off water for irrigation, and also to Los Angeles and the associate group of cities which will tap the Colorado for vitally necessary water.

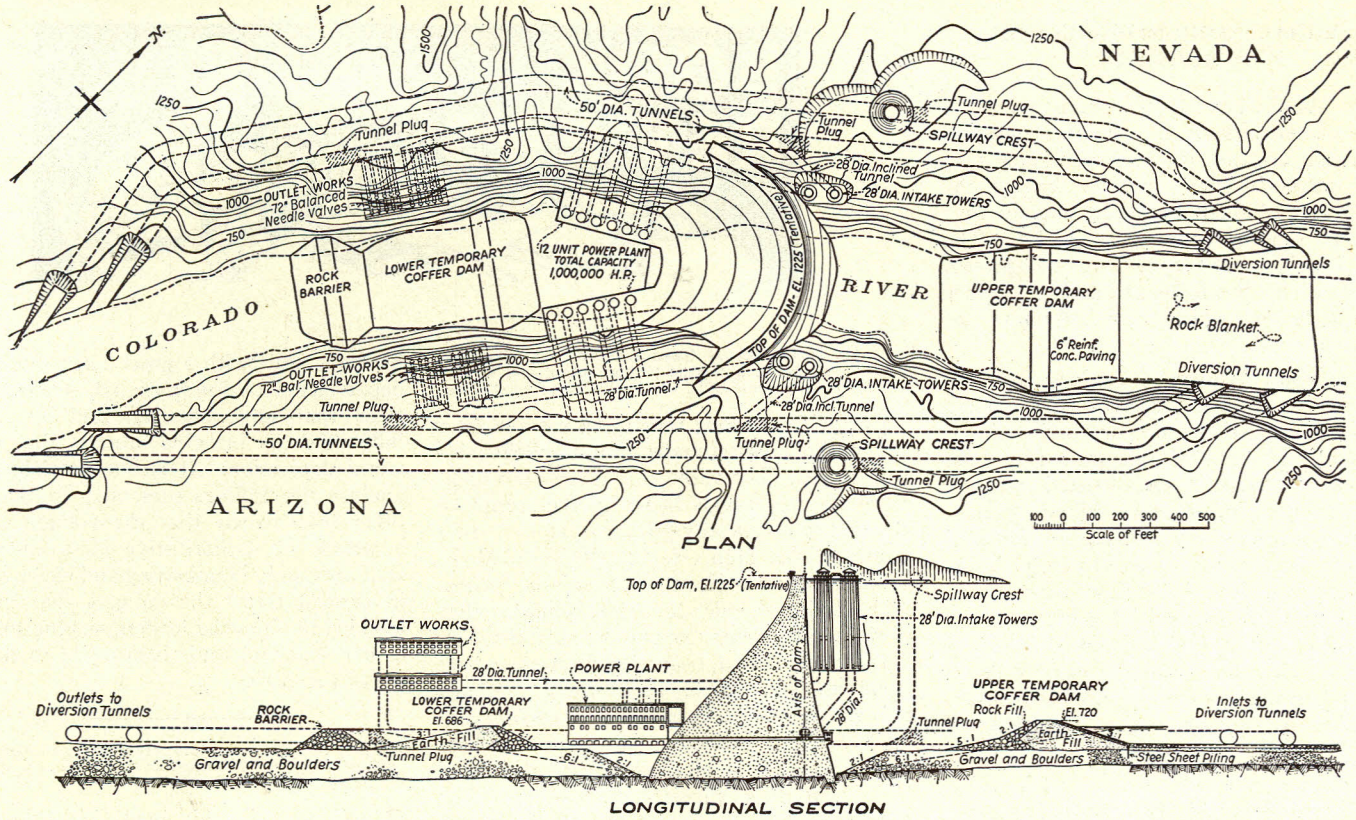
Work Started on Project

On April 20, 1931, a contract for the construction of the Hoover Dam was signed by the Secretary of the Interior, Ray Lyman Wilbur, and by W. A. Bechtel, now president



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Top—How Hoover Dam and its appurtenant power plant will look when ready for service. Bottom—Model of Hoover Dam and its associate features. The lake created by the dam will be 115 miles long and capable of impounding a maximum of 30,500,000 acre-feet of water.



of the Six Companies Incorporated. Six Companies Incorporated contracted to build the Hoover Dam, the power plant, and certain associate works for the sum of $48,890,995. That act brought to a close long years of waiting and, to that extent, relieved the anxieties of our people in the lower sections of the river where there has been an ever-recurrent fear that the Colorado would break loose and overrun and ravage the contiguous cultivated lands.

