Hoover Dam:
The Boulder Canyon Project

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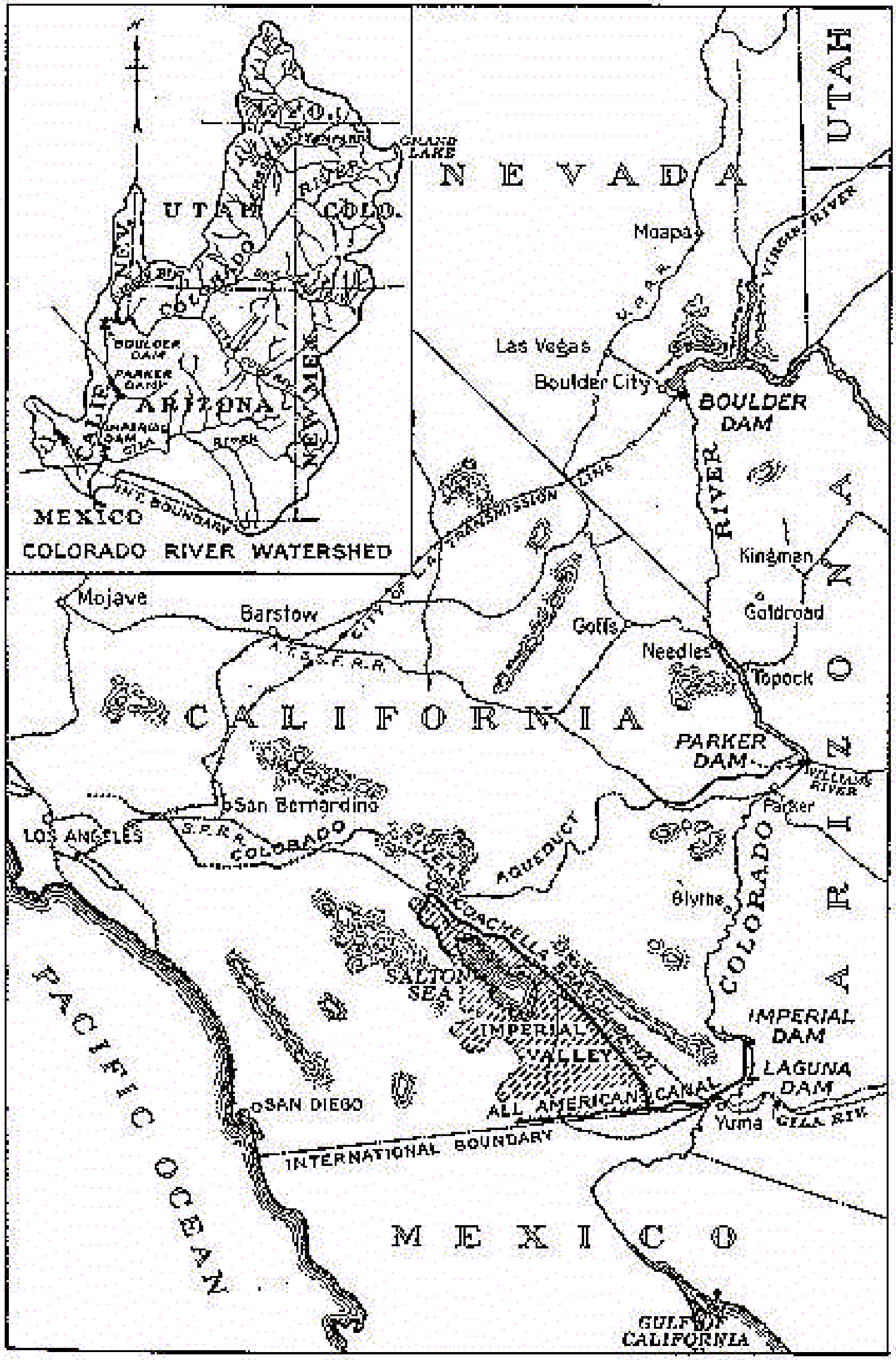

Figure 1: Historic Boulder Canyon Project Map

Hoover Dam:
The Boulder Canyon Project

Throughout human history, mankind has built monuments to its ingenuity and skill. In Egypt it was the Pyramids. Rome, built the Colosseum. The Greeks built the Acropolis. The great cathedrals of Europe raised the skills of their builders to unequalled heights, creating awe inspiring structures. In the Americas, the cliff dwellings of Mesa Verde and the high mountain city of Machu Picchu speak to the skill and ingenuity of their builders. In the modern era, it's buildings that reach near half a mile into the sky, bridges that stretch enormous distances in a single span, and machines that extend mankind's reach far into space. One monument that must surely be counted among the great achievements of mankind is Hoover Dam.

Location

Hoover Dam and Lake Mead are located in the Black Canyon of the Colorado River about 35 miles southeast of Las Vegas, Nevada. Located on the Arizona-Nevada State line, the dam and reservoir are in the counties of Mohave, in Arizona, and Clark, in Nevada. The Colorado River Basin is an area of over 242,000 square miles that includes parts of California, Nevada, Arizona, Utah, Colorado, New Mexico, and Wyoming. The basin also includes some 2,000 square miles in Mexico. The Colorado River itself originates in the high mountains of Colorado and flows 1,400 miles to the Gulf of California. Along the way, it gathers the waters of several major rivers including the Gunnison River in Colorado, the Green and San Juan Rivers in Utah, the Little Colorado and Gila Rivers in Arizona, and the Virgin River in Nevada. In all, some 15,000,000 acre feet (af) of water annually flows down the Colorado River on it's journey to the Gulf of California.[1]

The area around Hoover Dam and Lake Mead is the one of hottest and driest regions in the United States. The sun shines almost every day of the year and temperatures may reach as high as 125 degrees. With the exception of an occasional thunder storm, very little precipitation,

1. United States Department of Interior, Water and Power Resources Service, *Project Data*, 1981, (Denver: U.S. Government Printing Office, 1981), 79; United States Department of Interior, Bureau of Reclamation, *Hoover Dam: Fifty Years*, (Washington D.C.: U.S. Government Printing Office, 1985), 6; Stevens, Joseph E., *Hoover Dam, An American Adventure*, (Norman: University of Oklahoma Press, 1988), 2(map); State of California, Colorado River Commission, *The Boulder Canyon Project: To Convert a Natural Menace Into a National Resource*, (Sacramento: California State Printing Office, 1930), 26.

only about 4 inches per year, falls in the area. The winter months are mild with an average December temperature of 45 degrees.[2]

Historic Setting

The first Europeans to venture into the American Southwest were Spanish conquistadors and missionaries who traveled into what is now southern Arizona. They found the land populated by several native groups including the Pima, Yuma, Maricopa, and Papago. The Spaniards also discovered traces of earlier inhabitants who had developed cultures of fairly high order. Ruins of their towns and villages, some with structures three and four stories high, spoke of their high level of achievement. The Indians of the Southwest and their ancestors had been forcing a living from the desert with irrigation. Beginning sometime around A.D. 600, the Hohokam of Arizona began constructing elaborate irrigation systems to carry river water to fields of squash, maize and beans. By the time the Spanish entered the region, these systems had supported numerous cultures for over 1,000 years.[3]

Among the first Spaniards to explore the American Southwest and the Gulf of California was Francisco de Ulloa. In 1539, Ulloa sailed into the Gulf of California. Near the head of the Gulf he noted rolling, murky water and assumed that a large river or stream was in the area. Although he did not see the river, he noted its location. The following year, Hernando de Alarcon was sent into the Gulf to sail up the coastline until he made contact with Francisco Vasquez de Coronado, who was traveling overland in search of the legendary seven cities of Cibola. Alarcon did not find Coronado, but did locate the Colorado River, sailing upstream to a point just above where the Gila River meets the Colorado, near the present day site of Yuma, Arizona. Also in 1540, Lopez de Cardenas, a member of Coronado's party, led a group of men through northern Arizona until they reached the rim of the Grand Canyon. Unable to continue further, Cardenas and his men turned back.[4]

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2. *Hoover Dam: Fifty Years*, 6; United States Department of Interior, Bureau of Reclamation, "General Information Concerning The Boulder Canyon Project," (November 1, 1937), 2.
3. *Hoover Dam: Fifty Years*, 9; David E. Doyel, "The Hohokam: Ancient Dwellers of the Arizona Desert," in *The Hohokam: Ancient People of the Desert*, ed. David Grant Nobel (Santa Fe: School of American Research Press, 1991), 4, 6, 8.
4. *Hoover Dam: Fifty Years*, 9.

Cardenas was not the last person to be stopped by the Grand Canyon. Many who followed his party were turned back by the canyon's steep walls and awesome depth. It was not until the mid-1700 that the canyon was successfully crossed. In 1776, a party led by Father Silvestre Velez de Escalante and Father Atanacio Dominquez left Santa Fe bound for Monterey. They crossed the Colorado River near present day Parachute, Colorado, and headed west across the Wasatch Mountains to Utah Lake. Weakened by the hardships of winter, the party decided to abandon their journey and return to Santa Fe. Heading south through Utah, they crossed the Virgin River in northwestern Arizona and turned east, crossing the Colorado River near Glen Canyon.

The Colorado River blocked exploration of sections of the West for several centuries. Those who attempted to follow it's course were rewarded with hardship or death. Able to be crossed at only a few points, the majority of those who traveled west took a more southern route, crossing the Colorado near its junction with the Gila River. Following the end of the Mexican War in 1848 and the acquisition of Arizona, New Mexico and California by the United States, the desire to explore the unknown reaches of the Colorado River grew. In 1857, the War Department sent Lt. J. C. Ives up the Colorado River from the Gulf of California, and in 1858, Ives succeeded in taking his boat, *The Explorer*, almost 400 miles upstream to the lower end of Black Canyon. At that point, *The Explorer* struck a submerged rock and was destroyed. Ives continued upstream in a skiff until he reached Las Vegas Wash, about five miles upstream from the site of Boulder Dam.[5]

Twelve years after Ives traveled upstream from the Gulf of California, Major John Wesley Powell led an expedition down the Colorado River from the Green River in Wyoming to the Virgin River in Nevada. Traveling over 1,000 miles through uncharted canyons and rapids, Powell and his party became the first men known to have traveled through the Grand Canyon and live to tell about it.[6]

5. *Ibid.*, 10.
6. *Ibid.*

Even before Powell and Ives explored the river, others had seen the possibility of using its water to irrigate lands in California's Imperial Valley. The idea was proposed in the 1850s, but it was not until the 1890s that actual development began. In 1896, the California Development Company began constructing canals in the Imperial Valley and the first water from the Colorado River was delivered in 1901.

The Imperial Valley of southern California is a deep depression with its lowest point, the Salton Sink, some 280 feet below sea level. The Colorado River flows along the valley's southeastern rim, about 100 feet above sea level, and is separated from the valley by a ridge of alluvial material deposited by the river. The original Imperial Canal had its headworks on the California side of the river just upstream from the US/Mexico border. The canal ran along side the river for about four miles before turning west into the old Alamo River channel and into the Imperial Valley. In 1904, floods filled the first four miles of the canal with silt and prevented diversion of water. To solve the problem, a temporary channel was dug directly from the river to the old Alamo River channel. Since the channel was temporary and supposed to be closed before the spring floods, no control works were installed. Unexpected winter flooding caught the canal's owners off guard, sending floods into the Imperial Valley. The uncontrolled flows began to cut into the channel making it deeper and deeper until the entire flow of the Colorado River was flowing into the Alamo channel and the Salton Sink, creating the Salton Sea. The river ran uncontrolled into the valley until November 1906 when the bypass channel was finally blocked. In December 1906, the river once again flooded, breaching the dam that had been built across the bypass channel and the river again flowed into the Salton Sea. The river was again controlled in February 1907, but renewed flooding in 1908 and 1909 underscored the need to find a way to control the river.

The Imperial Valley was not the only place to suffer from the unpredictable nature of the river and its tributaries. Yuma, Arizona, and the Bureau of Reclamation's Yuma Project were subject to the effects of flooding by the Gila River. Levees built to protect the city and the project proved to be less effective than hoped, and the area became subject to regular floods. In 1916, flooding on the Gila River breached levees, and water stood four feet deep in the streets of

Yuma. Faced with constant cycles of flooding and drought, the people of the region looked to the Federal Government for relief, and the Bureau of Reclamation began investigations into how to control the river and best use its valuable resource.[7]

Authorization

The passage of the Boulder Canyon Project Act came after more than two decades of studies and investigations. One of the most difficult steps in gaining approval for the project was determining the equitable allocation of the waters of the Colorado River. The people living in the Colorado River Basin depended of the waters of the river, and in many cases water rights held greater value than land titles. While all of the Basin states recognized the advantages of a large dam on the river, there were concerns about one state's ability to claim the lions's share of the water, leaving the other state without sufficient water for development. Under the doctrine of prior appropriation which was recognized by all Basin states, an individual or agency meeting certain legal conditions and first appropriating water for beneficial use had first right to the water. Several of the Basin States feared that California, with it's vast financial resources and great thirst for water, would be the first state to begin beneficial use of the waters of the Colorado River and therefore claim rights to the majority of the water. It was clear that without some sort of an agreement on the distribution of water, the project could not proceed.

In 1920, representatives of the seven Basin states met and endorsed a proposal for an interstate compact. A commission was formed with a representative from each of the Basin states and one from the Federal Government. The Government's representative was Herbert Hoover, then Secretary of Commerce under President Harding. The commission first met in January 1922 with Hoover presiding. At first, negotiations attempted to establish amounts for each state, but an agreement could not be reached. Hoover proposed that the Colorado River water resources be divided into two groups, the Upper and Lower Basin States, with the division of water within each Basin to be agreed upon at a later date. The Upper Basin consisted of the area above Lee Ferry,[8] Arizona, about 30 miles south of the Arizona/Utah border, with the

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7. *Hoover Dam: Fifty Years*, 10-13.

8. Note that "Lee Ferry" and "Lee's Ferry" are not the same location. Lee's Ferry is the place name of the location at the mouth of the Paria River where John D. Lee established a ferry crossing of the Colorado River. Lee (continued...)

