UNITED STATES DEPARTMENT OF THE INTERIOR

THE CONSTRUCTION OF HOOVER DAM

PRELIMINARY INVESTIGATIONS, DESIGN OF DAM, AND PROGRESS OF CONSTRUCTION

BY

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Secretary of the Interior

AND

ELWOOD MEAD
Commissioner of Reclamation

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ORGANIZATION

The Boulder Canyon project, of which the Hoover Dam is the principal feature, is being constructed by the Bureau of Reclamation, Department of the Interior, Ray Lyman Wilbur, Secretary. All activities of the bureau are under the general supervision of Elwood Mead, Commissioner, with headquarters at Washington, D. C. Engineering and construction are under the direction of Raymond F. Walter, Chief Engineer, with headquarters at Denver, Colo., and Walker R. Young, Construction Engineer, at Boulder City, Nev. The personnel of the various offices is as follows:

Secretary's office.—Ray Lyman Wilbur, Secretary; Joseph M. Dixon, First Assistant Secretary; John H. Edwards, Assistant Secretary; E. C. Finney, Solicitor; E. K. Burlew, Administrative Assistant to the Secretary; Northcutt Ely, Charles A. Dobbel, and William A. DuPuy, Executive Assistants.

Bureau of Reclamation, Washington office.—Elwood Mead, Commissioner; Porter W. Dent, Assistant Commissioner; Miss Mae A. Schnurr, Assistant to the Commissioner; George O. Sanford, Chief of the Engineering Division; Percy I. Taylor, Assistant Chief of the Engineering Division; George O. Sanford, Acting Director of Reclamation Economics (Dr. Hugh A. Brown, Director of Reclamation Economics, deceased), L. H. Mitchell, Assistant Director of Reclamation Economics; W. F. Kubach, Chief Accountant; H. R. Pasewalk, Assistant Chief Accountant; C. N. McCulloch, Chief Clerk.

At the Denver office, the assistants to the Chief Engineer are as follows: S. O. Harper, Assistant Chief Engineer; John L. Savage, Chief Designing Engineer; William H. Nalder, Assistant Chief Designing Engineer; E. B. Debler, Hydraulic Engineer; L. N. McClellan, Chief Electrical Engineer; C. M. Day, Mechanical Engineer; Byram W. Steele, Engineer on Dams; Ivan E. Houk, Research Engineer; Armand Offutt, District Counsel; L. R. Smith, Chief Clerk; A. McD. Brooks, Purchasing Agent.

The field office for the Hoover Dam and power plant construction is located at Boulder City, Nev., and is in charge of Walker R. Young, Construction Engineer. He is assisted by John C. Page, Office Engineer; Ralph Lowry, Field Engineer; Sims Ely, Boulder City Manager; Roy B. Williams, Assistant Field Engineer; Earle R. Mills, Chief Clerk; J. R. Alexander, District Counsel; and by R. J. Coffey, District Council at Los Angeles.

The Hoover Dam Consulting Board, acting in an advisory capacity on all matters pertaining to the project, comprises Louis C. Hill, David C. Henny, William F. Durand, and F. L. Ransome. Andrew J. Wiley, now deceased, was a member of the board up to October 8, 1931.

The Colorado River Board, appointed by Secretary Wilbur, with the approval of the President, under authority of the joint resolution approved May 29, 1928, to examine the proposed site of the dam to be constructed and review the plans and estimates made therefor, comprised Maj. Gen. William L. Sibert, Chairman; Charles P. Berkey, Daniel W. Mead, Warren J. Mead, and Robert Ridgway.

INTRODUCTION

In order to understand Hoover Dam one must understand the relation of the Colorado River to the settlement and economic development of seven States of the arid region. A quarter of a million square miles send their waters down this river. Eighty per cent of its flow comes from two States, Wyoming and Colorado. Here are the lofty snow-capped mountains which furnish the turbulent summer floods.

The lower part of the river flows through the hottest and dryest part of the United States. There are places where the annual rainfall is only three inches, where no rain falls in summer, and where the existence of civilized life depends on ability to use the water of this river in irrigation. Without irrigation the land bordering this river in Arizona and California is a hideous desert; with irrigation it provides pictures of agricultural opulence not surpassed in any part of the world.

Without regulation the river has little value. The quick run-off, the absence of summer rains, make any large irrigation development, any large power development, uncertain and unprofitable, and it can not be depended on for the water supply of cities. Regulation of floods by storage is therefore the basis of all safe and profitable development. That requires a reservoir large enough to even out the variations of flow between seasons, and also to regulate the variations in flow in different years. Such regulation is now imperative because 800,000 acres of irrigated land and homes of 100,000 people depend on diversions made near the boundary between the United States and Mexico, and because of the rapid extension of irrigation in the Imperial Valley in California and in southwestern Arizona. These have created a demand for water greater than the low water flow of the river. An increased supply of pure water is also needed to supply the growing population of the cities and towns of southern California and the orchards and gardens which surround them. These social and economic changes have led the Federal Government to undertake to make available the entire flow of the river by building a dam which in size and in its future influence on the well-being of a large part of the arid region, is the most important undertaking now being carried on by the United States Government.

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PART I : ENGINEERING INVESTIGATIONS

SEARCH FOR THE MOST SUITABLE SITE FOR A RESERVOIR TO REGULATE THE FLOW OF THE COLORADO

The United States Reclamation Bureau began its investigations of the Colorado River Basin in 1904. After a prolonged study of the upper part of the main valley and principal tributaries, the investigation shifted to the lower river. As a result, work was concentrated on dam sites in Boulder and Black Canyons. Approximately half a million dollars were expended between 1918 and 1924 in geological examinations and engineering studies of feasibility and cost of the Boulder Canyon project.

The upper section of the river includes the section above Glenns Ferry or practically the drainage area in the States of Wyoming, Utah, Colorado and New Mexico. The lower section includes the drainage area below Glenns Ferry, or roughly, the States of Nevada, Arizona, and California. The most suitable sites in the upper section were the Flaming Gorge on Green River, with a capacity of 4,000,000 acre-feet, the Juniper on Yampe River, with a capacity of 1,500,000 acre-feet, and the Dewey, on Grand River, with a capacity of 2,270,000 acre-feet. None of these reservoirs was large enough to serve as a regulator of the river's flow. They were too remote from the place where regulation was most needed, and the use of Flaming Gorge as a storage for irrigation would seriously interfere with its great value as a power site.

As a result of these upper investigations the choice narrowed down to the sites in Boulder and Black Canyons in the lower section of the river where it was possible to build a dam which would create a reservoir large enough to hold the entire flow of the river for two years, and being below the large tributaries it would permit of an effective regulation of floods. Either of these sites was near enough to the great power markets of southern California to make transmission feasible, and each was in the center of mineralized country in Arizona and Nevada, in which cheap power would be a great aid to development.

The sites in the upper section of the river had one advantage. During most of the year the water which would flow into these reservoirs is clear. The tributaries of Green River have flowed through morainal lakes in their channels for unnumbered centuries, with a reduction of only a small fraction of their capacity. The heavy load of silt carried by the river in the lower section makes it necessary to provide a large surplus capacity to care for this silt, but the seriousness of this is lessened by the fact that a number of storages for the development of power will inevitably be built in the stream above, and so will help to solve the silt problem.