With the project actually underway, it is now possible to look backward and to realize that much has probably been gained by delay. Both the engineers responsible for the present magnificent scheme and the contractors engaged in carrying it out are richer in their knowledge and their experience than they would have been had they tackled a task of like proportions twenty years ago. Also, makers of machinery have, in the intervening decades, devised equipment of different kinds especially fitted to deal effectually and rapidly with the heavy and complex work involved. The contractors are called upon to rear a mountainous obstruction athwart the erratic flow of the Colorado and, at the same time, to divert that stream temporarily around this rising bulwark no matter what may be the state of the stream the while!

What the Contractor Must Do

The Hoover Dam site is about 25 miles southeast of Las Vegas, Nev., and situated in what was an utterly isolated desert region before steps were taken to provide means of transportation from the nearest railroad and to create accommodations for the army of workers that will be engaged on the job for quite 6½ years—the period during which Six Companies Incorporated pledges itself to complete its part of the great undertaking. Interesting as it would be to tell how these preliminaries were carried out and how a sizable town—Boulder City—was called into being in the midst of that hot and arid region, space compels us to confine ourselves strictly to the work involved in connection with the dam and its immediately appurtenant features.

Before any part of the dam can be started, the contractor must drive four tunnels which will be 56 feet in diameter and average more than 4,000 feet in length. Two of these are being driven on the Nevada side of the Colorado and two on the Arizona side—the tunnels piercing the rock at an elevation close to that of the low-water level of the river. These tunnels are counted upon to carry the entire volume of the flow at any likely stage. Upstream above the dam site, and just below the intake ends of the tunnels, a great cofferdam, 80 feet in height, will be constructed. This will block the normal course of the river and divert its flow into the diversion tunnels. Just upstream from the outlet ends of the tunnels, and below the dam site, will be built another massive cofferdam that will prevent the Colorado from encroaching upon the space between the two cofferdams. This space will be unwatered so that the river bed can be bared preparatory to removing the accumulated sand and gravel down to bedrock, from 80 to 100 feet below the low-water level. The excavation for the foundation of the dam will necessitate the removal of substantially 7,000,000 cubic yards of material.

In driving the diversion tunnels, which, with the cofferdams, will be completed in about two years, the contractor will drill, blast, and muck nearly 2,000,000 cubic yards of rock. Something like three-fourths of this rock will be used to stabilize the two cofferdams. With the cofferdams built and with the tunnels driven and lined with 3 feet of concrete, the contractor can start work on the dam itself, and he will then bring into play a multiplicity of facilities that he has been making ready and assembling in the meanwhile. As time goes on, it is our purpose to keep our readers posted on the progress of the work, and, therefore, we shall not confuse by entering into details now.

The building of the Hoover Dam involves a battle with climatic conditions that are extremely severe and trying during the warm months of each year. Again, we quote Doctor Mead: "The summer wind which sweeps over the gorge from the desert feels like a blast from a furnace. At the rim of the gorge, where much of the work must be done, there is neither soil, grass, nor trees. The sun beats down on a broken surface of lava rocks. At midday, they cannot be touched with the naked hand. It is bad enough as a place for men at work. It is no place for a boarding house or a sleeping porch. Comfortable living conditions had to be found elsewhere, and these are found on the summit of the Divide, five miles from the dam. Here there is fertile soil; here winds have an unimpeded sweep from every direction; and here there is also an inspiring view of deserts and lonely gorges and lofty mountain peaks."

When the dam is an accomplished fact, when the pent-up waters are available for controlled irrigation and for the generation of power, then that amazing structure will constitute a milestone for a civilization under which unnumbered generations will flourish. A vast new empire of industry and enterprise will center upon that towering monument to engineering skill and to the never-failing resourcefulness of the men responsible for its consummation.