Lower Basin that area south of Lee Ferry. The proposal, known as the Hoover Compromise, led to the Colorado River Compact, which was signed by the Commissioners on November 24, 1922. The Compact was approved by the legislatures of six Basin States (Arizona did not approve the Compact until 1944) and the Federal Government. The division of water within the Upper and Lower Basins was left to the Basin States. In October 1948, the Upper Basin States approved the Upper Colorado River Basin Compact dividing water resources among the states of the Upper Basin. The states of the Lower Basin could not reach agreement, and the Secretary of the Interior determined the state's allocation. The matter was sent to the courts for determination, and in 1963, the Supreme Court upheld the Secretary's decision. The Colorado River Compact allocated each Basin 7,500,000 acre feet (af) per year, slightly less than is, on average, available. The Upper Colorado River Basin Compact divided the Upper Basin's share in the following manner: Colorado, 51.75 percent; Utah, 23 percent; Wyoming, 14 percent; New Mexico, 11.25 percent, and 50,000 af to Arizona because a small portion of the state is within the upper basin. The Secretary of the Interior divided the Lower Basin's share with California receiving 4,400,000 ac/ft, Nevada 300,000 ac/ft, and Arizona 2,800,000 ac/ft.[9]

The first attempt to gain approval for construction of Boulder Dam came in 1922 with the introduction of two bills in the House of Representatives and the Senate. The bills were introduced by Congressman Phil D. Swing and Senator Hiram W. Johnson and were known as the Swing-Johnson bills. The bills failed to come up for a vote and were subsequently reintroduced several times. Many parties joined to oppose the bills. Arizona feared that a thirsty California was trying to get their water. Eastern legislators saw the project as a white elephant that would in no way benefit their constituents. The power lobby, under the guidance of Utah Senator Reed Smoot, saw the project as an attempt by the federal government to get into the power business, directly competing with private industry. Also joining the fight was the influential publisher of the *Los Angeles Times*, Harry Chandler, who owned 830,000 acres of irrigated land in Mexico. Chandler feared that the proposed project would siphon off water that

8. (...continued)
Ferry is a term defined in the Colorado River Compact as one mile below the mouth of the Paria River.
9. *Ibid.*, 14-6, 48.

was irrigating his land. In December 1928, after many failures, both the House and the Senate approved the bill and sent it to the President for final approval. On December 21, 1928, President Coolidge signed the bill approving the Boulder Canyon Project.[10]

The Boulder Canyon Project Act authorized construction of a dam in Boulder or Black Canyon, construction of the All-American Canal[11] to connect the Imperial and Coachella Valleys with the Colorado River, and divided the lower basin waters among the lower basin states. In addition, the Act authorized $165,000,000 for construction and stated the primary purposes of the project as flood control, improvement of navigation on the Colorado River, storage and delivery of water for reclamation and other beneficial uses, and generation of power. The Boulder Canyon Project Act became effective in June 1929 following ratification of the Colorado River Compact by six of the seven states of the Colorado River Basin.[12]

Construction History

Investigations

The Bureau of Reclamation began studying construction of dams to control the Colorado River in 1902. Early studies involved investigations throughout the entire Colorado River Basin. The basin is divided into two sections. The Upper Basin is that portion above Lee Ferry, Arizona, or roughly the drainage areas in Wyoming, Colorado, Utah, and New Mexico. The Lower Basin includes the area below Lee Ferry containing drainage areas in California, Arizona, Nevada, and a small portion of Utah and New Mexico.

In 1902, while on a reconnaissance boat trip through Boulder and Black Canyons, U.S. Geological Survey hydrologists J. B. Lippincott and Jeremiah Ahern noted several potential dam sites and suggested that surveys be conducted. In 1902 and 1903, E. T. Perkins made a number of topographical surveys in the Lower Basin for the Geological Survey. Over the next 15 years, investigations continued throughout the entire basin. These studies later served as the basis of a comprehensive plan of development for the entire basin.

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10. Kleinsorge, Paul L., *Boulder Canyon Project, Historical and Economic Aspects*, (California: Stanford University Press, 1941), 77-80; *Hoover Dam, An American Adventure*, 26-7.
11. The history of the Boulder Canyon Project's All-American Canal and associated features is covered under a separate title.
12. *Hoover Dam: Fifty Years*, 16-7.

The increasing demand for water in California's Imperial Valley and nearby cities, and the need to control the unpredictable habits of the river led to in-depth studies in the Lower Basin. In 1918, Director of the Reclamation Service, Arthur P. Davis, ordered a thorough investigation of Boulder and Black Canyons as sites for a high dam for storage and flood control. In the years that followed, many sites were mapped and several potential dam sites were located. In 1920, Homer Hamlin and Edward T. Wheeler reported to the Secretary of Interior, John B. Payne, that both the Boulder and Black Canyons contained several suitable sites. Their study was supplemented by Geological Survey studies conducted in 1919 and 1920. In 1920, as a result of the Reclamation Service and Geological Service studies, Congress passed the Kincaid Act authorizing Secretary Payne to fully investigate the potential of a large dam on the lower Colorado River.

Exploratory drilling at potential dam sites began in late 1920 and continued for three years. Detailed topographic surveys were conducted in 1920 and 1921 with geologic surveys being conducted from 1921 to 1923. Also during the period of 1921 to 1923, studies into the availability of materials for concrete aggregates were made and investigations were conducted to determine the locations of railroads and highways for transporting supplies and equipment to construction sites. In 1924, after several years of investigations, the Bureau of Reclamation recommended construction of a high concrete dam at a site in the Black Canyon. The Black Canyon site was chosen for several reasons including accessibility, better foundation material, depth to bedrock, and a greater reservoir capacity. Although the Black Canyon site was chosen, the name Boulder Canyon Project was retained because of prior legislation under that title.[13]

Design

The design of Boulder Dam evolved during several years of study that involved the efforts of some 200 engineers and other workers in Reclamation's design office in Denver and several consulting firms that were retained during the design process. Prior to the design of Boulder Dam, the highest dam in the world was Arrowrock Dam on the Boise Project in Idaho.

13. United States Department of the Interior, Bureau of Reclamation, *Boulder Canyon Project: Final Reports, Part IV–Design and Construction, Bulletin I, General Features*, (Denver, 1941), 19-21, 33; United States Department of the Interior, Bureau of Reclamation *Boulder Canyon Project: Final Reports, Part IV–Design and Construction, Bulletin 2, Boulder Dam*, (Denver 1941), 12.

At just over 348 feet high, Arrowrock Dam was less than half the height of the proposed dam in the Black Canyon. It was clear from the beginning that many new problems in design and construction would be encountered and solutions would have to be found before the dam could be built.

A tentative design produced in 1920 called for a straight, concrete gravity dam with a cross section similar to the design later adopted for construction. The diversion plan for the 1920 design was similar to the design adopted in the final plan: four large diversion tunnels, two on either side of the canyon. Spillway provisions included thirty-two, 16-foot by 16-foot siphons discharging into the diversion tunnels. Similar to the design of Arrowrock Dam, there were three banks of outlets running through the dam. When the 1920 designs were drawn up, there

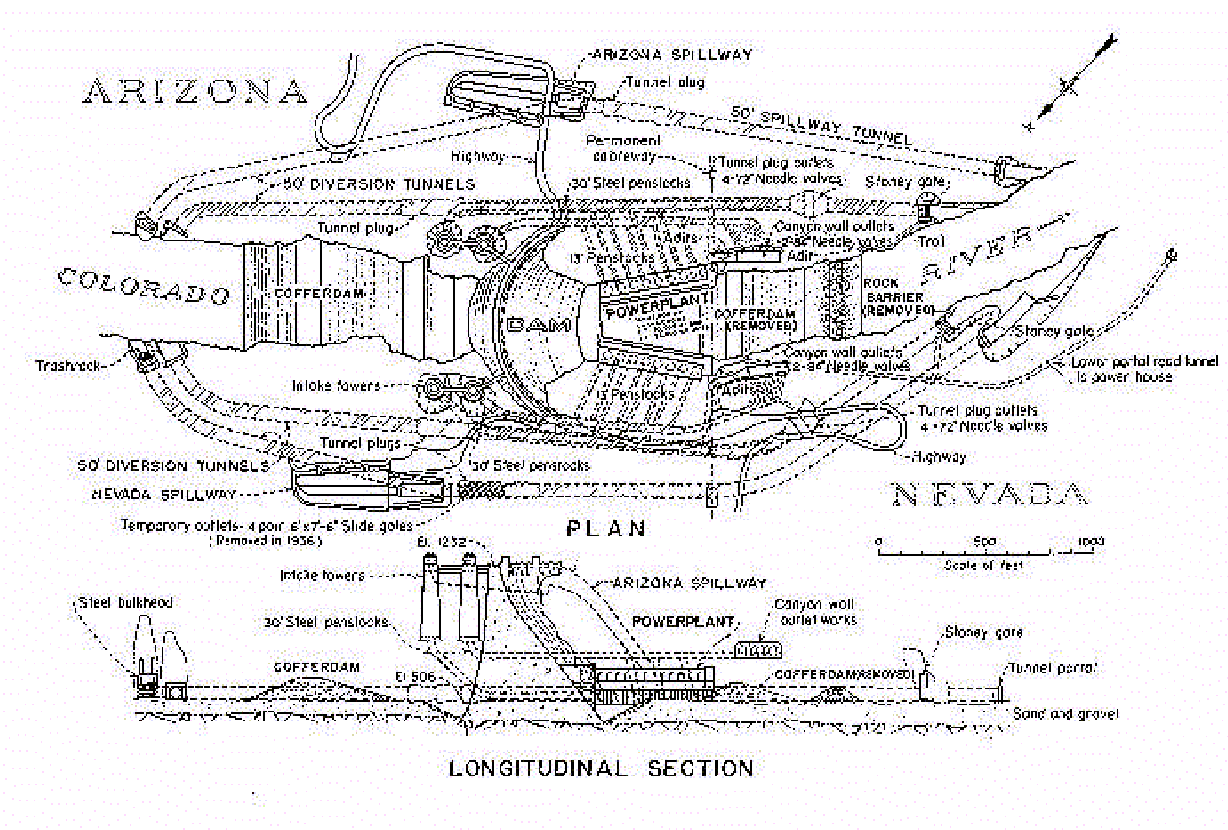

Figure 2 Boulder Dam–Plan & Section

were no plans for power development, so provisions for a powerhouse were not included in the plan.[14]

In 1924, a report on the development of the Colorado River Basin included a preliminary design for a concrete dam at the lower Black Canyon site. Prior to this time, several types of dams were considered, including earth and rock-fill, rock-fill with concrete face, multiple arch concrete, concrete gravity, and concrete arch. By the time the 1924 report was issued, all but the rock-fill with concrete face and concrete gravity or arch designs had been eliminated. Further studies determined that a concrete gravity or arch structure would be best.

The 1924 design was for a concrete arch structure. Although a preliminary design, it was selected as representing a reasonable estimate of the final design for use in cost estimates. Unlike the 1920 design, the 1924 design eliminated the spillways and was designed to be overtopped during maximum floods. Diversion would be handled via three 35-foot diameter tunnels through the Nevada side of the canyon. The design retained the outlet conduits through the dam structure and still did not have provisions for power development, although designs for future power development were considered.

In 1928, the Secretary of Interior appointed a board of engineers and geologists to review all designs and determine the best design from the standpoints of economy, safety, and engineering feasibility. The board, known as the Colorado River Board, approved the lower Black Canyon site and recommended changes to the diversion plan, doubling the diversion capacity to 200,000 second feet (s/f). The Board also increased the spillway capacity to 400,000 s/f, which would eliminate the possibility of overtopping during maximum flooding.

By 1928, power development had become an essential feature of the project. Studies into the best arrangement for the powerplant and dam led to two designs. The first design placed the powerplants and outlet works on the Nevada side of the canyon with two circular vertical shaft spillways on the Arizona side. The second design called for a "U" shaped powerhouse at the base of the dam with spillway tunnels and double banks of outlet works contained in both canyon walls. Intake towers would supply water to the power penstocks and outlet works. Both

14. *Boulder Canyon Project: Final Reports, Part IV–Design and Construction, Bulletin I, General Features,* 47-9.

designs eliminated the outlet conduits through the dam structure and were designed as gravity-arch structures. The second design would form the basis for the final plan.

The initial appropriation for construction was made in July 1930. At that time the design had been modified to eliminate the two vertical shaft spillways and replaced them with two side channel spillways with uncontrolled crests, with upstream openings controlled by 50-foot by 50-foot gates that would be opened if greater flows were required. Modifications in the tunnel layout and intake towers were added, but the design still retained the double banks of canyon wall outlet works that had been part of the 1928 design. In 1931, the contract for construction was awarded, and the final design was determined. In the final design, the side channel spillways were retained, but they would be controlled by drum gates and connected to the diversion tunnels by inclined shafts, and the upper set of canyon wall outlets was eliminated. The final design called for the diversion of the river via four, 50-foot diameter tunnels driven through the walls of the canyon, two on each side. Following completion of the dam, the outer tunnels would be plugged at about mid-point, and inclined shafts from the spillways would discharge into the downstream portion of the tunnels. The inner tunnels would also be plugged about one-third of the way downstream from their openings and 30-foot diameter steel penstocks would be placed in the downstream portion connecting the powerhouses to the intake towers. In addition to the diversion tunnels, two additional tunnels, one on each side of the canyon, would be driven to house penstocks that would supply water from the intake towers to the power houses. When not needed for power generation, these tunnels would discharge through the canyon wall outlet works.[15]

Construction

Boulder City and Pre-Construction Activities

Before construction of the dam and appurtenant works could begin, an enormous amount of preparatory work had to be undertaken. The site of the dam is a deep canyon more than 30 miles from the nearest town. The site was in the middle of the desert with limited access and no provisions for housing the almost 5,000 people that would work on the project. Before work on

15. *Ibid.*, 49-57.

the dam itself could begin, many support features had to be constructed. These included transportation and communication facilities, housing, water and sewage systems, power and lighting facilities, and a 150-ton cable way for handling heavy equipment at the dam site.

To house the estimated 5,000 workers and officials involved with the project, the Government designed and built Boulder City. The site for the town, about six miles west of the dam, was chosen because it was at a higher elevation than the surrounding countryside. It was felt that the climate at the higher ground would be more mild and hospitable than at lower altitude were the temperature was often well over 100 degrees, 24 hours a day. The town was planned using the accepted standards for municipal development and was constructed with paved streets, a water and sewer system, electrical power, a city hall, administrative building, schools, a hospital, and houses for the workers and their families.