Black Canyon was finally chosen by A. P. Davis, Director of the Reclamation Bureau, and this choice was approved by the following advisors to the Secretary of the Interior:

Hon. F. C. Emerson, Governor of Wyoming.
Prof. W. F. Durand, Stanford University.
Hon. J. G. Scrugham, Governor of Nevada.
Hon. James R. Garfield, former Secretary of the Interior.

Owing to the fact that the upper site in Boulder Canyon had been first approved, the name Boulder Canyon was retained in the legislative act, although the selection had been shifted to the Black Canyon site when this act was passed.

GEOLOGY OF DAM AND RESERVOIR SITES

Black Canyon, the site of the Hoover Dam, has a width of from 290 to 370 feet at low-water level, and from 850 to 970 feet at elevation 1,232, the crest of the dam The top of the canyon walls is approximately 1,500 elevation. The foundation is a volcanic breccia or tuff, originally an accumulation of fragments of many kinds derived from volcanic eruptions, and now transformed into a well-cemented, tough, durable mass of rock standing with remarkably steep walls and resisting the attack of weather and erosion exceedingly well. Material exposed from the upper end to a point about a quarter of a mile below the dam site is mainly andesitic tuff-breccia. Although the formation is somewhat jointed, the rock is well cemented, tough, durable, impervious, and an excellent material for tunneling, as well as for the foundation and abutments of a high dam. This has been confirmed in a very satisfactory manner by the experience in driving four 56-foot diameter tunnels, around the site and through the canyon walls, as it was not found necessary to use any timbering for roof support.

Extensive geological investigations were made of the dam and reservoir sites by F. L. Ransome, consulting geologist. He says that the "Dam Breccia" is excellent material upon which to construct the highest dam in the world, and that the faults in Black Canyon are of such character as to require very little attention in connection with engineering operations. These faults are exposed on the canyon walls near the dam site, but none of them show any evidence of recent movement. Undisturbed potholes, crossed by faults, exist on the Arizona side, about 900 feet above the river, thus indicating no movement along the faults during the period in which the river channel was lowered 900 feet by erosion.

The reservoir formed by the dam will be about 115 miles long, and the greater part of the storage will be obtained in valleys of the Virgin River and Las Vegas Wash on the Nevada side, and in the Detrital Valley on the Arizona side. The upper end of the reservoir is a narrow canyon. The major portion of the reservoir is a hilly basin of hard rock floored chiefly by gypsiferous silty beds of the Muddy Creek formation and to a less extent by coarser detrital deposits of the same or younger age. There is no evidence of the existence of any porous rock formations through which water might escape.

TECHNICAL DESIGN STUDIES

The dimensions of Hoover Dam and appurtenant works are of unusual magnitude, which present many unusual problems to be solved in design, construction, and operation. In applying previous theories and practices to the design and construction of a dam of such unprecedented dimensions, great caution must be exercised. Development of new theories and practices from fundamental data is necessary, and these must be checked, tested, and proved in every way, in order that no mistakes may be made in their development or application, and that maximum economy consistent with permanence and absolute safety may be secured. Accordingly the bureau has undertaken a program of research that will establish beyond question the suitability and sufficiency of the methods of design and construction to be adopted.

Hoover Dam will be of the massive concrete arch-gravity type, about 730 feet high above foundation rock, and having a thickness of 650 feet at the base. Water pressure on the upstream face at the base of the dam will be about 45,000 pounds per square foot, and the total pressure on the upstream face will be about three and a quarter million tons. This pressure will be transmitted to and supported by the rock of the canyon walls and of the foundation under the dam. With such conditions existing, the amount and distribution of stresses in the dam and also in abutments and foundation must be known with certainty. The dam must be so proportioned as to support these tremendous loads with maximum safety and economy, with no possibility of development of destructive stresses.

Technical design of the dam was largely a matter of mathematical analysis, supplemented by model testing, but many problems of a research nature were involved. A satisfactory method of analyzing stresses in massive arch dams was unknown, until a few years ago, when the Bureau of Reclamation engineers evolved the trial load method of analysis. In connection with the design of Hoover Dam, this method has recently been developed to a highly satisfactory working state, and its accuracy and dependability have been established by field observations and particularly by model tests.

Engineers of the bureau have analyzed and determined the effects of internal-temperature variation, twist, shear, Poisson's ratio, flow under stress, foundation and abutment deformation, uplift pressure at the base, uplift pressure in the pores of the concrete, earthquake shock, and spreading of canyon walls due to reservoir water pressure. They have determined the magnitude and distribution of stresses in all parts of foundation and abutments under all conditions of loading. Stress conditions caused by subcooling of the concrete during the hardening period, by pressure grouting of the construction joints, and by other load conditions to be encountered during construction have been investigated.

The program of arch-dam model testing that was started several years ago in cooperation with the Engineering Foundation Arch Dam Committee has been considerably extended in connection with design studies for the Hoover Dam. This testing program included the building, testing, and analyzing of a concrete model of the Stevenson Creek test dam, a concrete model of the Gibson Dam on the Sun River project, Montana, a plaster of Paris and celite model, and also a soft-rubber model of Hoover Dam.

The plaster and celite model of the dam and a portion of the canyon walls was used in studying the stress distribution and deformations of the dam under different conditions of reservoir loading. It was built at the University of Colorado, Boulder, Colo., in the spring of 1931 and on a scale of 1 inch equals 20 feet. The reservoir load was applied to the model by filling a rubber bag with mercury, the bag being braced against the upstream face of the model, so that the mercury pressure corresponded to the water pressure on the real dam. All deformations, except twisting, were measured with one-ten-thousandth inch measuring dials. Results of the model tests furnished very satisfactory confirmation of the trial-load stress analyses and the special-stress studies.

The technical design of the dam was based on three fundamental requirements: (1) That the dam should be of the massive arch-gravity type; (2) that the base of the dam should be located wholly within the area bounded by the two adjacent fault lines in the canyon rock; (3) that the maximum compressive stress in the dam should not exceed 30 tons per square foot.

Thirty-two different designs were made for study in selecting the final cross section and plan. These included all practicable variations in horizontal curvature, many different thicknesses of cross section at all elevations, and various slopes of upstream and downstream faces. Each design was analyzed under both empty and full conditions of reservoir loading.

In their studies and investigations the engineers of the Bureau of Reclamation had the assistance of Harold M. Westergaard and Dr. Frederick Vogt as consulting engineers. Mr. Westergaard, an expert mathematician, made special studies of a highly technical nature in connection with the mathematical treatment of arch-dam designs. Doctor Vogt assisted in conducting investigations and making tests on model arch dams, and assumed almost entire execution of tests of model arch dams made in the laboratory of the University of Colorado.

HYDRAULIC RESEARCH

The enormous volume of water that must be handled in the operation of Hoover Dam and appurtenant works, together with the high heads involved, presented extraordinary problems of design and construction.

SPILLWAYS

The design of the spillways, spillway channels, inclined shafts, diversion tunnels and outlet works structures involved important problems in hydraulic research, many of which could not be solved on the basis of existing hydraulic theory. Investigation by means of models was necessary. The importance of the hydraulic research problems is shown by the fact that if the spillways should ever discharge at full capacity the total energy involved would be eight times as great as that developed by Niagara Falls.