Work on Boulder City began in December 1930. The original plan called for completion of the town before work on the dam began, but the construction schedule for the dam was accelerated, and the town was not ready when the first dam workers arrived at the site in early 1931. During the first summer of construction, workers were housed in temporary camps while work on the town progressed. In April 1931, the Boulder City Company was organized as a wholly owned subsidiary of Six Companies to manage the town for the Government, and Sims R. Ely was named city manager by Interior Secretary Ray Lyman Wilbur. By the end of 1931, most of the town was ready for occupancy.[16]

A project of the magnitude of Boulder Dam required an enormous amount of material and equipment. In order to transport the material to the site, it was necessary to construct a 22.7-mile branch railroad from a point about 7 miles south of Las Vegas. The railroad was built and operated by the Union Pacific Railroad, which also built a 400 car switchyard at Boulder City. The railroad issued the contract for construction of the branch line September 10, 1930, and regular service to Boulder City began on April 17, 1931.

The railroad was continued from Boulder City to the rim of the canyon above the dam

16. *Hoover Dam, An American Adventure*, 143; *Boulder Canyon Project: Final Reports, Part IV–Design and Construction, Bulletin 1, General Features*, 59, 71-4; E. H. Heinemann, "The Building of Boulder City–Six Companies, Inc..." An unpublished manuscript contained in a larger collection of material labeled "Boulder City, Nev.: History." A holding of the Library of the Bureau of Reclamation, Denver, Colorado.

site. Construction of this section of the line, just over 10 miles, was carried out under contract by the Lewis Construction Company. The final four miles of the line required significant excavation and fill, and construction of five tunnels totaling over 1,400 feet. Work on the line was completed in September 1931 at a cost of $635,000, of which over $460,000 was for labor.[17]

To facilitate the movement of men and equipment to and from the construction site, the State of Nevada constructed a 24 mile long highway from Las Vegas to Boulder City. The road from Boulder City to the canyon rim, about seven miles, was constructed for the Government by the General Construction Company. Designed to transport men and equipment to and from the dam site, these roads later formed a link in the main highway between Las Vegas and Kingman, Arizona.[18]

Since it was not practical to transport much of the equipment and material to the canyon floor by means of a roadway, a permanent cableway with a 150-ton capacity was constructed by the government. The cableway spans the canyon near the downstream ends of the powerhouses. The loading station was constructed on the Nevada side of the canyon near the end of the highway and rail line, and several landing platforms were constructed on both canyon walls. The cableway is supported by a 118-foot high steel tower on the Nevada side, and is anchored into the side of the canyon on the Arizona side. The cableway is 1,580 feet long from anchor to anchor and has a usable span of 1,256 feet. The operating machinery is located in the hoist house on the Nevada side of the canyon. The cableway can be remotely controlled from the control house that overlooks the canyon or from any of the landing platforms. The cableway was supplied and constructed by the Lidgerwood Manufacturing Company and cost $172,000.[19]

Since no source of electrical power existed in the vicinity of the dam site, two alternatives were investigated: construction of a diesel or steam powered generating plant near the dam site, or securing power from distant plants already in operation. After examining

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17. *Boulder Canyon Project: Final Reports, Part IV–Design and Construction, Bulletin 1, General Features,* 59-61.

18. United States Department of the Interior, *The Construction of Hoover Dam, Preliminary Investigations, Design of Dam, and Progress of Construction,* by Ray Lyman Wilbur and Elwood Mead, (Washington, D.C.; United States Government Printing Office, 1933), 24; *Boulder Canyon Project: Final Reports, Part IV–Design and Construction, Bulletin 1, General Features*, 61-3.

19. *Boulder Canyon Project: Final Reports, Part IV–Design and Construction, Bulletin 1, General Features,* 63-6.

several proposals, the Government determined that securing power from existing powerplants was the best solution. On October 28, 1930, the Government signed a contract with the Southern Sierras Power Company and the Nevada-California Power Company for the construction of a 222 mile-long power transmission line from San Bernardino to a substation at Boulder City, and the delivery of power to the construction site. The transmission line served two purposes: transmission of power to the dam site during construction, and from the dam to markets in Southern California following completion of the dam. Construction of the line began in December 1930, and was completed in late April 1931. During construction, 1,250,000 pounds of conducting line was used along with 5,000,000 pounds of steel and 49,000 insulator disks. The total cost of the transmission line and substation was approximately $1,500,000.[20]

Providing for the needs of over 5,000 men and their families was no easy task. To accommodate the workers and their families at Boulder City, Six Companies constructed housing for both single and married employees, a fully stocked department store, a post-office, laundry, recreation hall, school, and hospital. Single employees at Boulder City were housed in eight 171-man dormitories, and one 53- man dormitory. The bunkhouses contained water coolers, toilets, and one shower for every 13 men. For $1.60 per day, workers received a private room with a bed, mattress, pillow, bedding, a chair, meals, and transportation to and from the construction site. In addition to the dormitories at Boulder City, Six Companies constructed six dormitories and a 400 man mess hall at Cape Horn, a bend in the river downstream from the dam site. Married employees were housed in 758 cottages that ranged from one to five rooms each. Rents ranged from $15.00 per month for a one room cottage to $30.00 per month for a three room cottage. The larger cottages were reserved for Six Companies managers and officials.[21]

When Boulder City was constructed, Six Companies and the Government saw that all needs of the workers and their families were met, including police and fire protection. The Boulder City Ranger Force was organized in August 1931 under the leadership Glen E. Bodell, Chief Ranger. The primary task of the Ranger Force was enforcing safety regulations and

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20. *Ibid.*, 66-71.
21. "The Building of Boulder City–Six Companies," 1, 5-7, 14-5.

policing the area in and around Boulder City. One of the chief concerns was bootlegging, and in 1931 and 1932, 91 raids were conducted resulting in 72 arrests and the seizure of eight stills. During construction of the dam, there were few major crimes in Boulder City and the majority of arrests were for drunkenness.[22]

Fire protection in a town consisting almost entirely of wood frame buildings was a major concern. In December 1932, the Boulder City Company formed a 45 man fire department under the leadership Chief A. J. Kaminske. Fire fighting equipment consisted of a 350 gallon pumper truck and a ladder truck. In addition, there were 1,500 water barrels placed throughout Boulder City that were inspected and refilled regularly, and each individual dwelling and all dormitories were supplied with fire extinguishers. Dormitories were also constructed with standpipes and automatic sprinkler systems.[23]

To deal with the high number of accidents that were anticipated on a project the size of Boulder Canyon, Six Companies constructed a state of the art hospital in Boulder City. The sixty bed facility was headed by Dr. R. O. Schofield, Chief Surgeon, and staffed by six doctors, nine full-time nurses, two full-time orderlies, and several support personnel. The hospital was equipped as well as any of its size in the county, and due to the high number of orthopaedic injuries, significant advancements in the care and treatment of fractures occurred.[24]

Feeding 5,000 men was an enormous undertaking. To meet this challenge, the Boulder City Company contracted with Anderson Brothers Supply Company to provide food service for Boulder City and the Six Companies River Camp at Cape Horn. The contract called for three meals a day for the day and night shifts, with an extra lunch provided to the night shift. To accommodate the workers, a 1,200 man mess hall was constructed at Boulder City, and a 100 man mess hall at the River Camp. Provisions had to be shipped to Boulder City from the nearest supplier that could provide the amounts needed. Beef, veal, lamb, and pork was purchased in 20,000 pound lots and shipped from Reno, Nevada, as were eggs. Canned goods, specially

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22. United States Department of the Interior, Bureau of Reclamation, "Policing on the Boulder Canyon Project," (February 12, 1936), unpublished manuscript contained in a larger collection of material labeled "Boulder City, Nev.: History." A holding of the Library of the Bureau of Reclamation in Denver, Colorado.
23. "The Building of Boulder City–Six Companies."
24. "The Building of Boulder City–Six Companies," 15-6.

packed for Anderson Brothers by Del Monte and S & W, were shipped from as far away as Los Angeles and San Francisco. The same was true for fruits and vegetables. Since there were no dairies in southern Nevada, Anderson Brothers purchased a 160-acre farm at Mesquite, Nevada, about 80 miles away, and constructed facilities for 200 dairy cows. Fresh milk, cream, and butter were shipped to Boulder City daily.

A typical menu consisted of grapefruit, oatmeal, bacon omelet, wheat cakes, coffee, and milk for breakfast, and a salad, roast sirloin of beef, mashed potatoes and gravy, spinach, mince pie, rice pudding, milk, and coffee for supper. Workers were allowed to pack a lunch before each shift. The choices included roast beef or pork sandwiches, jelly rolls, and several varieties of pie and fruit. Workers were allowed to take as much as they wanted. During the construction period prior to January 1936, Anderson Brothers served over 7,400,000 meals, averaging over 4,300 meals per day.[25]

Hoover Dam[26]

Because of the seriousness of the unemployment problem in 1930, Interior Secretary Wilbur ordered that the Bureau of Reclamation speed up preparation of plans and specifications so that the contract for construction could be awarded at the earliest possible date. In response to the Secretary's request, engineers at the Denver office, led by Raymond F. Walter, Chief Engineer, and John L. Savage, Chief Design Engineer, completed and printed specification for the dam and appurtenant works in December 1930, six months ahead of schedule. Bids were opened at the Denver office on March 4, 1931, with the lowest bid being submitted by Six Companies, Inc., of San Francisco. The winning bid was $48,890,995. Six Companies was a joint venture of the Utah Construction Company of Ogden, Utah; Henry J. Kaiser & W. A. Bechtel Company of Oakland, California; McDonald & Kahn Ltd., of Los Angeles; Morrison-Knudsen Company of Boise, Idaho; J. F. Shea Company of Portland, Oregon; and the Pacific Bridge Company of Portland, Oregon. The contract was awarded to Six Companies on March

25. "The Building of Boulder City–Six Companies," 2-5.
26. Originally named Hoover Dam by Ray Lyman Wilbur, President Herbert Hoover's Secretary of the Interior, the name was changed by Secretary Harold Ickes to Boulder Dam soon after he took office under President Franklin D. Roosevelt. In 1947 the Congress officially changed the name back to Hoover Dam.

11, 1931 and the order to proceed was issued on April 16, 1931.[27]

Work at the dam site was supervised by Walker R."Brig" Young, Construction Engineer for the Bureau of Reclamation, and Frank T. Crowe, General Superintendent for the Six Companies. Also overseeing work at the construction site were Ralph Lowry, Field Engineer, and John C. Page, Office Engineer.

Transportation was a key element is the success of the project. In addition to the railroads and roadways constructed by Union Pacific and the Government, the primary contractor built several miles of railways and over twenty miles of roadways. The contractor's rail line ran from the Government railroad to the aggregate plant located at Hemenway Wash, about two miles northeast of the dam site. From the aggregate plant, a seven mile long line was constructed to gravel deposits about 4 miles north of the dam. A second line was constructed down Hemenway Wash to the upper end of the canyon, then down the canyon to the construction site. The railroad was excavated out of the canyon wall for almost its entire length and required the construction of two tunnels, each over 1,000 feet long. A portion of a temporary trestle remains embedded in the structure of the dam.[28]

Six Companies constructed numerous roads to provide adequate access to all areas of construction activity. One road ran to the upper end of the canyon where supplies were loaded onto barges and floated downstream to the dam site. This road was later extended down the Nevada side of the canyon to the construction area. Access to the lower tunnel portals was provided by a road that ran down a steep side canyon to the river, then upstream to the site. Following completion of the dam, this road was taken over by the Government to be used for maintenance access to the powerhouse. A 1,974-foot long tunnel was excavated to allow travel to the Nevada wing of the powerhouse.[29]

Before excavations for the foundation and abutments could begin, it was necessary to make the dam site accessible. This required unwatering a half-mile section of the canyon and

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27. *The Construction of Hoover Dam, Preliminary Investigations, Design of Dam, and Progress of Construction,* 49.
28. *Boulder Canyon Project: Final Reports, Part IV–Design and Construction, Bulletin 1, General Features,* 99-100.
29. *Ibid.*, 100-2.

protecting the unwatered section from flooding during construction. This was a particularly difficult task as the flows of the Colorado River could fluctuate from 2,000 cubic feet per second (cfs) to 200,000 cfs. After numerous studies, it was determined that the best plan was to construct four, 50-foot diameter tunnels, two on each side of the canyon, and divert the river through those tunnels. The tunnels are designated numbers one through four, with number one being the tunnel furthest from the river on the Nevada side. They are also referred to as the outer and inner Nevada tunnels and the outer and inner Arizona tunnels. Because the final design of the dam eliminated outlet works through the dam structure, the tunnels were designed and constructed to be incorporated into the reservoir outlet and power penstock systems following their use for diversion.[30]

Construction of the four tunnels began on May 12, 1931, with excavation work on the construction adit on the Arizona side of the canyon. Work on the Nevada side of the canyon began shortly after. The 8-foot high, 10-foot wide adits were driven into the canyon walls until they intersected with the lines of the main tunnels. When work on the construction adits began, the only access to the work site was by barge. The Arizona side of the river had the only area suitable for placement of equipment and supplies, so work was begun from that side. To access the Nevada side of the canyon, a cable suspension bridge was placed across the river and a shelf blasted into the canyon wall. Debris from the excavations was used to enlarge the landing area along the river and to construct a roadway downstream to where the tunnel outlet portals were constructed. The construction adits were completed on September 5, 1931. The Arizona adit is 826 feet long and the Nevada adit is 607 feet long.[31]

The design of the four diversion tunnels called for the excavation of the tunnels to a diameter of approximately 56 feet so that when lined with concrete, the diameter would be 50 feet. Excavations were carried out in three sections: a 12-foot by 12-foot top heading, a 29-foot high by 56-foot wide main heading, and a 15-foot invert, or lower heading. Excavations began on the top heading and were advanced a short distance before work began on the main headings.

30. *Boulder Canyon Project: Final Reports, Part IV–Design and Construction, Bulletin 3, Diversion, Outlet, and Spillway Structures*, (Denver, 1947), 25-6.
31. *Ibid.*, 32-3, 45.

Wing sections on either side of the top headings were excavated at the same time as the main headings. The 15-foot invert section was left in place to provide a level surface for trucks and machinery, and was excavated following completion of the upper and main sections.[32]

Drilling operations on the main headings were handled by a drilling carriage specially constructed for the project. The carriage was a structural steel frame with several platforms that provided work stations for the drilling crews. Each of the four drill carriages was manned by an 50 man crew that consisted of 22 miners, 21 chucktenders, 5 nippers, 1 safety foreman, and 1 drilling foreman. Each carriage was mounted on a truck and carried 30 drills in five rows of six drills each. Half the main face would be drilled and the bores loaded with explosives, and the carriage repositioned to drill and load the other half of the face. When drilling and loading was complete, the carriage was moved away from the face and the entire heading was shot at once. On average, 126 holes were drilled and 2,000 pounds of dynamite used for each shot. The headings were advanced approximately 15 feet with each shot. By drilling the adits, 16 possible faces were available for work, although 12 were the most worked at any one time.[33]

The top 12-by-12-foot headings began from the construction adits on June 11, 1931 and were completed on January 7, 1932. Excavations on the main headings began from the tunnel portals in September 1931, and were completed in April 1932. Excavations of the invert sections began February 23, 1932, and were completed May 23, 1932. The estimated total amount of material excavated from the four tunnels is 1,450,934 cubic yards (cu\yd). At the peak of the excavations, about 100 trucks, ranging in capacity from 5 to 14 cu\yd, were in use removing material from the tunnels. The cost of excavating the tunnels was approximately $15,073,891.[34]

Life at Boulder Canyon and Boulder City was not easy. Temperatures would often reach over 115 degrees during the day while falling only to 95 degrees at night. Before housing at Boulder City had been completed, workers and their families were forced to live in temporary encampments and tent cities. One such camp was located at Cape Horn, about a mile upstream

32. *Ibid.*, 29-30.
33. *Ibid.*, 30-7.
34. *Ibid., 45-7.*

from the dam site. The encampment was officially known as Williamsville, but among the workers it was known as Ragtown; a more appropriate name. Conditions at Ragtown were horrible; no fresh water or sanitary facilities, and little or no shade in which to escape the stifling heat. The heat was so bad that groups of people would huddle in the shadow of tents or small bushes or stand up to their necks in the river in an effort to keep cool. In the diversion tunnels the problem was even worse. Temperatures underground often reached as high as 140 degrees. Heat prostration became a deadly problem, killing one worker every two days during the summer of 1933. In July 1933, three women, wives of workers, died at the Cape Horn camp from heat prostration.[35]

Tunnel lining operations followed the excavations as closely as possible. Placement of the concrete lining began in Tunnel No. 3 on March 16, 1932. The contract called for a lining of 36-inches giving the tunnel a final diameter of 50-feet. Lining was placed in three separate operations starting with the invert, or bottom section of the tunnel. The first step in the lining operation was the construction of a shelf along each side of the tunnel to support the track for the gantry crane used for concrete placement. Concrete forms for the invert section consisted of two, 4-foot by 12-foot steel plates that were shaped to conform to the curvature of the tunnel. Once the forms were placed, concrete was poured into the space between the forms and the tunnel wall. After the concrete had set sufficiently, the forms were lifted up and moved to the next section. Following completion, the invert section was covered with sand and gravel to provide a level roadway for trucks and other equipment. Upon completion of the lining operations, the sand and gravel covering was removed.

Lining of the side-walls and arch, or overhead section, closely followed lining of the invert section. Two 18-inch concrete shelves were constructed along the upper edge of the invert section and rails to support the side wall and arch forms and equipment were set on the shelves. The side-wall forms were carried on a structural-steel framework 80-feet long and 40-feet high. The forms were made from 1/4-inch thick steel plate. To make the forms adapt to the curve of the tunnels, each side form was divided into three, 20-foot sections, and two, 10-foot sections.

35. *Hoover Dam: An American Adventure,* 53-4, 60-3.

The forms were held in place by means of jacks. Once the forms were in place, concrete was poured into the space between the tunnel wall and the forms by a 5-ton electric crane mounted atop the form carriage. The concrete was poured through a series of chutes placed along the forms at various heights. Concrete placement began through the lowest set of chutes and continued progressively upwards. When concrete would reach the level of the placement chute, a steel cover would be bolted over the chute opening and placement would continue from the next highest set of chutes. Placement continued in this manner until the concrete reached the top of the form. Concrete was compacted into place by several men working between the tunnel wall and the forms. When each section was complete, the forms were removed and the carriage advanced to the next section.[36]

Concrete placement in the arch section followed about 150 feet behind the side-wall placement. Forms for the arch section were carried on a carriage similar to that of the side-wall forms. Like the side-wall forms, the arch forms were 80-feet long and divided into three 20-foot sections and two 10-foot sections. The forms were held in place by vertical jacks while inclined jacks held the edge of the form securely against the upper section of the side-wall. Concrete was pumped into the forms and allowed to set for about twelve hours before the forms were removed.[37]

Following completion of the tunnel lining, it was necessary to fill any seams, cracks or voids between the lining and rock walls with grout. Grout is a mixture of cement and water that is injected into holes to seal cracks and other voids in rock. During grout operations in the four diversion tunnels, 122,000 feet of grout holes were drilled and more than 200,000 cubic feet (cu/ft) of grout injected into the holes.[38]

Work on the Arizona diversion tunnels was completed in early August 1932 with work on the Nevada tunnels completed shortly after. On November 13, 1932, temporary dams that had been built to keep the river out of the Arizona tunnels were removed and the river began to flow through the completed tunnels for the first time. As soon as water began to flow through

36. *Boulder Canyon Project: Final Reports, Part IV–Design and Construction, Bulletin 3, Diversion, Outlet, and Spillway Structures*, 47-57.
37. *Ibid.*, 53-4, 59-60.
38. *Ibid.*, 64.

the tunnels, work on the upper temporary coffer dam was begun. The temporary coffer dam protected the site until a more permanent coffer dam was completed. The temporary coffer dam consisted of rock and gravel from the tunnel excavations that was dumped into the river from a temporary trestle built for that purpose and was completed in less than 24 hours, diverting the entire flow of the river through the Arizona tunnels.

While work was progressing on the upper coffer dam, a lower coffer dam was being constructed just upstream from the tunnel outlet portals. Once the two temporary coffer dams were completed, the area between the two structures was dewatered by pumping and work on more permanent coffer dams began. The upper temporary coffer dam was 470 feet long, 50 feet high and contained 94,000 cu/yd of material. The lower temporary coffer dam was 375 feet long, 30 feet high and contained about 40,000 cu/yd of material.[39]

While work on the diversion tunnels and coffer dams progressed, workmen began stripping the canyon walls of loose rock and material. Stripping was necessary so that the dam would abut against solid rock at all areas of contact with the canyon wall and to prevent loose rock from falling into the construction area. To access the canyon walls, workmen were lowered over the rim of the canyon by safety belts or boatswain chairs. Beginning at the top of the canyon wall, loose rock was knocked down using steel bars. Some of the material, though too solid to be barred loose, was so fragmented or seamed that it could be knocked loose by later construction or blasting. This material was drilled with jackhammers and blasted loose. Both canyon walls from the location of the upstream intake towers to the downstream ends of the canyon wall outlet houses had to be thoroughly stripped. Stripping operations began in August 1932 and were completed in June 1933. During operations, more than 137,000 cu/yd of materials were stripped from the canyon walls.[40]

Construction of the permanent upstream coffer dam began in September 1932, about seven weeks prior to diversion of the river. A temporary dike was extended outward from the Nevada canyon wall to the middle of the river, then downstream about 1,000 feet, and then back

39. *Ibid.*, 88-90.
40. *Boulder Canyon Project: Final Reports, Part IV–Design and Construction, Bulletin 2, Boulder Dam*, 77-82.

to the canyon wall. The area enclosed was about half the site of the permanent coffer dam. The area was dewatered and excavation began. By the time the river was diverted through the tunnels, much of the work on the Nevada side of the permanent coffer dam had been completed. Following diversion of the river, work on the Arizona side of the dam was begun. Much of the material for the permanent coffer dam was obtained from gravel deposits located at Hemenway Wash, about 3.5 miles upstream from the construction site.

Work on the permanent downstream coffer dam began as soon as the construction site was unwatered. Like the upstream coffer dam, materials for the downstream dam came from Hemenway Wash. The upstream coffer dam was a rolled earth and rockfill dam 98 feet high and 510 feet long. The upstream face was a 3-foot thick rock blanket with a 6-inch thick, reinforced concrete slab face. The downstream coffer dam was also a rolled earth and rockfill structure. It was 66 feet high and 350 feet long. The upstream face had a rock blanket that varied in depth from 13 to 25 feet. The downstream slope of the dam was protected by a rock barrier 55 feet high and 400 feet long. The upstream coffer dam was completed in March 1933 and the downstream dam completed in April 1933.[41]

Once the coffer dams were in place and the construction site unwatered, excavation for the dam foundation began. In order for the dam to rest on solid rock, it was necessary to remove all loose material until solid rock was reached. The depth of the excavations ranged from 35 to 40 feet at the base of the canyon walls, to 100 to 125 feet at the mid point of the canyon. Work on the foundation excavations was completed in June 1933. During excavations for the foundation, approximately 1,500,000 cu/yd of material was removed, including material that was the result of canyon wall stripping operations.[42]

Excavations for the abutment began December 21, 1932. In addition to exposing solid rock to support the dam, proper shaping of the abutment excavations was necessary so that the dam abutments could handle the load that would be carried to them by the arch action of the dam. Excavations on the abutments involved the removal of over 283,000 cu/yd of material and

41. *Boulder Canyon Project: Final Reports, Part IV–Design and Construction, Bulletin 3, Diversion, Outlet, and Spillway Structures*, 82-99.

42. *Boulder Canyon Project: Final Reports, Part IV–Design and Construction, Bulletin 2, Boulder Dam*, 86-94.

were completed by June 1933.[43]

Following completion of foundation and abutment excavations, grouting operations began in the foundation and abutments. The objective of grouting operations was to provide a barrier to seepage through the foundation and abutments, and to consolidate the surface zones into a more monolithic rock. The process involved drilling holes to various depths, usually 100 to 150 feet, and injecting grout under high pressure into those holes. Holes of less than 50 feet in depth were drilled using pneumatic percussion drills while deeper holes were drilled using air-driven diamond drills. For the greater portion of the grouting operations, the grout plants consisted of compact, self-sustaining units mounted on 5-ton flatbed trucks. Since no roads led to where much of the grouting operations took place, the units were picked up by cableway and set down were they were needed. During grouting operations in the foundation and abutment areas, 143 holes were drilled totaling over 5,300 feet, and 6,395 cubic feet (cu/ft) of grout were injected into the holes.[44]

Once the foundation and abutment areas were grouted, work on the main dam itself could begin. The primary goal of the designers was that the completed dam be a single monolithic mass. To achieve this goal, the dam was constructed in a series of columns that were raised systematically. Each of the columns, or blocks, were of a constant dimension that ran vertically from their bases to the upstream face, downstream face, or top of dam depending on their location in the structure, and were separated by radial and circumferential contraction joints. Each block was interlocked with adjacent blocks by vertical and horizontal keyways. Concrete was placed in each block in 5-foot lifts and was restricted to no more than one, 5-foot lift per block in 72 hours, and no more than 7 lifts per block in 30 days. In addition, the height of the tallest block could not be greater that 35 feet higher than the lowest block. The relative height of the blocks was maintained throughout the construction process.

Since no structure the magnitude of Boulder Dam had ever been constructed, many of the procedures used in construction of the dam were untried. One of the problems that faced the

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43. *Ibid.*, 82-6.
44. *Ibid.*, 95-124.

designers was cooling and contraction of the concrete in the dam. Many investigations into how to cool the dam were conducted before a cooling system was adopted. To remove the heat created by the hardening process and the reduce the cooling and contraction time, an artificial cooling system was designed. The system consisted of pipe loops embedded in the concrete with air-cooled or refrigerated water circulated through them. During the Summer of 1931, 2 years before concrete placement at Boulder Dam began, Reclamation conducted an experiment at the Owyhee Dam, which was being constructed in Idaho, to test the effectiveness of the proposed system. Each 4-foot lift of a 28-foot by 210-foot section of the dam was cooled using river water circulated through pipes embedded in the dam. The results of the experiment proved to engineers that the cooling system proposed for Boulder Dam would work. At Boulder, the water was chilled by a cooling and refrigeration plant constructed at the site. To accommodate the header pipes of the cooling system, an 8-foot slot running through the center of the dam from the upstream toe to the downstream toe was provided. As each 50-foot height of dam was cooled to the desired temperature, the contraction joints were grouted and the slot filled with concrete to the top of the cooled section.[45]

The first bucket of concrete was placed in the dam the morning of June 6, 1933, nearly 18 months ahead of schedule. The first bucket was placed in block J-3, the third block from the upstream face on the Arizona side of the cooling slot. This was in the deepest section of the foundation excavation; an area known as the inner gorge. By the end of June 1933, more than 24,000 cu/yd of had been placed in the dam. Concrete was placed using 8 cu/yd, bottom-dump buckets that were hoisted to the area of the pour by one of 5 temporary, 20-ton cableways built by the contractor. Each of the cableways included self-propelled traveling head and tail towers that were mounted on tracks and could travel up and down the canyon as needed. Four of the temporary cableways served the dam with the fifth serving the power house and downstream areas.[46]

Concrete was mixed in one of two plants erected at the construction site. The low-level

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45. *Boulder Canyon Project: Final Reports, Part IV–Design and Construction, Bulletin 2, Boulder Dam*, 136-8, 191-3.
46. *Ibid.*, 143-4, 172-3.

mixing plant was located on the canyon floor on the Nevada side about 4,000 feet upstream from the dam. Concrete was transferred to the construction site by rail where it was lifted to the area of the pour by cableway. The upper-level plant was located on the rim of the Nevada side of the canyon. Concrete was transported to the canyon rim by rail were it was lifted by cableway and conveyed to the pour area. Both plants had a mixing capacity of about 280 cu/yd per hour.[47]

Following placement of each 5-foot lift, the surface was thoroughly cleaned by a pressurized stream of water and air. In addition, the concrete surface had to be kept moist until the next lift was placed or until curing was complete in sections that were permanently exposed. During summer months, this task required as many as 20 men whose sole job was to keep the concrete moist by spraying the surface with water.[48]