Because of the great height of the dam (730 feet), the location of the power plant at the upstream face of the dam, and the damage which might result should an abnormally large flood overtop the dam, it was necessary to provide spillways of ample capacity. Securing a discharge from side channel spillways sufficiently quiet to enter the inclined shafts without causing undesirable disturbances in flow was a serious problem. The solution of this problem was aided by means of models, the use of which was also helpful in determining the type of spillway.

The Colorado Agricultural College, Fort Collins, Colo., loaned its hydraulic laboratory to the Bureau of Reclamation for making tests on spillway models. Various shapes of spillways were investigated. The first to be studied was the glory-hole type, consisting of a vertical shaft with funnel-shaped top. Tests showed that this type was not as desirable as the side channel type. The first side channel spillway model had no gates and while it worked satisfactorily it would have been expensive to construct on account of the excessive length of channel requried. The second model of the same type was provided with a large Stoney gate at the upstream end for regulation of flow. Under tests of this model, the conditions of flow were not satisfactory. A model with gates on the crest, the adopted design, was next built and tested and was found to provide satisfactory flow conditions.

Tests on the small model of the adopted design were closely checked on a larger model constructed on a 1:20 scale on the Uncompahgre project at Montrose, Colo. Studies of the action of water as it will pass through the inclined shaft connecting the side channel with the diversion tunnel were also made by models, particular attention being given to the hydraulic conditions of flow at the vertical bend between the inclined shaft and the horizontal tunnel. A transparent celluloid pipe in which action of the water could be observed was used in these experiments.

EROSION OF TUNNEL LINING

The concrete lining in the spillway tunnels must withstand the flow of water at unprecedented velocities without excessive erosion. Under extreme flood conditions the maximum velocity will be approximately 175 feet per second. Consequently it was considered imperative that actual tests be made to determine the effects of high velocities of water under conditions that might exist in the tunnels. Tests were made on concrete specimens, usually 18 by 18 inches square and 6 inches thick. These specimens were cast in Denver and shipped to the Guernsey Dam, on the North Platte project in Nebraska-Wyoming, where they were tested at a small experimental plant erected for the purpose. The blocks were subjected to the action of a continuous stream of water from a 1-inch nozzle at velocities ranging from 100 to 175 feet per second, and inclined at various angles to the surfaces under test. The tests indicated that the tunnel lining will resist erosion under maximum discharge velocities, but emphasized the importance of good alinement and smooth surfaces.

OUTLET WORKS

The plan of using vertical intake towers located above the dam to control the flow of water to the power-plant turbines and needle-valve outlets necessitated the testing of a model of these towers to investigate hydraulic flow conditions and to determine the shape and proportions of openings to minimize losses of head. A model was constructed on a scale of 1:64, testing of which led to important improvements in the hydraulic design and established the fact that an extensive air-vent system, which had been included as a feature of design was unnecessary, thereby effecting a large saving in cost.

Outlet pipes and penstocks, unprecedented in size, will be constructed of welded plate steel, arranged in four similar systems and installed in concrete-lined tunnels. In each of the four systems the maximum discharge will be about 33,500 second-feet, which will mean a velocity of 47½ feet per second in the main header pipes. Under the most severe conditions as to water hammer the conduits will operate under internal water pressure of about 300 pounds per square inch. To determine the pressure rise due to water-hammer under these conditions required extensive original research.

A model of one of the outlet systems was built, and hydraulic losses and flow conditions were determined by means of pressure measurements. A transparent model of one branch connection was made and tested visually for flow conditions.

Discharges from the reservoir for uses other than development of electrical energy will be controlled by large balanced needle valves. Some valves discharge into the open from canyon-wall houses, while others discharge into the inner diversion tunnels. Valve discharge into tunnels effects a large economy in length of outlet pipes and provides a considerable portion of the outlet capacity, which can be operated without causing objectionable spray conditions adjacent to the power plant, where high-voltage conductors will be installed. Correct arrangement of these valves to avoid objectionable conditions from the standpoint of flow and erosion of concrete could only be determined by model testing. Models of valve settings and tunnels were therefore made and tested.

OUTLET PIPES AND PENSTOCKS

Many unusual problems were presented in designing the outlet pipe and penstock systems. There were no precedents for handling the quantities of water involved under such high pressures. The narrowness of Black Canyon precluded taking outlet pipes through the dam, and made it necessary to carry them in tunnels in the canyon walls. A tentative plan given first consideration was to carry the water in concrete-lined tunnels. After careful studies of the stresses that would be developed in the rock of the canyon walls it was concluded that this would not be safe construction. Other studies showed that it was not economically feasible to make the concrete-lined tunnels positively water-tight by steel reinforcement in the concrete, or by placing continuous welded-steel lining against the inner surface of the concrete lining. Accordingly, the plan of constructing welded plate-steel pipes in the tunnels with sufficient plate thickness to support the full hydrostatic pressures was adopted, thereby insuring full strength and water-tightness and providing space in the tunnels surrounding the pipes for inspection and maintenance.

CONCRETE INVESTIGATIONS

The engineers of the Bureau of Reclamation have the advice of a Concrete Research Board in solving numerous important concrete problems. Membership of the board is as follows: Dr. P. H. Bates, chief of cement division, Bureau of Standards, Washington, D. C., chairman; F. R. McMillan, director of research, Portland Cement Association, Chicago, Ill.; Prof. H. J. Gilkey, University of Colorado; Prof. Raymond E. Davis, University of California; and Prof. William K. Hatt, Purdue University.

Massive concrete in large dam construction where the dimensions of the structure are of the order of several hundred feet and where the aggregate varies from fine sand to 9-inch cobbles, presents problems hitherto unsolved in the science and art of concrete design. In ordinary concrete construction the maximum size of aggregate is about 1½ inches. The unprecedented magnitude of the Hoover Dam, with its 3,400,000 cubic yards of concrete, and the requirement for absolute safety and permanence in this monumental structure make the solution of these mass concrete problems more important than in any dam hitherto constructed.

Heat generation in concrete during the hardening period, which causes volume changes in the concrete, has constituted a major portion of the bureau's concrete research program. In a massive structure such as Hoover Dam, the control of volume changes is of utmost importance. The law of heat dissipation or cooling of masses is that the time required for cooling is proportional to the square of the dimensions. If Hoover Dam was built without control of the rate of placing and without special provision for cooling the concrete, the setting heat would probably not be dissipated for several hundred years, during which time destructive volume changes would take place, resulting in undesirable and possibly dangerous open joints or cracks in the mass.

These conditions caused the reclamation engineers to provide two new and special features in the design of the dam: First, circumferential construction joints in addition to the usual radial contraction joints, thereby dividing the mass into a series of approximately square columns or blocks; and, second, a complete artificial cooling system consisting of pipes embedded in the concrete through which cold water will be circulated. This cooling system will lower the temperature to normal and cause the resulting volume change to take place during the construction period, so that the joints between the columns, which will be opened as the concrete cools and contracts, may be filled with cement grout forced into place under pressure before the structure is placed in service. Extensive pioneer research was required in order to intelligently study and efficiently solve these problems.

All properties of cement, both chemical and physical, must be exhaustively studied in order that a type of cement with controlled and known heat evolution may be specified. The University of California at the Engineering Materials Laboratory at Berkeley, Calif., has assisted in researches into the properties of cement. The principal cement companies in southern California have also cooperated in this work. The Bureau of Standards has also investigated the properties of various brands of commercial Portland cement. Cement investigations have involved a study of approximately 100 different cements, and have included tests on more than 15,000 specimens. Studies have been made of the effect of chemical composition; fineness of grinding; and, to a limited extent, the effect of manufacturing processes upon heat generation, volume changes, strength and durability. At the Bureau of Reclamation cement laboratories in Denver, Colo., these studies have been supplemented by tests on mass concrete. Theoretical computations and laboratory tests have been supplemented by studies of the available records of heat development and volume changes in concrete dams previously built and by field tests on the concrete in the 405-foot Owyhee Dam in Oregon, completed by the bureau in July, 1932. These tests were started while the dam was under construction and are being continued throughout the cooling and pressure grouting periods. Concrete cores across contraction joints have been drilled in the interior of the Gibson Dam, on the Sun River project, Montana, from which the actual joint opening and efficiency of the pressure grouting could be determined. At the Owyhee Dam special instruments were developed and installed in the mass concrete to accurately measure the volume changes.

Many other important problems in concrete research have been solved in the two large and adequately equipped Bureau of Reclamation laboratories in Denver, with the assistance of the other cooperating agencies. At Denver, test specimens in great number, varying in size from 3 inches in diameter and 6 inches in length to 36 inches in diameter and 72 inches in length have been manufactured and tested. Among other equipment is a 4,000,000-pound hydraulic compression testing machine. At the contractor's concrete-mixing plant at the damsite the bureau has maintained a laboratory where tests have been carried on in connection with concrete lining of the diversion tunnels.

From the investigations carried on at the University of California, the most promising cements were selected for further and final tests at the Denver laboratories. The bureau engineers, with the advice and assistance of the Concrete Research Board, then wrote a set of specifications covering the requirements for construction of the Hoover Dam, power plant, and appurtenant works. The board in a report emphasizing the need for a new cement specification for the Hoover Dam work said:

> The unprecedented height of Hoover Dam, the rapidity of its construction, and the climatic conditions prevailing at the site of the work introduce problems of unusual character in design and construction. This is true particularly with respect to the generation of heat by hydration of the cement in the concrete mass. The expansion during the heating period subsequently changing to contraction during cooling has caused cracks in many concrete dams built during the last 20 years. It is of the utmost importance that cracking of concrete be avoided in the Hoover Dam and one of the principal means to that end is the use of a cement particularly suited to the requirements of the work. This fact necessitates the drafting of a cement specification more comprehensive and more restrictive in its provisions than is provided by existing standard specifications.

The specifications embrace two types of cement, one of low-heat properties (type A) and the other of moderate-heat properties (type B). The proportionate requirement for each type of cement is not definitely known, and determination of this division may be dependent on experience gained during the first year's construction operations. It is not anticipated that the requirement for type B cement will exceed 25 per cent of the total cement requirement (after July 1, 1933) of about 4,000,000 barrels, or that type B cement will be used in any appreciable amount, if at all, during the summer season. The contractors expect to begin placing mass concrete in the dam by July 1, 1933. Samples of cement obtained at the mills are tested and analyzed at one of the Bureau of Standards laboratories. The Bureau of Reclamation is constructing a cement-blending plant at Boulder City for blending cements of the same type but originating from different mills, and for combining cements of the two types in any desired proportions.

The Engineering News-Record in discussing the new cement specifications said:

> Above all, the Hoover Dam specification is welcome because it will bring a new and potent inspiration to the art and industry of cement making. There has long been crying need for such inspiration; art and industry alike have suffered from being centered all too much on production, too little on how cements might be made of broadest service to man. Especially in the present era of industrial stress can this inspiration exercise momentous influence by shaping thought and practice, by reorienting the industry, and by revitalizing the art of concrete making and use.

The tentative specifications have been sent to the following cement companies for their comments: Monolith Portland Cement Co., Los Angeles; Southwestern Portland Cement Co., Los Angeles; California Portland Cement Co., Los Angeles; Yosemite Portland Cement Corporation, San Francisco; Pacific Portland Cement Co., San Francisco; Santa Cruz Portland Cement Co., San Francisco; Calaveras Cement Co., San Francisco; Henry Cowell Lime & Cement Co., San Francisco; Utah-Idaho Cement Co., Ogden, Utah; Union Portland Cement Co., Denver; Idaho Portland Cement Co., Pocatello, Idaho.

The tentative specifications are as follows:

TENTATIVE SPECIFICATIONS FOR PORTLAND CEMENT FOR HOOVER DAM, POWER PLANT, AND APPURTENANT WORKS

Denver, Colo., November 2, 1932

GENERAL

1. **Purpose.**—These specifications cover the requirements for cement for construction of the Hoover Dam, power plant, and appurtenant works, or any part thereof.

2. **References.**—Those parts of Federal Specifications SS–C–191 for Portland cement, dated October 14, 1930, and Paper No. 21, Portland Cement Association Fellowship, on "Calculation of the Compounds in Portland Cement," referred to herein shall form a part of these specifications.

3. **Definition and types.**—Portland cement purchased under these specifications shall be the product obtained by finely pulverizing clinker produced from an intimate and properly proportioned mixture of materials selected to give the properties hereinafter specified, with no addition subsequent to calcination excepting water and/or uncalcined gypsum. Portland cement shall be of the following types, as specified:

(*A*) *Type A cement.*—Type A cement shall be a Portland cement of low heat evolution as fully defined in the detailed requirements included herein.

(*B*) *Type B cement.*—Type B cement shall be a Portland cement of moderate heat evolution, as fully defined in the detailed requirements included herein.

4. **Patents and/or copyrights.**—The contractor shall hold and save the Government, its officers, agents, servants, and employees, harmless from liability of any nature or kind, including costs and expenses, for or on account of any copyrighted or uncopyrighted composition, secret process, patented or unpatented invention, article, or appliance manufactured or used in the performance of this contract, including their use by the Government, unless otherwise specifically stipulated in this contract.

DETAIL REQUIREMENTS FOR TYPE A CEMENT

5. **Chemical composition.**—The following limits shall not be exceeded:

	Per cent
Loss on ignition	3.00
Insoluble residue	.50
Sulphuric anhydride (SO_3)	2.00
Magnesia (MgO)	4.00
Uncombined lime (CaO)	1.50

The ratio of the percentage of iron oxide to the percentage of aluminum oxide shall not exceed 1.5.

6. **Compound composition.**—The theoretical compound composition when computed according to the method described in paragraph 25 shall be within the following limits:

Dicalcium silicate ($2CaO \cdot SiO_2$)	Not over 60 per cent.
Tricalcium aluminate ($3CaO \cdot Al_2O_3$)	Not over 5 per cent.

NOTE.—Final specifications may include limits on tricalcium silicate and tetracalcium aluminoferrite of approximately 35 and 20 per cent, respectively.

7. **Fineness.**—The specific surface of the cement shall be not less than 1,300 nor more than 1,700 square centimeters per gram.

NOTE.—The above limits are roughly equivalent to finenesses of 87 and 97 per cent passing the No. 200-mesh sieve, respectively. The specific surface limits specified are based on determinations using the microneter apparatus of the Riverside Cement Co. of Riverside, Calif. The finenesses are not likely to be changed although the specified values may be altered to correspond with values obtained by the turbidimeter method described in paragraph 26. Plans have been made for the Bureau of Standards, the Bureau of Reclamation, and the University of California to determine independently the relation between experimental specific surface values obtained by the use of the turbidimeter and the microneter.