Concrete cooling operations began in August 1933 when the cooling tower went into operation. The refrigeration plant began operation in October 1933. The cooling tower was located on the downstream coffer dam and the refrigeration and pumping plant was located at the base of the Nevada canyon wall near the downstream coffer dam. Cooling was carried out in two stages. The first stage involved circulation of air cooled water through tubing embedded in the concrete. The second stage involved circulation of refrigerated water through the same series of tubes. The system was designed so that first stage cooling could be carried out at one elevation while second stage cooling was in progress in the next lower elevation. When cooling operations began, the cooling pipes were placed in newly poured lifts by forcing the pipes several inches into the fresh concrete. This system proved to be difficult and was abandoned when it was discovered that placing the cooling pipes atop the previous lift just prior to pouring the new lift produced adequate results. By the time cooling operations were completed in May 1935, more than 590 miles of cooling pipe had been embedded in the dam with over 159 billion BTU[49] of heat removed.[50]

Work on the spillways and the inclined tunnels that would connect them with the

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47. *Ibid.*, 161-7, 170-2.
48. *Ibid.*, 181-2.
49. BTU–British Thermal Unit. The amount of heat required to raise a pound of water from 62° to 63° F. It is equal to 252 calories.
50. *Ibid.*, 193-9.

diversion tunnels began in early 1932 with excavation of the spillway channels. The final design of the twin spillways resulted from extended studies that involved testing of several designs. The final design was subject to numerous tests using models of various scale to determine the properties of flow through the system. These flow tests were conducted at Reclamation's engineering laboratories in Denver. Excavations in the spillway channels were completed in March 1933. Excavation of the inclined tunnels began in January 1932. The tunnels were excavated by first driving a 7-foot high by 14-foot wide pilot bore along the top of the tunnel heading. The pilot bore was driven upward from the diversion tunnel and gradually expanded until the bore reached the final diameter. Excavations of the Nevada inclined spillway tunnel were completed in December 1932 with the Arizona spillway tunnel being completed in January 1934. In total, spillway excavations required the removal of over 725,000 cu/yd of material with approximately 600,000 cu/yd coming from the spillway channels and the remainder from the incline tunnels.[51]

Concrete placement in the Nevada spillway began in March 1933 with placement in the Arizona spillway beginning in April 1933. Concrete work began with placement of the spillway weir base. The bases were placed in alternating lifts of 5-feet each. When completed, the bases were used as runways for cranes and trucks during placement of the spillway channel side walls. The steep side walls were placed in 14- by 15-foot rectangular sections. Placement began in alternating sections with placement of three panels before placement in the remaining sections began. Work continued in this manner until the sidewalls were completed. Although the design had called for a minimum thickness of 18-inches, the sidewalls were generally 2-feet or more in thickness. Placement of concrete in the overflow section of the spillway followed completion of the side walls, with placement of the channel floor following completion of the overflow weir.[52]

The two spillways are each controlled by four, 100-foot long, automatically controlled drum gates. Each gate is controlled by the water level in the gate chamber. As the level of the reservoir rises, the gates raise in advance of the water surface. If the lake continues to rise past

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51. *Boulder Canyon Project: Final Reports, Part IV–Design and Construction, Bulletin 3, Diversion, Outlet, and Spillway Structures*, 323-4.
52. *Ibid.*, 328-30.

the maximum height of the gates, 1,221-feet above sea level, the gates will remain in the raised position until the depth of the flow over the top of gates reaches seven and a half feet. At that point, the gates will begin to drop, allowing a greater flow over the crests. As the water level drops, the gates will rise, maintaining a constant flow until the water drops below the spillway crest. At a peak water surface of 1,229-feet above sea level, the flow through the spillways is about 400,000 cfs. The elevation of the spillway crest is approximately 1,205-feet above sea level. The gates may also be controlled manually. The installation of the gates and control equipment in the Arizona spillway was completed from March to July, 1934, and in the Nevada spillway from June to November, 1934.[53]

Concrete placement in the inclined tunnels began in the Nevada tunnel. At first, tunnel sections were placed in a single, monolithic lift. After some experimentation, this procedure was changed, and the lining was poured in sections beginning with the tunnel invert with the remaining section poured in a single operation. In the Arizona tunnel, the invert was completed for the entire length of the tunnel before work on the remaining sections began. At first, a 14-inch pipeline conveyed concrete to the work site and deposited it in a hopper at the bottom of the tunnel. Concrete then flowed into the forms through chutes. This method proved to be troublesome and was soon abandoned. Concrete was then transported to the forms down an inclined track in 4 cu/yd buckets. Concrete placement in the spillways and inclined tunnels was completed in September 1935.[54]

On a project the size of Boulder Dam, accidents and injuries are not uncommon. One of the most notable accidents occurred during tunnel lining operations in the Arizona inclined tunnel. Three men had just finished loosening a section of the form in the tunnel invert when the cable hoisting the form upward to the next section gave way. The form, with the three men still standing on it, plummeted down the inclined shaft towards the Colorado River flowing through the diversion tunnel below. The remaining workers in the inclined tunnel heard a tremendous splash as the form hit the water below. One of them telephoned a warning to workers

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53. *Ibid.*, 294, 296-7, 333.
54. *Ibid.*, 330-3.

downstream from the tunnel portals, and a rescue team was ready when the form, with the men still clinging to it, emerged from the tunnel. The men, battered and beaten, had somehow survived their quarter-mile ride through the tunnels of Boulder Dam.[55]

In addition to the four diversion tunnels, several other tunnels were driven in order to convey water to the powerhouses and outlet works. Two tunnels, known has the upper Nevada and Arizona header tunnels, connect the downstream intake towers with the powerhouse and canyon wall outlet works. These tunnels were connected to the power turbines via four 18-foot penstock tunnels, and to the canyon wall outlet works via six 11-foot outlet tunnels. Two inclined tunnels connect the upstream intake towers with the downstream portions of the inner diversion tunnels, known as the lower Nevada and Arizona header tunnels. These tunnels are also connected to the power turbines by four 18-foot penstock tunnels.

To excavate the upper header tunnels, construction adits were driven into the canyon walls from points near the downstream end of the powerhouses. The upper header tunnels were driven both directions from the construction adits without the aid of a pilot bore. For each shot, the entire face, minus a 5-foot invert, was drilled and blasted. The invert was removed in advance of lining operations. The tunnels were excavated to a diameter of 41-feet with a lined diameter of 37-feet. Each 20-foot section of concrete was placed in a single pour using specially designed collapsible forms. The upper Arizona header tunnel required the removal of 64,000 cu/yd of rock and the placement of 17,500 cu/yd of concrete, while the upper Nevada header tunnel required the removal of 72,000 cu/yd of rock and the placement of more than 20,000 cu/yd of concrete. Work on the upper header tunnels began in January 1933 and was completed in May 1934.[56]

Excavations for the inclined portions of the lower header tunnels began with the driving of a 7-foot by 14-foot pilot heading. The pilot heading was driven upwards from the lower header tunnel to the base of the upstream intake tower. The heading was then expanded to its full 41-foot diameter beginning at the base of the intake tower downward to the lower tunnel.

55. *Hoover Dam: An American Adventure*, 215.
56. *Boulder Canyon Project: Final Reports, Part IV–Design and Construction, Bulletin 3, Diversion, Outlet, and Spillway Structures*, 178-82.

Concrete was first placed in the upper portions of the tunnels, and then upward from the lower end of the tunnels. The lined diameter of the inclined portions of the lower tunnels is 37-feet. Excavations of the two inclined tunnels involved the removal of over 28,000 cu/ft of rock and placement of 18,500 cu/yd of concrete. Work on the inclined tunnels began in January 1933 and was completed in December 1933.[57]

One of the more unique features of Boulder Dam are the twin sets of intake towers. These structures, each 395-feet tall, contain the gates that control the flow of water through the combination power penstocks and reservoir outlet works. Each tower is made up of an inner barrel, 30-feet in diameter, supported and stabilized by twelve concrete buttresses that extend outward from the inner barrel like spokes from a wheel hub. The buttresses also provide support for the trashracks and emergency gates. Each inner barrel has twelve openings at the base of the tower and twelve at a point about midway up, allowing water to enter at two levels. Flows into the openings are controlled by two 32-foot diameter, 11-foot high, cylinder gates. Controls and hoists for the gates are located in the control house atop the tower. The outside diameter of the towers is 84 feet at the base, and 64 feet at the level of the control room floor, 342 feet above the base. The four towers are identical but for minor details. The downstream tower on each side is connected to a 30-foot diameter steel pipe that conveys water to the powerhouse and canyon wall outlet works, while the upstream towers convey water to the powerhouse and river outlet works via 30-foot diameter steel pipes installed in the downstream portions of the two inner diversion tunnels. The towers are located just upstream from the dam. A bridge from the crest of the dam to each of the two downstream towers, and a bridge connecting the upstream towers with the downstream towers, provides access to the four towers.[58]

Excavations for the towers was carried out in conjunction with excavations for the dam abutments, and involved removal of 359,000 cu/yd of material. The towers were constructed on reinforced circular bases 88 feet across and 10 feet thick. The lower ring gates and associated equipment were placed following the completion of the tower bases. Concrete in the twelve

57. *Ibid.*, 177-8.
58. *Ibid.*, 137-42.

radial buttresses and the tower barrel was placed in lifts of just over 10 feet. The sequence was to start at one buttress and progress both directions around the tower to the opposite side. Each lift involved the use of concrete forms that contained 156 separate panels. Because the design engineers believed the towers to be more vulnerable to seismic activity than other features of the dam, the towers were heavily reinforced with 4,000,000 pounds of reinforcement steel placed in each tower. Construction of the towers began in February 1932 and was completed in March 1935.[59]

Six Companies' paydays came on the tenth and twenty-fifth of each month. When payday arrived, a long string of cars could be seen exiting the gates of the construction reservation heading northwest towards Las Vegas, twenty-eight miles away. The saloons, gambling halls and brothels of Las Vegas gave the dam workers the chance to live it up and unwind after two long weeks of hard work and danger. And many people in Las Vegas were more than willing to help the workers find their relief - for a price. For those who were married or more conservative in their pursuits, sixty cents bought admission to the Airdome or El Portal theaters. The Apache Hotel, the Golden Camel, or the Meadows offered drinks and dancing in a reasonably civilized atmosphere. But for those seeking real action, there was the Nevada Bar, the Boulder Club, the Las Vegas Club, and dozens more, each seeking to outdo the others. Free-flowing liquor and gambling tables of questionable fairness made for a delirious and wild scene. If companionship was what one sought, Block 16 was were it could be found. A constant stream of prostitutes and customers saw to it that the block prospered, and the fear of disease did little to stem the flow.

If one did not feel like traveling all the way to Las Vegas, their desires could be met at any one of dozens of bars and brothels that stretched from the settlement of Midway, about half way to Las Vegas, back to the gates of the federal reservation at Boulder City. These many "resorts" as they were called, offered a cheaper and grimier alternative to the pleasures of Las Vegas. Two of the more notorious were the Railroad Pass Club and Texas Acres. These clubs, surrounded by tents and cabins where prostitutes plied their trade, had vicious reputations, and

59. *Ibid.*, 141-2, 146, 157, 159-62.

beatings, knifings and shootings were common. When the night was over and the last dollar spent, carloads of drunken workers would race back to Boulder City trying to beat the clock and return before the start of the day shift. Because of the many accidents on the road between Boulder City and Las Vegas, the highway became known as the “Widowmaker.”[60]

In order to use the four diversion tunnels as part of the spillway, power penstock and outlet systems, it was necessary to plug the tunnels upstream of the intake towers and spillway tunnels. A concrete plug at the point where the inclined tunnels from the intake towers met the diversion tunnels closed the two inner diversion tunnels. Each concrete plug is 306-feet long and consists of three conical sections that range in diameter from 62-feet at the upstream end to 52-feet at the downstream end. The downstream sections form a portion of the transition from the inclined tunnels to the diversion tunnels. The outer tunnels were sealed using a combination of concrete plugs, and steel bulkhead gates located at the upstream portals of the tunnels. The tunnel plugs are similar to the plugs used in the inner tunnels except that they are 393-feet long and the plug in the outer Nevada tunnel was constructed with four high pressure gates that were used to control the river until the level of the lake reached the level of the lower gates in the intake towers.

The inner Nevada tunnel was sealed in August 1933, followed shortly after by the closure of the inner Arizona tunnel. The upstream 214 feet of the outer Nevada plug containing the high pressure gates was constructed in 1933 during low river flow. The two bulkhead gates located at the upstream portals of the outer tunnels are 55 feet, 7 inches wide and 50 feet, 6 inches high and weigh 2,180,000 pounds each. These gates were provided so the tunnels could be sealed off during placement of the tunnel plugs allowing work to be carried out at any time, not just at periods of low river flow. In addition to the gate, a trashrack was installed with the gate at the outer Nevada tunnel portal. The bulkhead gate at the Arizona tunnel was closed on February 1, 1935, and water began to back-up behind the dam. Releases downstream were handled by the gates in the Nevada tunnel plug until the water level reached the lower gates of the intake

60. *Hoover Dam: An American Adventure*, 222-6.

towers.[61]

In addition to the plugs placed in the upstream portions of the diversion tunnels, plugs were also placed just upstream from the outlets of the inner tunnels. Within each of these plugs there are six outlet conduits each controlled by 72-inch needle valves. Each of the needle valves are protected by an 86-inch emergency bulkhead gate. The valves and control systems for the tunnel-plug outlet works are contained in 115 foot long, 35 foot wide, and 66 foot tall control chambers that are constructed in enlarged sections of the diversion tunnels. Access to the control chambers is via adits from the cableway landings at the downstream ends of the power houses. Excavation of the access and construction adits began with work on the Nevada side in December 1932, and the Arizona side in March 1933. Work in the adits was completed in June 1933, and excavations for the tunnel-plug outlets and control chambers began in October 1933. Excavations were completed in early 1934, and concrete placement in the tunnel plugs and control chambers began in October 1935. Work on the tunnel-plug outlet works, including the installation and testing of the needle valves and emergency gates, was completed in September 1937.[62]

To facilitate dewatering of the outlet tunnels downstream from the tunnel-plug outlets, 35-foot by 50-foot bulkhead gates were constructed at the downstream portals of both tunnels. These gates, when lowered, prevent the river from backing up into the tunnels so that the tunnels may be inspected and maintained. The gates are held in reinforced concrete structures 117 feet high and 79 feet wide. The controls for the gates are located atop the structures. The control houses are 73 feet long, 18½ feet wide, and 14½ feet high. The Nevada gate is accessed via an adit from the powerhouse road, while the Arizona gate is accessed via an adit from the tunnel-plug gate chamber to a trail excavated in the canyon wall.[63]

Many memorable characters were involved in the construction of Boulder Dam, but perhaps the most memorable was not a person, but a black dog named "Nig." Nig came from a litter of puppies born under the floor of the first police building in Boulder City in early 1934. A

61. *Boulder Canyon Project: Final Reports, Part IV–Design and Construction, Bulletin 3, Diversion, Outlet, and Spillway Structures*, 101-34.
62. *Ibid.*, 223-45.
63. *Ibid.*, 247-52.