8. Soundness.—A pat of neat cement shall remain firm and hard and show no signs of distortion, cracking, checking, or disintegration in the steam test for soundness.

NOTE.—In the final specifications a neat cement and/or mortar bar, approximately 1 by 1 inch by 6 inches, for length measurements before and after exposure to the steam, may be substituted for the conventional neat cement pat.

9. Time of setting.—The cement shall not develop initial set in less than 1 hour and 45 minutes when the Gillmore needle is used. Final set shall be attained within 10 hours.

10. Compressive strength.—The average compressive strength in pounds per square inch of not less than 3 concrete cylinders (see par. 31 (A)) for each age of test, composed of 1 part of cement and 5.2 parts by weight of Hoover Dam aggregate graded to ¾-inch maximum size as hereinafter specified shall be equal to or higher than the following:

Age at test (days)	Storage of specimens	Compressive strength (Lbs./in.^{2})
7	1 day in moist air, 6 days in water or fog	1,000
28	1 day in moist air, 27 days in water or fog	2,000

The average compressive strength at 28 days shall be at least 50 per cent higher than the strength at 7 days.

11. Heat of hydration.—The cumulative heat of hydration as determined by the heat of solution method (see par. 32) shall not exceed the following:

Age (days)	Heat of hydration
7	60 calories per gram.
28	70 calories per gram.

12. Temperature of cement.—The temperature of the cement at time of delivery shall not exceed 135° F. during the months of May to September, inclusive.

DETAIL REQUIREMENTS FOR TYPE B CEMENT

13. Chemical composition.—The following limits shall not be exceeded:

	Per cent
Loss on ignition	3.00
Insoluble residue	.50
Sulphuric anhydride (SO_3)	2.00
Magnesia (MgO)	4.00
Uncombined lime (CaO)	1.50

The ratio of the percentage of iron oxide to the percentage of aluminum oxide shall not exceed 1.5.

14. Compound composition.—The theoretical compound composition when computed according to the method described in paragraph 25 shall be within the following limits:

Tricalcium silicate ($3CaO \cdot SiO_2$)	Not over 60 per cent
Tricalcium aluminate ($3CaO \cdot Al_2O_3$)	Not over 8 per cent

15. **Fineness.**—The specific surface of the cement shall be not less than 1,200 nor more than 1,600 square centimeters per gram.

NOTE.—The above limits are roughly equivalent to finenesses of 85 and 95 per cent passing the No. 200-mesh sieve, respectively. See also note attached to paragraph 7.

16. **Soundness.**—A pat of neat cement shall remain firm and hard and show no signs of distortion, cracking, checking, or disintregation in the steam test for soundness.

NOTE.—See note attached to paragraph 8.

17. **Time of setting.**—The cement shall not develop initial set in less than 1 hour and 45 minutes when the Gillmore needle is used. Final set shall be attained within 10 hours.

18. **Compressive strength.**—The average compressive strength in pounds per square inch of not less than 3 concrete cylinders (see par. 31 (A)) for each age of test, composed of 1 part of cement and 5.2 parts by weight of Hoover Dam aggregate graded to ¾-inch maximum size a hereinafter specified shall be equal to or higher than the following:

Age at test (days)	Storage of specimens	Compressive strength (lbs./in.²)
7	1 day in moist air, 6 days in water or fog	2,000
28	1 day in moist air, 27 days in water or fog	3,000

The average compressive strength at 28 days shall be higher than the strength at 7 days.

19. **Heat of hydration.**—The cumulative heat of hydration as determined by the heat of solution method (see par. 32) shall be greater than 70 calories per gram at 7 days and less than 100 calories per gram at 28 days.

SAMPLING AND INSPECTION

20. **Test samples.**—Samples for testing in accordance with the methods hereinafter prescribed may be individual or composite samples. Each test sample shall weigh at least 5 pounds. Every facility shall be provided the Government for careful sampling and inspection at the mill. At least 14 days from the time of sampling shall be allowed for completion of all 7-day tests and at least 35 days shall be allowed for the completion of all 28-day tests.

(*A*) *Bulk cement.*—Samples of bulk cement shall be taken at the mill and one test sample shall represent each 400 barrels unless otherwise specified by the contracting officer.

(*B*) *Sacked cement.*—Samples of sacked cement shall be taken at the mill or from cars. If sampled at the mill, one composite test sample shall be taken to represent not more than 200 barrels unless otherwise specified by the contracting officer. If sampled in cars, one sample shall be taken from 1 sack in each 40 sacks (or 1 barrel in each 10 barrels) and combined to form one test sample to represent 50 barrels.

21. **Method of sampling at the mill.**—Unless otherwise specified by the contracting officer, the sampling of cement at the mill shall be from the conveyor delivering to the bin. Samples may be secured by taking the entire test sample at a single operation, known as the "grab method," or by combining several portions taken at regular intervals, known as the "composite method." The sampling shall be done by or under the direction of a responsible representative of the Government.

22. **Treatment of sample.**—Samples shall be shipped and stored in moisture-proof, airtight containers.

23. **Storage.**—The cement shall be stored in sealed weather-tight bins which will suitably protect the cement from dampness.

24. Rejection.—Cement will be rejected if it fails to meet any of the requirements of these specifications. Cement remaining in storage prior to shipment for a period greater than six months after test shall be retested. Cement failing to meet the test for soundness in steam may be accepted if it passes a retest using the original sample at any time within 28 days thereafter. The provisional acceptance of the cement at the mill shall not deprive the Government of the right of rejection on a retest of soundness and time of setting at the time of delivery of cement to the Government at destination.

TESTS

25. Chemical analysis and compound composition.—The method of chemical analysis shall be as specified below. The method of compound computation from the chemical analysis shall be the method outlined by Bogue in Paper No. 21, Portland Cement Association Fellowship, on "Calculation of the Compounds in Portland Cement." Compound percentages shall be computed to the nearest one-tenth of 1 per cent and reported to the nearest 1 per cent.

(*A*) *Loss on ignition.*—One gram of cement shall be heated in a weighed covered platinum crucible, of 20 to 25 c c capacity, as follows, using either method (1) or (2) as specified:

Method (*1*).—The crucible shall be placed in a hole in an asbestos board, clamped horizontally so that about three-fifths of the crucible projects below, and blasted at a full red heat for 15 minutes with an inclined flame; the loss in weight shall be checked by a second blasting for 5 minutes. Care shall be taken to wipe off particles of asbestos that may adhere to the crucible when withdrawn from the hole in the board. Greater neatness and shortening of the time of heating are secured by making a hole to fit the crucible in a circular disk of sheet platinum and placing this disk over a somewhat larger hole in an asbestos board.

Method (*2*).—The crucible shall be placed in a muffle at any temperature between 900° and 1,000° C. for 15 minutes and the loss in weight shall be checked by a second heating for 5 minutes.

(*B*) *Insoluble residue.*—To a 1-g sample of cement shall be added 25 c c of water and 5 c c of concentrated hydrochloric acid (specific gravity 1.19). Material shall be ground with the flattened end of a glass rod until it is evident that the decomposition of the cement is complete. The solution shall then be diluted to 50 c c and digested on a steam bath for 15 minutes. The residue shall be filtered, washed with cold water, and the filter paper and contents digested in about 30 c c of a 5 per cent solution of sodium carbonate, the liquid being held at a temperature just short of boiling for 15 minutes. The remaining residue shall be filtered, washed with hot water, then with a few drops of hot hydrochloric acid (1:9), and finally with hot water, then ignited at a red heat and weighed as the insoluble residue.

(*C*) *Sulphuric anhydride.*—To a 1-g sample of cement shall be added 25 c c of water and 5 c c of concentrated hydrochloric acid (specific gravity 1.19). Material shall be ground with the flattened end of a glass rod until it is evident that decomposition of the cement is complete. The solution shall be diluted to 50 c c and digested on a steam bath for 15 minutes, filtered, and the residue washed thoroughly with hot water. The solution shall be diluted to 250 c c, heated to boiling, and 10 c c of a hot 10 per cent solution of barium chloride shall be added slowly, drop by drop from a pipette and the boiling continued until the precipitate is well formed. The solution shall then be digested on the steam bath at least three hours, preferably overnight. The precipitate shall be filtered, washed, and the paper and contents placed in a weighed platinum crucible and the paper slowly charred and consumed without flaming. The barium sulphate shall then be ignited and weighed. The weight obtained multiplied by 34.3 gives the percentage of sulphuric anhydride. The acid filtrate obtained in the determination of the insoluble residue may be used for the estimation of sulphuric anhydride instead of using a separate sample.

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(*D*) *Uncombined lime.*—One gram of the cement shall be ground to an impalpable powder and transferred to a 200 c c Erlenmeyer flask, which has previously been dried in an electric oven to remove all traces of moisture. To this shall be added 60 c c of standard alcoholic glycerin solution, and 1 gram of anhydrous barium chloride which as been dried in the electric oven at 800° C. Shake the materials well in order to disperse the cement in the solution. Insert a water or air reflux condenser in the neck of the flask and boil the mixture on the hot plate. Titrate the solution with standard 0.2N alcoholic solution of ammonium acetate at 20 to 30 minute intervals until there is no further color change. After the end point has been reached, the flask and contents shall be subjected to a further boiling until no perceptible color change is noticed after 1 hour's continued boiling. The percentage of uncombined lime shall then be calculated by multiplying the number of c c of standard ammonium acetate solution used by the calcium oxide titer times 100. The standard solutions shall be prepared as follows:

(1) *Glycerol alcohol solution.*—Prepare a solution consisting of 1 part by volume of U. S. P. glycerol and 5 parts by volume of absolute ethyl alcohol or anhydrous alcohol denatured in accordance with formula 3–a or formula 2b of the Bureau of Internal Revenue. To each liter of this solution add 2 c c of an indicator prepared by dissolving 1 gram of phenolthalein in 100 c c of absolute alcohol.

NOTE.—It is essential that the glycerol-alcohol solution be neutral to the indicator. If the solution is colorless, add a dilute alcoholic solution of sodium or potassium hydroxide until the pink color appears, and just remove this by a drop of an alcoholic solution of ammonium acetate. If the initial color is pink, just remove by the alcoholic solution of ammonium acetate.

(2) *Approximately 0.2N alcoholic solution of ammonium acetate.*—Dissolve 16 g of crystalline ammonium acetate in 1 liter of absolute ethyl alcohol or anhydrous alcohol denatured by formula 3–a or formula 2–b. Standardize this solution by titrating against pure calcium oxide which has been freshly prepared by calcining pure calcite or calcium oxalate in a platinum crucible at 900° to 1,000° C. to constant weight.

(*E*) *Silica.*—Five-tenths grams of the finely powdered cement shall be transferred to an evaporating dish, preferably of platinum for the sake of celerity in evaporation, moistened with enough water to prevent lumping, and 5 to 10 c c of strong hydrochloric acid added and digested with the aid of gentle heat and agitation until solution is complete. Solution may be aided by light pressure with the flattened end of a glass rod. The solution shall then be evaporated to dryness, or as far as this may be possible on the bath. The residue without further heating shall be treated at first with 5 to 10 c c of strong HCl which is then diluted to half strength or less, or upon the residue may be poured at once a larger volume of acid of half strength. The dish shall then be covered and digestion allowed to go on for 10 minutes on the bath, after which the solution shall be filtered and the separated silica washed thoroughly with water. The filtrate shall again be evaporated to dryness, the residue being baked in an oven one hour at a temperature of about 110° C. or less. The residue shall then be taken up with 10 to 15 c c of dilute hydrochloric acid (1:1) heated on the hot plate and the small amount of silica it contains shall be separated on another filter paper. The papers containing the residues shall be transfererd to a weighed platinum crucible, dried, ignited first over a Bunsen burner until the carbon of the filter paper is completely consumed without flaming, and finally over a blast burner or in an electric oven at 900° to 1,000° C. until constant weight. The silica thus obtained will contain small amounts of impurities. It shall then be treated in the crucible with about 10 c c of hydrofluoric acid and 4 drops of sulphuric acid and evaporated over a low flame to complete dryness. The small residue shall be finally blasted for a minute or two, cooled and weighed. The difference between this weight and the weight previously obtained gives the amount of silica. Washing of the silica precipitates can be made more effective by using a hot solutiou of dilute hydrochloric acid (1:99), and then completing the washing with hot water. The weighed residue remaining after volatilization of the silica shall be taken up with dilute hydrochloric acid and added to the filtrate from the silica precipitation or may be considered as combined aluminum and ferric oxides and added to the result obtained from that determination.

(*F*) *Ferric oxide and alumina.*—The filtrate, about 250 c c from the second evaporation for SiO_2 after adding hydrochloric acid if necessary to insure a total of 10 to 15 c c of strong acid and a few drops of methyl red indicator, shall be treated with NH_4OH, drop by drop, until one drop changes the color of the solution to a distinct yellow. The solution containing the precipitated iron and aluminum hydrates shall be brought to a boil, washed once by decantation and slightly on the filter. Setting aside the filtrate, the precipitates and filter paper shall be transferred to the same beaker in which the first precipitate was effected. The iron and aluminum hydrates shall then be dissolved in hot dilute hydrochloric acid, the solution made up to about 100 c c, and the hydrates reprecipitated as in the first case. The precipitates shall then be washed with two 10 c c portions of a hot 2 per cent solution of ammonium chloride, placed in a weighed platinum crucible, slowly heated by a Bunsen burner until the papers are charred, and finally ignited for five minutes with care to prevent reduction, and weighed as $Al_2O_3 + Fe_2O_3$.

(*G*) *Ferric oxide.*—The combined ferric and aluminum oxides shall be fused in a platinum crucible at a very low temperature with about 3 or 4 g of potassium bisulphate, until all the oxides are dissolved. The melt shall be allowed to cool, and taken up with so much dilute sulfuric acid, that there shall be no less than 5 g absolute acid and enough water to effect solution on heating. The solution shall then be evaporated and eventually heated until acid fumes come off copiously. After cooling and redissolving in water the small amount of silica that may separate shall be filtered out and corrected by hydrofluoric acid and sulfuric acid. The filtrate shall then be reduced by zinc, using either a gas bottle or a reductor, and titrated with permanganate. The strength of the permanganate solution shall not be greater than 0.0040 g of ferric oxide.