Black Labrador mix, Nig became the project mascot. Nig had free reign to go anywhere he wanted to. Each morning he would ride to the dam in the company transport. At night he was always ready to head back to town with the other workers. At the Anderson Brothers' mess hall he was given anything he wanted. In the mornings the workers would pack him a lunch and he would eat with them at noon. In the evenings he would hang out at the drug store in Boulder City where the workers would buy him ice cream and candy. Once Nig got sick from all the sweets and went to the town doctor. The doctor placed an ad in the local paper that said "Please do not feed me ice cream and candy bars. It makes me sick." It was signed "Nig." After that, the people were a little more careful about what they would feed him. Nig liked to ride on the equipment at the dam. He could be seen riding on one of the trains or on one of the skips that carried men up and down the side of the canyon. Often he would spend his time riding around the construction site with Frank Crowe, the Six Companies superintendent. Once an angry worker kicked Nig while he was asleep on the porch of one of the dormitories. "Bud" Bodell, chief of the Boulder City Ranger Force, saw to it that that worker never kicked Nig again.

One hot summer day in 1936, Nig was sleeping in the shade beneath a truck. The driver didn't see him and Nig didn't hear the truck start. The truck ran over him and killed him. He was buried near the dam and the workers took up a collection and placed a plaque on the canyon wall near where he is buried. Many years later, a visitor to the dam saw the plaque and believed the name "Nig" to be racist. He started a campaign to have the plaque removed, and in 1979, the Bureau of Reclamation removed the plaque. The citizens of Boulder City began a petition drive protesting the removal of the plaque. Bob Parker, a former worker at the dam, noted that ". . .Nig was [all he was] ever known by. He was the friend of the black men and the white men and every other kind of person that worked down there."

The plaque was replaced with a new plaque that has Nig's picture on it, but not the word "Nig." When the workmen were pouring the concrete for the new plaque, they scratched "Nig" in the concrete, and its still there.[64]

64. Andrew J. Dunar and Dennis McBride, *Building Hoover Dam, An Oral History of the Great Depression,* (New York: Twayne Publishers, 1993), 189-90.

Providing water to the power turbines and outlet works required the installation of over 14,000-feet of piping that ranged in diameter from 8 feet 6 inches, to 30 feet. On June 15, 1932, Reclamation awarded the contract for manufacture and installation of the penstock and outlet pipes to the Babcock & Wilcox Company of Barberton, Ohio. Their bid was $10,908,000. Because the enormous size of the pipe sections to be manufactured prevented them from being transported to the site from existing factories, Babcock & Wilcox built and equipped a fabrication plant near the Nevada rim of the canyon, about a mile and a half from the dam. The shop building was 520 feet long and 93 feet wide. There was an attached laboratory used to make chemical analyses of the steel used in the pipes, and a 41-foot long, 36-foot wide, and 30-foot tall furnace used to relieve stress from the fabricated sections of pipe. The contractor also built 14 houses, seven 4-unit apartment houses, and a 100-room dormitory at Boulder City. Work on the fabrication plant and employee housing began in November 1932 and was completed in April 1933.[65]

The steel plates that formed the pipes were shipped by rail to the fabrication plant at the dam. The plates were 12 feet wide and ranged in length from just over 31 feet, to more than 41 feet, and weighed as much as 21 tons. The plates were manufactured at the mills of the Illinois Steel Company of Gary, Indiana. Over 43,000 tons of steel were required for the penstock and outlets systems.[66]

The first step in forming the pipe involved preparing the edges of the steel plate to be welded together. The second step involved bending the plate to the required curvature. This was done by passing the plates through bending rolls until the desired radius was achieved. The radius was determined using steel templates. The fabrication of the 30-foot diameter pipes required the use of three plates each just over 31 feet long. The 25-foot diameter pipes were manufactured using two plates approximately 40 feet long, and the 13 foot pipes required a single plate of over 41 feet. Once the required radius had been achieved, the sections were placed on an assembly rig and welded together by automatic welding machine. After the

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65. *Boulder Canyon Project: Final Reports, Part IV–Design and Construction, Bulletin 5, Penstocks and Outlet Pipes*, (Denver 1949), 191-2, 370.
66. *Ibid.*, 212-3.

welding operation was completed, each section of pipe was subjected to radiographic examination to locate any faulty welds. If any were located, they were removed and the pipe rewelded. Following welding, each section was placed in the furnace where it was slowly heated to a temperature between 1,100 and 1,200 degrees Fahrenheit for one hour and then cooled to about 500 degrees before being removed. This process of heating then cooling relieved stresses in the steel that had built up during the bending and welding process. Following the heat treatment, the sections were cleaned and the ends machined to ensure a proper fit with adjoining sections. While this was the general procedure for forming sections of the pipe, curved sections, "Y" sections, and other specialized sections required additional fabrication steps.[67]

Moving the completed sections of pipe to the construction site and into their locations in the tunnels presented a significant challenge. To move the 25-foot and 30-foot sections from the fabrication plant to the cableway landing at the canyon, a specially designed trailer with a capacity of 200 tons was constructed. The trailer was 38 feet long and 22 feet wide and rode on 16 wheels. It was moved using two caterpillar tractors, one pulling, with the other attached to the rear used for braking. At the canyon rim, the pipe sections were hoisted from the trailer by the 150-ton cableway and lowered to one of the landings in the canyon.

Moving the pipe sections from the cableway landings through the adits to their final locations in the tunnels was not an easy task. Babcock & Wilcox contracted with Eichleay Engineering Corp. of Pittsburgh to supply the necessary tools and equipment, to move the sections to within one foot of their final location. Space limitations within the adits and tunnels made it impossible to turn the railcars with the sections on them or to curve the tracks. To solve this problem, a unique system of a car on a car was used. The lower car only moved in and out of the adits, with the upper car only able to move back and forth through the tunnels. The upper car sat on a section of track that was mounted atop the lower car. The pipe sections were placed atop the upper car and the entire unit was moved through the adit to the tunnel. Once in place, the upper car was rolled from atop the lower car onto a set of tracks that ran through the tunnel

67. *Ibid.*, 213-5, 233.

and the section was moved to its final location.[68]

Once a section had been moved to its final location its was attached to the previous section using an assembly rig consisting of three "spider" sections mounted on a 20-foot long central hub. The spider sections consisted of 16 steel H-beams extending outward from the hub like spokes, with braces welded between the spokes. Mounted at the end of each spoke was a hydraulic jack. The rig was held in place in the previously placed section using two of the spiders, with the section being placed held and aligned using the third spider. When the new section was securely attached to the previous section, the jacks were released and the rig, which was mounted on wheels, was moved ahead and readied for the next section.[69]

Assembling pipe sections in the inclined portions of the tunnels was significantly more difficult. The tunnels of the Arizona side have slopes greater than 52 degrees while the Nevada tunnels have slopes just over 37 degrees. In the lower headers, the first pipe section had to be hoisted 237feet to the base of the intake tower, while in the upper headers, the first section had to be raised 70 feet. The sections were hoisted up the inclined portions using rubber wheeled cars that rode on the tunnel lining, and a series of cable hoists. The pipe sections rode on the car until they reached a point on the incline where they could be lifted into place vertically. Each of the upper sections required about 12 hours to be lifted into place from the lower tunnels. After the first three sections had been secured, they were embedded in concrete to provide additional support for the other sections. Following placement of all sections in the inclined portions of the tunnels, the entire section was embedded in concrete.[70]

To transport the 13-foot diameter penstock sections that run from the headers to the power turbines, a third car was added to the two-car unit used for moving larger sections. Because the 13-foot diameter penstock sections are lighter, the third car was mounted on rubber wheels and rode along on the lining of the penstock tunnels. This car was also used to transport the eight-and-a-half foot diameter sections of the outlet pipes.[71]

The headers and penstocks are supported on piers placed along the tunnels at regular

68. *Ibid.*, 251-9.
69. *Ibid.*, 264-6.
70. *Ibid.*, 259-64.
71. *Ibid.*.

intervals. The weight of the pipe and water is transferred to the piers via supporting brackets that are attached to stiffener rings located at the center of each fabricated pipe section. The headers and penstocks are firmly anchored in place by several concrete anchors placed at various sections of the pipe. These anchors consist of concrete rings that encircle the pipe and anchor it firmly to the tunnel wall. Six anchors are used in the upper headers, and seven in the lower headers. In addition, the upstream and downstream ends of the headers and penstocks, and the entire length of the eight-and-a-half foot canyon wall outlet pipes are embedded in concrete to form terminal anchors. In the lower headers, the tunnel plugs at the outlet works form additional terminal anchors.[72]

Because the Boulder Canyon Project straddled the Arizona/Nevada State line, the laws that applied at the site depended which side of the canyon one was on. With regards to accidents or deaths, the State of Arizona paid more to victims and their families than did the State of Nevada. If a man was killed or injured on the job, it was to his family's financial advantage if the accident took place on the Arizona side of the project. Whenever possible, workers who were killed or injured on the Nevada side of the canyon were moved to the Arizona side before the accident was reported. There are stories of badly injured workers dragging themselves through rock and dirt and across busy roads to get to the Arizona side. Determining if an accident occurred in Arizona or Nevada was sometimes difficult. Before the river had been diverted, the state line was as wide as the river. Following diversion, the line became razor thin and difficult to locate. When the location of an accident was very near the line, as often as not, the investigator placed the victim in Arizona.[73]

One of the more notable features of Boulder Dam are the canyon wall outlet works. Built on benches excavated in the canyon walls about 800 feet downstream from the dam, these reinforced concrete structures each house six, 84-inch needle valves which were designed to control the release of water from the upper headers when power operations were suspended or to dewater the penstocks for inspection. The two valve houses are about 175 feet above the river

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72. *Ibid.*, 147-68.
73. *Hoover Dam: An American Adventure*, 164-6.

level. Excavations for the valve houses began in November 1932 in conjunction with canyon wall stripping operations. Placement of concrete in the structures began in January 1935, following installation of the eight-and-a-half foot diameter outlet pipes, and was completed in October 1935. Installation of the needle valves and the 96-inch emergency gates that protect the needle valves from water pressure when the valves are closed began in August 1935 and was completed in November 1935. All work on the canyon wall outlet works was completed in early 1936. The two valve houses differ only slightly, with the Nevada valve house about 15 feet shorter than the Arizona valve house, which is 202 feet long. Both structures are 63 and one half feet high and just over 33 feet deep. Access to the valve houses is via pathways cut into the canyon walls from the cableway landings at the upper construction adits.[74]

Excavation for the powerhouse was carried out in conjunction with excavations for the dam foundation and abutments. Excavations for the U-shaped structure located at the downstream toe of the dam were completed in late 1933 with the first concrete placed in November 1933. The powerhouse consists of three sections. The Arizona and Nevada wings extend from the face of the dam about 610 feet downstream and are connected by the center section that runs across the face of the dam. The center section actually rests upon the face of the dam, with the downstream edge of the dam extending some 40 feet further downstream than the downstream wall of the center section of the powerhouse. The center section houses the control room, administration offices, shops, and storage areas. The wing portions house the generating units and were designed to house a total of seventeen units: eight in the Nevada wing and nine in the Arizona wing. The wings are 650 feet long, 120 feet wide and 230 feet high. During normal operations, the bottom 220 feet of the powerhouses are submerged. Construction of the powerhouse required 255,000 cu/yd of concrete, 24,000,000 pounds of steel reinforcement, and 12,000,000 pounds of structural steel.[75]

Initial plans called for the eventual installation of fifteen, 82,500 kilowatt (kW), and two

74. *Boulder Canyon Project: Final Reports, Part IV–Design and Construction, Bulletin 3, Diversion, Outlet, and Spillway Structures*, 191-211.

75. Denver, Colorado. National Archives and Records Administration: Rocky Mountain Region, Records of the Bureau of Reclamation, Record Group No. 115, "Project Histories: Boulder Canyon Project," 1933, 205; 1934, 233 (Hereafter cited as "Project Histories" with volume number, year, and page, if applicable.); *Boulder Canyon Project: Final Reports, Part IV–Design and Construction, Bulletin 1, General Features*, 199.

40,000 kW units. The power turbines are connected to the downstream ends of the sixteen, 13-foot diameter penstock pipes: eight for each power house, with the downstream penstock on the Arizona side branching into two smaller pipes to provide water to the two, 40,000-kW units. Flow to each of the turbines is controlled by 13-foot diameter butterfly valves located between the ends of the penstocks and the turbine casings. Through the use of the butterfly valves, it is possible to shut off the flow to one or more units without interrupting the operation of other units. Initial plans called for the immediate installation of four 82,500-kW units on the Nevada side, units N-1, N-2, N-3, and N-4, and one of the 40,000-kW units on the Arizona side, unit A-8. Other units would be installed when firm contracts for the sale of power were signed. In addition, there are two small 2,400-kW service units that supply operating power to the dam and powerplant. These units are located in the upstream end of the powerhouse wings and receive water via 30-inch penstocks that branch from the penstocks serving the two upstream units in each powerhouse. The service unit penstock system is interconnected so that the units can be operated if only one of the four main penstock systems is operational.[76]

While construction of Boulder Dam led to advancements in many areas, advancements in some areas was strongly resisted. The contract between Six Companies and the Government carried a standard U.S. Government contract clause prohibited hiring of "Mongolian" labor, and discrimination on the basis of color or race was a common practice, with blacks bearing the brunt of the discrimination. Boulder City Manager Sims Ely prohibited blacks from living in Boulder City and few places in town would serve them. The few blacks who were employed on the project were forced to live in Las Vegas, thirty-five miles away. Government investigations into discrimination in hiring practices confirmed the situation, but little was done to correct the matter, and few of the concessions made by Six Companies were carried out.[77]

Bids for 115,000 horsepower (hp) turbines to drive five of the 82,500-kW generators were opened in March 1933. The contract was awarded to the Allis-Chalmers Manufacturing Company of Milwaukee, with a bid of $1,718,000 that was the lowest of four bids. The Newport

76. *Hoover Dam: Fifty Years*, 47; *Boulder Canyon Project: Final Reports, Part IV–Design and Construction, Bulletin 1*, *General Features*, 199, 202-3, 216; “Bids Opened on Large Turbines for Hoover Dam Power Plant,” *Engineering News-Record*, March 30, 1933, 418.

77. *Building Hoover Dam, An Oral History of the Great Depression*, 306-7.

News Shipping & Dry Dock Company of Newport News received the contract for two 55,000-hp turbines to drive the 40,000-kW units. Their bid was $338,000. The $80,796 contract for governors to control the turbines was awarded to the Woodward Governor Company of Rockford.[78] 82,500 kW generators, Westinghouse Electric and Manufacturing Co.

The contract for the first two of the four 82,500-kW generators to be installed under the initial plan was awarded to the General Electric Company, with the contract for the other two units being awarded to the Westinghouse Electric and Manufacturing Company. The contract for the 40,000-kW unit was let to the Allis-Chalmers Manufacturing Company.[79]

Installation of machinery in the powerhouses began in early 1935, with installation of the two, 300-ton capacity gallery cranes beginning in July 1935. Installation of the first generator by General Electric began on October 11, with Westinghouse Electric beginning installation of a second generator on October 24.[80]

The final bucket of concrete was placed in the main dam on May 29, 1935, and grouting of the contraction joints was completed on June 7, but work was not complete. On May 1, 1936, the temporary gates in the Nevada tunnel plug were closed, and the bulkhead gate at the opening of the Nevada tunnel was closed on May 6. From that point on, all normal releases have been made through the gates of the four intake towers. Work on the penstocks and outlet system continued until September 1936, when Babcock & Wilcox completed all work under their contract with Reclamation.[81]

The first of the five power units to be installed under the initial plan went into operation on October 26, 1936 when unit N-2 was placed on line. Unit N-4 came on line in November, with unit N-1 beginning production in December. Units N-3 and A-8 began operation in March and August 1937, completing the initial power installation.[82]

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78. "Bids Opened on Large Turbines for Hoover Dam," *The Reclamation Era*, May 1933, 16.
79. "Boulder dam Generators to Be World's Largest," *Engineering-News Record*, December 7, 1933, 682.
80. Project History, 1935, 10-9.
81. *Boulder Canyon Project: Final Reports, Part IV–Design and Construction, Bulletin 2, Boulder Dam*, 147; *Boulder Canyon Project: Final Reports, Part IV–Design and Construction, Bulletin 5, Penstocks and Outlet Pipes*, 382.
82. *Hoover Dam: Fifty Years*, 5; *Boulder Canyon Project: Final Reports, Part IV–Design and Construction, Bulletin 3, Diversion, Outlet, and Spillway Structures*, 104; *Boulder Canyon Project: Final Reports, Part IV–Design and Construction, Bulletin 5, Penstocks and Outlet Pipes*, 370.

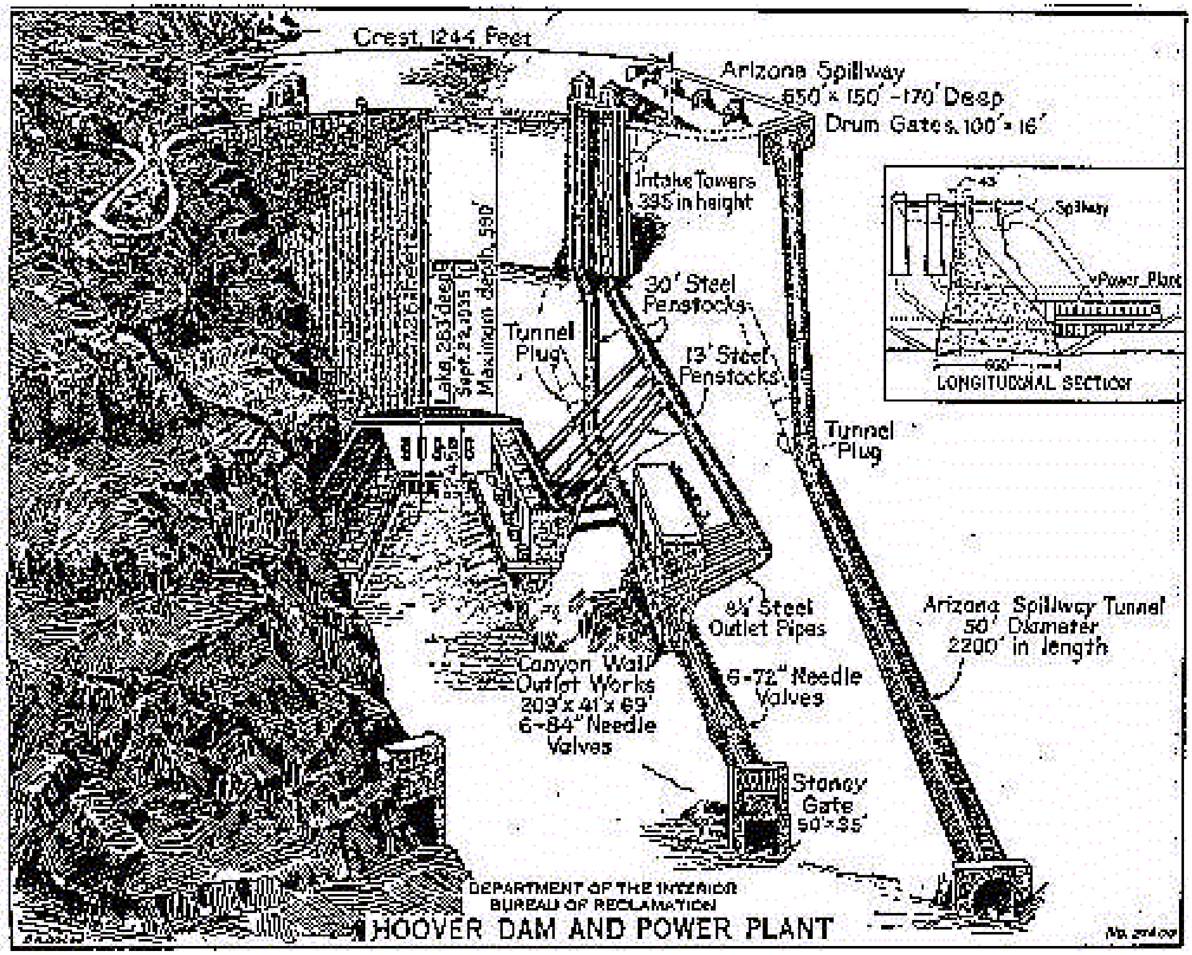

Figure 3 How Hoover Dam Works

Almost everything about Hoover Dam can be narrowed down to one word: BIG. The numbers relating to the project are enormous: 5,500,000 cu/yd of material excavated; 4,400,000 cu\yd of concrete placed; 45,000,000 pounds of reinforcement steel used; 21,670,000 pounds of gates and valves. Over 44,000,000 tons of steel were formed and welded into 14,800 feet of penstock and outlet pipes. Over 5,000,000 barrels of cement were used in construction of the dam, which weighs more than 6,600,000 tons. The average number of people employed on the project was 3,500 with over 5,200 employed during the peak of construction. Two-hundred and twelve men died due to accidents or illness related to construction activities.[83]

Boulder Dam is a concrete gravity arch structure just over 726 feet tall and 1,244 feet long. The dam is 660 feet wide at the base, and 45 feet wide at the top. The total volume of

83. *Building Hoover Dam, An Oral History of the Great Depression*, 317-20; *Hoover Dam: Fifty Years*, 43-4.

concrete in the dam, powerplant, and associated structures is 4,400,000 cu/yd. The combination power penstock and outlet system consists of four, 395-foot tall intake towers, each controlled by two 32-foot diameter cylinder gates, discharging into tunnels excavated through the abutments. The tunnels branch into sixteen, 13-foot diameter power penstocks, eight on each side of the canyon, leading to the powerhouse wings. The upper outlet tunnels that originate from the downstream intake towers terminate at the canyon wall outlet houses, while the lower outlet tunnels terminate at the tunnel plug outlet works. Peak floods are passed via two, side channel spillways discharging into inclined tunnels that connect with portions of the original diversion tunnels. The spillways have overflow concrete weir crests each controlled by four, 100-foot long drum gates. The maximum capacity of the spillways is 400,000 cfs.

Lake Mead is over 110 miles long with a 550 mile long shoreline and has a maximum capacity of over 32,000,000 ac/ft. The surface area of the lake at full capacity is 162,700 acres. The two powerhouse wings contain at total of seventeen power units, eight in the Nevada wing and nine in the Arizona wing. When the project was completed, there were fourteen 82,500-kW units, one 95,000-kW unit, one 50,000-kW unit, and one 40,000-kW unit. The total capacity was 1,344,800 kW. In addition to the seventeen primary units, each wing contains one 2,400 kW unit that supplies power to the dam and powerplant.[84]

Post Construction History

Boulder Dam was dedicated by President Franklin Roosevelt on September 30, 1935. Among the dignitaries in attendance was Elwood Mead, Commissioner of Reclamation; Harold Ickes, Secretary of Interior; John Savage, Raymond Walter, and Walker Young, of the Bureau of Reclamation; and the Governors of California, Utah, Arizona and Wyoming. Representing the Six Companies was Harry Morrison of Morrison-Knudsen; Steve and Kenneth Bechtel of the Bechtel Corporation; and Frank T. Crowe, Six Companies Construction Superintendent.

Speaking to thousands of onlookers, the President referred to the dam as "an engineering victory of the first order - another great achievement of American resourcefulness, skill and determination." On February 29, 1936, in a ceremony witnessed by only a few reporters and a

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84. *Project Data,* (Denver: U.S. Government Printing Office, 1981), 84-5.

lone cameraman, Ralph Lowry, who had replaced Walker Young as construction engineer, stood upon the dam crest and shook hands with Frank Crowe, accepting the dam from Six Companies. The next day, Secretary of the Interior Harold Ickes officially accepted the dam and powerhouse, ending the contract with Six Companies, more than two years ahead of schedule.[85]

Acceptance of the dam and powerplant was an event touched with sadness. On January 26, 1936, Dr. Elwood Mead, Commissioner of the Bureau of Reclamation, passed away following a heart attack. Although not in the spotlight as much as others involved in the project, he was a strong advocate of the project and had earned the respect of all who knew him. On February 6, 1936, in honor of his dedication to Reclamation and his support of the Boulder Canyon Project, the huge reservoir created by the dam was named in his honor.[86]

To many in the political circles of Washington, Walker Young seemed destined to rise to the top the Bureau of Reclamation following the death of Mead. Young, a Republican who led survey teams in the Black Canyon in the twenties before guiding the project through to its end, reached the top of his career at the same time the Democrats were gaining power in Washington. In a purely political decision, the less senior John C. Page was picked to succeed Mead. He had served as Young's office engineer during construction of Hoover Dam. Although denied the leadership of Reclamation, Young continued his career with the Bureau. From 1935 to 1940, he was first Construction, then Supervising Engineer for the Central Valley Project in California. In 1945, he returned to the Denver office as Assistant Chief Engineer, and then finally, Chief Engineer. He retired from Reclamation in 1948.[87]

Frank Crowe left the Boulder Canyon Project a rich man. In addition to his $18,000 a year salary, he had received bonuses in excess of $250,000. Not content to retire, Crowe continued working for Six Companies. In 1938, he brought Parker Dam in ahead of schedule. Following that he supervised construction of two smaller dams on the Colorado River Aqueduct system before turning his attention to Shasta Dam in California. The key feature in the Central Valley Project, Shasta rivaled Hoover Dam in size. Crowe spent six years at Shasta, guiding the

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85. *Hoover Dam: An American Adventure*, 243-7.
86. *Ibid.*, 250; *Boulder Canyon Project: Final Reports, Part IV–Design and Construction, Bulletin 1, General Features*, 235.
87. *Hoover Dam: An American Adventure*, 254.

project to a successful conclusion in spite of manpower and material shortages caused by World War II. Crowe retired in 1945 and passed away in early 1946.[88]

In 1938, generators N-5 and N-6 were installed and placed in operation. Generators A-7 and A-8 followed in 1939, bringing the capacity of the powerplant to 704,800 kW and making it the largest hydroelectric powerplant in the world - a distinction held until surpassed by Grand Coulee Dam in 1949.