NOTE.—For analytical purposes any small amounts of manganese shall be calculated as manganese oxide and added to the percentage of alumina, whereas titanium shall be considered as ferric oxide. Sodium oxalate shall be used in the standardization of all permanganate solutions. The small percentage of SiO_2 which may separate from solution after the bisulphate fusion shall be added to the percentage of silica and reported as such, after purification with hydrofluoric acid.

(*H*) *Calcium oxide.*—To the combined filtrates from the alumina and ferric oxide precipitation shall be added a few drops of NH_4OH and the solution brought to boiling. To the boiling solution shall be added 25 c c of a saturated solution of ammonium oxalate, the boiling being continued until the precipitated calcium oxalate assumes a well-defined granular form. It shall then be allowed to stand for 20 minutes or until the precipitate has settled, filtered, and washed with hot water. The filter paper containing the precipitate shall then be placed wet in a platinum crucible and the paper burned off over the small flame of a Bunsen burner. The precipitate shall then be ignited, redissolved in HCl and the solution made up to 100 c c with water. Ammonia shall be added in slight excess and the solution brought to a boil. If a small amount of alumina separates at this point it shall be filtered out, weighed, and the amount added to that found in the original alumina determination. The lime shall then be reprecipitated by ammonium oxalate, allowed to stand until settled, filtered, washed, care being taken to avoid an excess of water, and finally weighed as the oxide after ignition and blasting to constant weight in a weighed, covered platinum crucible.

(*I*) *Magnesia.*—The combined filtrates from the calcium precipitation shall be acidified with HCl and concentrated to about 150 c c. To this solution shall be added about 10 c c of diammonium phosphate solution (25 g of the salt per 100 c c of water) and the solution boiled for several minutes. The solution shall then be cooled by placing in a beaker of ice water. After cooling, NH_4OH shall be added drop by drop with constant stirring until the crystalline ammonium-magnesium orthophosphate begins to form, and then in moderate excess (5 to 10 per cent of the volume of the solution), the stirring being continued for several minutes. It shall then be set aside for several hours in a cool atmosphere and filtered. The precipitate thus obtained shall be redissolved in hot dilute HCl, the solution made up to about 100 c c, 1 c c of the solution of diammonium phosphate added, and ammonia drop by drop, with constant stirring until the precipitate is again formed as described and the ammonia in moderate excess. It shall then be allowed to stand for about two hours, filtered, and washed with two 10 c c portions of wash solution (200 c c concentrated ammonium hydroxide; 100 g ammonium nitrate; 800 c c water), placed in a weighed platinum crucible, the paper slowly charred, and the resulting carbon carefully burned off. The precipitate shall then be ignited at a temperature between 1,100° and 1,200° C. to constant weight, care being taken to avoid bringing the pyrophosphate to a melt. The weight of magnesium pyrophosphate obtained multiplied by 72.5 gives the percentage of magnesia.

26. Fineness.—Fineness as represented by specific surface shall be measured by means of a type of apparatus which is essentially a turbidimeter and consists of a source of light of constant intensity which passes through a suspension of the cement to be tested, into a sensitive photo-electric cell. The current generated in the cell is measured with a microammeter and the indicated reading is a measure of the turbidity of the suspension. General considerations indicate that turbidity is a measure of the surface area of a suspension, and that change in turbidity due to settling of the suspended material is a measure of the distribution of that surface area.

(*A*) *Apparatus.*—The apparatus consists, more specifically, of the following parts:

(1) *Source of light.*—The source of light shall be a 3-candlepower electric lamp operated by a 6-volt storage battery in connection with a parabolic reflector which shall be mounted behind the lamp and focused in such a manner as to permit a beam of approximately parallel light to pass through the windows of the settling tank. The light intensity shall be regulated by means of two rheostats, mounted in parallel, of 6 and 30 ohms resistance, respectively.

(2) *Water cell.*—The light shall pass through a water cell before entering the windows of the settling tank, in order that heat rays may be absorbed. The cell shall be so arranged that all beams of light from the source shall pass through it before entering the settling tank. The dimensions of the cell shall be approximately 4 by 4 inches by 2¾ inches high, and shall be made of glass or contain glass panes to permit the transmission of light.

(3) *Settling tank.*—The settling tank shall be of noncorroding metallic material rectangular in form, and shall be of the following approximate dimensions: Length of base, 2 inches; width of base, 2 inches; height, 18 inches. The tank shall be fitted with windows at two levels or depths from the top, these levels being 1 inch and 14 inches, respectively. The windows, approximately 2 inches high and 1¾ inches wide, shall be rectangular and shall be cemented to the metallic surface of the tank by means of some suitable material as sealing wax. The windows shall be so arranged as to permit a beam of parallel light to pass completely through the suspension or clear liquid in the tank and into the photo-electric cell.

(4) *Photo-electric cell.*—The means for measuring the light intensity shall be a sensitive photo-electric cell (Weston Photronic) which shall be connected directly to a microammeter of 0–50 microamperes range. The internal resistance of the microammeter shall not be over 100 ohms.

(5) *Mounting.*—The source of light, water cell, and photo-electric cell shall be so mounted on a movable shelf, which rests on brackets, to bring it in position of the windows at the top or lower levels of the settling tank as desired.

(*B*) *Test procedure.*—One gram of the cement after passing a standard 325-mesh sieve shall be placed in a test tube with about 10 ml of kerosene and 5 drops of oleic acid. (Oleic acid is added since it is a suitable dispersing agent and has slight or no effect on the viscosity of the suspending medium.) The mixture shall then be stirred for one minute with a rotating brush attached to a stirring motor, and shall then be boiled for one or two minutes, cooled and restirred for another minute. The mixture shall then be transferred to the settling tank, the brush and tube being thoroughly washed with clear kerosene, which is also added to the suspension, and the tank filled to the required depth with clear kerosene. The tank shall then be vigorously shaken for two minutes and placed in the proper postion in the path of the light beam. A timing clock shall be started at the instant shaking of the settling tank is topped and microammeter readings shall be taken alternately at the upper and lower windows at half-minute intervals. The readings taken at the lower level give the turbidity values for the larger size particles and in consequence the first turbidity reading taken at the lower level gives an indication of the total surface of the sample. The specific surface of the sample finer than about 75 microns shall be obtained from this first lower reading, taken after the elapse of a definite time interval approximating 1½ minutes. The theoretical relation is expressed by—

$$S = C \log I_o/I_d$$

in which

S = specific surface.

C = constant of transmittancy.

I_o = intensity of light transmitted through clear kerosene, microamperes.

I_d = intensity of light transmitted through suspension, microamperes.

(*C*) *Derivation of transmittancy constant "C."*—The transmittancy constant "*C*" varies with each cement. For cements produced at a single plant, however, it is probable that "*C*" will not vary greatly unless the fineness varies greatly. Therefore, for such a product it will only be necessary to establish the constant once, or only occasionally.

The determination of the transmittancy constant requires the calculation of the average particle diameter in microns and the corresponding log of the ratio of the light intensity at these points. The determination shall be carried out in the following manner. The equation that represents the evaluation is—

$$C = \frac{W}{0.0000525 \times \sum d \, \Delta \log I_o/I_d}$$

in which

C = constant of transmittancy.