In 1938, Imperial Dam, about 300 miles south of Boulder Dam, was completed, followed by the All-American Canal in 1940, completing those portions of the Boulder Canyon Project and bringing water to the fields of the Imperial Valley. In 1941, the All-American Canal was modified to supply water to the Yuma Project, which serves 65,000 acres near Yuma, Arizona. Water for the Yuma Project had been supplied by the Laguna Diversion Dam on the Colorado River, which was abandoned in 1948. The final feature of the Boulder Canyon Project, the 123-mile long Coachella Canal, was completed in 1948.[89]

In 1941, the level of Lake Mead reached to within one foot of the top of the spillway gates, and on August 6, the gates on the Arizona side were lowered and water flowed into the spillways for the first time. When the spill was halted in early December, inspection of the spillway tunnel revealed that a 112- by 38- foot section of the tunnel lining had been eroded away by the action of the water as it flowed through the tunnel. Repairs to the tunnel lining were completed in early 1943.[90]

On October 9, 1941, generator A-1 was placed into operation, bringing to ten the number of units in service. On December 7, 1941, in response to the bombing of Pearl Harbor, the Government closed the dam to public access. For the duration of World War II, traffic across the dam would move under convoy. The dam reopened to the public in 1945.[91]

Generator A-2 began operations in July 1942, followed by unit A-5 in January 1943, and unit N-7 in November 1944. In October 1946, a ceremony was held at the dam commemorating

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88. *Ibid.*, 252.
89. *Project Data*, 67, 71.
90. "Project History," 1941, 11-2; 1943, 10; *Hoover Dam: Fifty Years*, 5.
91. *Hoover Dam: Fifty Years*, 5.

ten years of commercial power production.[92]

In 1947, the 80th Congress passed legislation officially designating the dam "Hoover Dam," in honor of President Herbert Hoover. This brought to a close a political debate that had been raging since the early 1930s. In 1930, Secretary of Interior Ray Lyman Wilbur suggested the name Hoover in honor of Hoover's contribution to the project in seeing the completion of the Colorado River Compact through. But in 1930, with the dawning of the Depression, Hoover's name was not held in high regard. In May 1933, following Roosevelt's inauguration, the new Secretary of Interior, Harold Ickes, issued an order that henceforth, the dam would be known as Boulder Dam. Ickes claimed that Wilbur had been out of line in naming the dam after a sitting president and that the dam had already been known as Boulder Dam. The restoration of the name Hoover ended the debate once and for all.[93]

During the design of Boulder Dam, it was recognized that the tremendous weight of the dam and lake, more than 41,000,000,000 tons, might have a localized affect on the Earth's crust. Estimates made prior to construction indicated that there could be as much as three feet of deformation due to the weight. Precise measurements taken in the area surrounding the site before and after filling of Lake Mead showed seven inches of settlement in the Earth's crust in the first fifteen years following completion of the dam. In addition to settlement of the crust, construction of the dam led to another first: the creation of the first reservoir induced earthquakes. During the first ten years of operation, more than 6,000 minor tremors, the strongest in 1939, were recorded in the vicinity of Lake Mead where no tremors had been recorded for the fifteen years prior to construction of the dam.[94]

In 1952, units A-3, A-4, and A-9 were placed into service, and during 1952 and 1953, a record of 6,400,000 kW was generated. The final generating unit was placed into service in 1961, when unit N-8 was placed on-line, bringing the capacity of the powerplant to 1,334,800

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92. *Ibid.*
93. *Building Hoover Dam: An Oral History of the Great Depression*, 305.
94. Eric B. Kollgaard and Wallace L. Chadwick, editors, *Development of Dam Engineering in the United States*, (New York: Pergamon Press, Inc., 1988), 28, 280; *Boulder Canyon Project: Final Reports, Part IV–Design and Construction, Bulletin 1, General Features*, 243.

kW.[95]

In the early 1980s, Reclamation began updating the power units at Hoover Dam, and by 1990, ten of the 82,500-kW units had been upgraded to 130,000-kW, and two to 127,000-kW. The remaining 82,500-kW units have been upgraded to 130,000-kW with the 40,000-kW unit upgraded to 61,500-kW and the 50,000-kW unit to 68,500-kW. The upgrade was completed in 1993.[96]

With the completion of the dam, many believed that Boulder City would become a ghost town, housing only the small number of workers need to operate and maintain the dam and powerplant. But this was not to be. The population of Boulder City dwindled following completion of the project, but many held on. World War II brought revival to the town. The opening of a large magnesium plant in Henderson and the growth of defense industries in the area led to housing shortages in Henderson and Las Vegas and many workers found housing at Boulder City. Having survived the post-construction era until the war related population surge, Boulder City looked to secure its future. In 1949, Reclamation began look into ways to institute self-rule in Boulder City. In 1951, the Secretary of the Interior issued an order separating Boulder City from the Boulder Canyon Project. In 1959, the municipality of Boulder City was incorporated under Nevada law, and in 1960, it was officially separated from the U.S. Government.

Many resisted separation of the town from the Government. The policies against gambling and hard liquor sales enforced by the Government appealed to many and made Boulder City immune from the growth and turmoil that towns like Las Vegas encountered. Opponents feared Boulder City would follow the same course. But following separation, the leaders of Boulder City elected to continue these conservative restrictions. While it might be expected that such restrictions would suppress growth, many found the wholesomeness appealing, and the population of Boulder City grew. The popularity of Boulder City grew so rapidly that in 1979, the city was forced to pass restrictions on future expansion. By 1985, the population of Boulder

95. *Hoover Dam: Fifty Years*, 6.
96. United States Department of the Interior, Bureau of Reclamation, *Hydropower 2002: Reclamation's Energy Initiative*, (November 1991), 69-71.

City had reached over 10,000.[97]

In 1968, construction of the Robert B. Griffith Water Project began. This project, now called the Southern Nevada Water Project, pumps water from Lake Mead and transports it to Boulder City, Henderson, Las Vegas, and Nellis Air Force Base for municipal and industrial use. The first stage of the project was completed and placed into operation in 1971. The second stage was begun in 1977 and completed in the mid-1980s.[98]

In October 1977, part of the operation of the Parker-Davis Project was combined with operations of the Boulder Canyon Project. Davis Dam, about 67 miles downstream from Hoover Dam, was constructed to help meet the obligations of the United States to deliver water to Mexico under the Mexican Treaty of 1944. The reservoir formed by the dam, Lake Mohave, helps meet these requirements. Parker Dam, about 88 miles downstream from Davis Dam, forms Lake Havasu, which acts as the forebay for the Colorado River Aqueduct and the Central Arizona Project. The aqueduct supplies water to the city of Los Angeles and is owned and operated by the Metropolitan Water District. The Central Arizona Project is managed by the Central Arizona Water Conservation District[99] and supplies water to cities, farms and Indian communities in central Arizona.[100]

Completion of the Glen Canyon Dam on the Colorado River near the Arizona\Utah border significantly altered the flood control operation of Hoover Dam. The 710- foot high Glen Canyon Dam, completed in 1964, holds back Lake Powell and provides significant flood control benefits in the area upstream from Hoover Dam. As a result of the benefits provided by Glen Canyon Dam, it was possible to reduce the capacity of the outlet works at Hoover Dam without reducing its flood control benefits. In 1979, the outlet works were modified by elimination of two needle valves from each of the tunnel plug outlet works, and six needle valves from each of the canyon wall outlets. The abandoned outlet conduits were permanently sealed with steel bulkheads and new valves to replace the worn valves are being designed for the remaining

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97. *Hoover Dam: Fifty Years*, 25; *Hoover Dam: An American Adventure*, 262-3.
98. *Project Data*, 1177.
99. Recently the district has been renamed the Central Arizona Project.
100. *Ibid.*, 82, 767-70.

conduits.[101]

The number of visitors to Hoover Dam and Lake Mead has steadily increased since visitor services began in 1937. In 1951, 2,000,000 people visited the Lake Mead National Recreation Area. By 1970, that number had risen to over 4,900,000, and in 1991, more than 7,000,000 people visited Lake Mead. In 1953, 448,081 people toured Hoover Dam, and by the end of 1958, over 7,000,000 people had toured the dam and powerplant. In 1959, a new annual record of 472,639 visitors was set, and in 1962, the record was raised to 500,000 visitors. In 1967, the number of yearly visitors exceeded 600,000, and in 1968, the 12,000,000th visitor toured the facilities. The 15,000,000th visitor was recorded in 1972, and in 1983, on the eve of the dam's fiftieth anniversary, the 23,000,000th person visited Hoover Dam. In the late 1980s, the Bureau of Reclamation began construction of new visitors facilities at Hoover Dam. Controversial and over budget, the new visitors facilities improve visitor safety, interpretive capability, and visitor capacity at the dam.[102]

In 1983, Hoover Dam faced its greatest challenge. Heavy winter snows followed by a hot and rainy spring sent more than one and one half times the normal runoff down the Colorado River and its tributaries. Lake Powell and other reservoirs upriver from Lake Mead quickly filled to capacity requiring emergency spills. By early July, Lake Mead was almost at capacity, and on the evening of July 2, water flowed over the spillway gates for the first time in over forty years. The spill continued until September 6 and at its peak, water was more than four- feet deep over the top of the raised spillway gates. Upstream, at Glen Canyon Dam, the spills caused significant damage to the spillway tunnels which are similar to those at Hoover Dam. At Hoover, the spills caused damage similar to the damage caused during the 1941 spill, and during repairs, Reclamation instituted modifications to prevent similar damage in the future. Even with the operation of Hoover Dam and the other dams up river, flood damage along the Colorado

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101. *Ibid.*,362-3; United States Department of the Interior, Bureau of Reclamation, *Safety of Existing Dame, Analysis Summary: Hoover Dam*, (June 3, 1992), Section A, SEED Analysis Summary, 2.

102. *Hoover Dam: Fifty Years*, 5-7; United States Department of the Interior, Bureau of Reclamation, *Federal Reclamation Projects: Water & Land Resource Accomplishments, 1970, Statistical Appendix*, 249; United States Department of the Interior, Bureau of Reclamation, *Summary Statistics. Land, Water and Related Data*, (1991), 101.

River had been great. But without Hoover, the damage would have been much greater.[103]

Even before it was completed, Hoover Dam was recognized as one of the greatest engineering feats of the modern era. In 1955, the American Society of Civil Engineers selected Hoover Dam as one of the seven modern civil engineering wonders of the United States. In 1985, the Society named the dam as a National Historic Civil Engineering Landmark. Also in 1985, in recognition if the dam's contribution to the history of the southwest, it was designated as a National Historic Landmark by the Department of Interior.[104]

For more than two decades after its completion, Hoover Dam stood as the tallest dam in the world. Today, more than twenty dams are higher, but all owe their existence to the advancements that were made during the design and construction of Hoover Dam. The unprecedented size of the dam led to studies in almost every aspect of dam construction including concrete composition and cooling, stress analysis, hydraulic design, and hydraulic and structural modeling. Even the form of the contracting organization was a new development that changed the face of the construction world. Too large for a single contractor, the project required the formation of a joint venture of six contractors, pooling their talents and resources and sharing the risks. This organizational structure became a model for future large construction projects.[105]

Settlement of Project Lands

The development of the Boulder Canyon Project helped provide a secure base for the settlement and development of the region along the Colorado River. By controlling the unpredictable flows of the river and securing a reliable water supply, many of the risks associated with settlement in the area were removed. One of the most obvious effects on the settlement of the area was the creation of Boulder City. The town, built as a temporary home for the thousands of workers who constructed the dam and powerplant, grew to become one of the largest cities in Nevada with a population of over 10,000 people. While many argue that the development of gambling provided the primary force behind the increased settlement in the area,

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103. *Building Hoover Dam: An Oral History of the Great Depression*, 303; *Hoover Dam: Fifty Years*, 7; *Hoover Dam: An American Adventure*, 264-5.
104. United States Department of the Interior, *Hoover Dam, Arizona/Nevada*, pamphlet, (May 1992).
105. *Development of Dam Engineering in the United States*, 26-9.

the benefits provided by Hoover Dam were certainly a factor in that development. In addition to the benefits to the immediate area, securing a reliable water source for the Colorado River Aqueduct and generating large amounts of power for southern California likely had an effect on development patterns in the Los Angeles Basin as well.

Although municipal and industrial users are the primary recipients of benefits from Hoover Dam, agricultural users receive significant benefits as well. In 1965, more than 25,000 agricultural users benefitted directly from the Boulder Canyon Project. When the indirect benefits provided to the Gila and Yuma Projects are added, the number rises to over 34,000 people. During that same period, more than 265,000 non-agricultural users received direct and in-direct benefits from Hoover Dam. In 1970, the number of municipal and industrial users increased to 316,000, while the number of agricultural users dropped to just under 28,000. In 1980, following combining of the Parker-Davis Project with Boulder Canyon, and the completion of the Southern Nevada Water Project, the total number of people benefiting from Hoover Dam rose to over 12,700,000. This dramatic increase was due to the inclusion of the population served with water from the Colorado River Aqueduct which receives water from the Parker-Davis Project. In that same period, agricultural users totaled over 29,000.[106]

In 1991, the total number of people benefiting both directly and indirectly from Hoover Dam and Lake Mead was over 15,800,000. Irrigation water supplied 7,539 farms totaling over 846,000 acres with a total crop value of more than $1,342,671,000. The total number of agricultural users benefiting from water secured by Hoover Dam during 1991 was over 25,000.[107]

Uses of Project Water

Hoover Dam and the Boulder Canyon Project helped pioneer development of multi-purpose water resource projects. In addition to controlling the unpredictable and often devastating floods of the Colorado River, the Project, acting in conjunction with the All-

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106. *Federal Reclamation Projects: Water & Land Resource Accomplishments, 1970, Statistical Appendix*, 235; United States Department of the4 Interior, Bureau of Reclamation, *Federal Reclamation Projects. Statistical Appendix to 1965 Crop Report and Related Data*, 198; United States Department of the Interior, Bureau of Reclamation, *1980 Annual Report. Appendix I: Crop and Related Data*, (U.S. Government Printing Office, 1981), 277-8.

107. *Summary Statistics, Water and Related Data*, 26-7, 36-7, 51, 54.

American Canal and the Parker-Davis Project, the Yuma, Yuma Auxiliary, and Gila Projects, the Central Arizona Project, and the Southern Nevada Water Project, provides irrigation benefits to over 1,500,000 acres of land in the southwest United States while also helping to meet the municipal and industrial needs of over 16,000,000 people. The low cost power generated by the seventeen power units at Hoover Dam provides enough energy each year to light over 500,000 homes. In addition to benefits to the people of the Southwest, the waters of Lake Mead support a variety of recreational uses and provides habitats to a large variety of fish and wildlife. The dam and lake also help to maintain water quality in the lower Colorado River.[108]

Conclusion

The goal of the designers and builders of Hoover Dam was simple:

To Convert a Natural Menace
Into a National Resource

They succeeded beyond their wildest dreams. The benefits provided by Hoover Dam and Lake Mead extend far beyond the arid regions of the American Southwest, touching almost all parts of the world. The lessons learned during the design and construction of the dam helped to ensure the success of large dam projects throughout the world; projects that have benefitted thousands of people who have never heard of Hoover Dam. Even though dwarfed by other dams, some over 1,000-feet high, Hoover Dam stands as one of the most successful projects of Reclamation and one of the greatest engineering achievements of the modern era.

About the Author

William Joe Simonds was born and raised in Colorado and has a clear understanding of the importance of water in the American West and its influence on the development of that region. He attended Colorado State University where he received a BA in History in 1992 and a Masters in Public History in 1995. He lives with his wife and two children in Fort Collins, Colorado.

108. *Hoover Dam, Arizona/Nevada*, pamphlet.

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