W = weight of suspended sample.

0.0000525 = a constant.

$\sum d \Delta \log I_o/I_d$ = summation of the products of the mean diameters of corresponding particles in microns times the corresponding increments with respect to log I_o/I_d referring to relative light intensity.

W shall be determined as percentage passing a No. 325 sieve of the sample of cement to be tested and is equivalent to approximately 75 microns separation, the limiting value of the analysis. This value W shall be expressed as parts by weight of a 1-gram sample and shall be obtained by sieving several samples of the cement to be tested to the end point using a certified No. 325-mesh sieve to check results within ±0.5 per cent.

The value $\Sigma d \Delta \log I_o/I_d$, termed the value of the summation, shall be obtained by following the method for obtaining specific surface area as above mentioned and continuing by taking alternate readings at the high and low levels at ½ minute intervals for a period of 10 minutes, meanwhile recording all data. The summation value shall then be obtained by taking the differences or increments between values of log I_o/I_d at succeeding time intervals and multiplying them by the corresponding average particle size in microns for that particular range of particle distribution. The sum of these cumulative products taken during a 10-minute interval at both upper and lower windows is the value of the summation.

The value d in this calculation is obtained from the following equation:

$$t=\frac{3lu\times 10^7}{(P_1-P_2)gd^2}$$

in which

t = time of settling in minutes.
d = diameter of particle in microns.
l = depth of suspension to level of light, in cm.
u = viscosity of suspending medium in poises.
P_1 = density of cement.
P_2 = density of suspending medium.
g = gravity constant of acceleration, in cm/sec.^{2}.

The value for density of cement P_1 shall be taken as 3.15.

27. Mixing cement paste and concrete.—The method for mixing cement paste shall be carried out as described in section F-3c of Federal Specifications SS-C-191 for Portland cement. The method of mixing concrete for the 3 by 6 inch cylinders shall be carried out as hereinafter described in paragraph 31 of these specifications.

28. Normal consistency.—The method for determining normal consistency shall be carried out as described in section F-3d of Federal Specifications SS-C-191 for Portland cement.

29. Soundness.—The method for the determination of soundness shall be carried out as described in section F-3e of Federal Specifications SS-C-191 for Portland cement.

NOTE.—See note attached to paragraph 8.

30. Time of setting.—The method for the determination of the time of setting shall be carried out as described in section F-3f of Federal Specifications SS-C-191 for Portland cement.

31. Compression tests.—The procedure for making compression tests of concrete shall be essentially as follows:

(*A*) *Form of test piece.*—The test piece shall be cylindrical, 3 inches in diameter and 6 inches in height.

(*B*) *Aggregate.*—The aggregate used shall be Hoover Dam aggregate obtained from the Arizona gravel deposit near the dam site. (A supply of this aggregate, separated into the standard sieve sizes, will be furnished on request and without charge to prospective bidders under these specifications.)

(*C*) *Proportioning and mixing.*—The concrete shall consist of 1 part by weight of cement, 5.2 parts by weight of aggregate, and sufficient water (estimated average W/C = 0.55 by weight) to produce a fixed consistency as hereinafter specified. A batch of concrete made with 4 pounds of cement and 20.8 pounds of aggregate is slightly more than sufficient for making the consistency determination and casting six test cylinders. Aggregate of the proper gradation shall be obtained for each concrete batch by weighing out and recombining the separated aggregate in the following proportions:

Retained on—	Percentage of total	Batch weight in pounds
¾ inch	0	0
⅜ inch	31.0	6.4
No. 4	22.0	4.6
No. 8	8.0	1.7
No. 14	5.0	1.0
No. 28	7.0	1.5
No. 48	20.0	4.2
No. 100	6.0	1.2
Pan	1.0	.2
Total	100.0	20.8

Materials shall be brought to room temperature (18° to 24° C., 65° to 75° F.), before beginning the tests and the aggregate shall be in a room-dry condition. The concrete shall be mixed by hand in a premoistened shallow metal pan (approximately 20 by 20 by 3 inches) with a 10-inch bricklayer's trowel which has been blunted by cutting off about 2½ inches of the point. The cement and aggregate shall first be mixed dry until the mixture is uniform in color, and a crater formed in the center, into which a known quantity of clean water slightly less than the total estimated requirement shall be poured. After allowing 30 seconds for partial absorption of the water, the material on the outer edge shall be turned into the crater and the whole continuously mixed for 2½ minutes, additional water of known amount being added during the mixing process as may be found necessary to produce concrete of the required consistency. The concrete shall be of the proper consistency when the slump, as measured and hereinafter defined, is 3 inches, plus or minus ½ inch. If the consistency of the concrete is found by test to be outside the limits specified, the concrete shall be discarded and a new batch made.

(*D*) *Consistency and quantity of mixing water.*—The concrete to be tested for consistency shall be formed in a mold of No. 16 gage galvanized metal in the form of the lateral surface of the frustrum of a cone with the base 7 inches in diameter, the upper surface 3½ inches in diameter, and the altitude 10½ inches. The base and the top shall be open and parallel to each other and at right angles to the axis of the cone. The mold shall be provided with foot pieces and handles.

The mold shall be placed on a flat, stationary, nonabsorbent surface and the operator shall hold the form firmly in place, while it is being filled, by standing on the foot pieces. The mold shall be filled to about one-third of its height with the concrete which shall then be puddled, using 25 strokes of a ½-inch steel rod, 20 inches long, bullet-pointed at the lower end. The filling shall be completed in successive layers similar to the first and the top struck off so that the mold is exactly filled. The mold shall then be removed by being raised vertically, with a slow steady motion, immediately after being filled. The molded concrete shall then be allowed to subside until quiescent and the mean height of the specimen measured.

The consistency shall be recorded in terms of inches of subsidence of the specimen during the test, which shall be known as the slump.

The quantity of mixing water used shall be expressed in terms of the water-cement ratio by weight.

(*E*) *Fabrication.*—The cylinder molds shall be of metal and shall be tight to prevent the escape of mixing water during molding. Each mold shall be oiled with a heavy mineral oil before using and placed on an oiled plate glass or machined metal base plate.

The test specimens shall be molded by placing the fresh concrete in the mold in two approximately equal layers and rodding each layer with 25 strokes of the ½-inch rod previously specified. After the top layer has been rodded, the surface of the concrete shall be struck off with a trowel and covered with plate glass or a machined metal plate.

In order that the cylinder may present a smooth plane end for testing, the test specimens shall be capped with a thin layer of stiff neat-cement paste or sulphur compound. If a neat-cement cap is used, it shall be placed two to four hours after molding the specimens and shall be formed by means of a piece of plate glass or a machined metal plate. The plate shall be worked on the cement paste until the plate rests on top of the mold. The cement for capping should be mixed to a stiff paste two to four hours before it is used in order to avoid the tendency of the cap to shrink. If a sulphur cap is used, it shall be placed just prior to making the compression test. The sulphur cap shall be formed by placing a narrow strip of paper and rubber band around the specimen so that the paper extends slightly above the top, pouring the molten compound on top of the specimen, and pressing a warm, machined metal plate on top of the compound while the cap is cooling. The sulphur compound shall consist of a mixture of about 3 parts powdered commercial sulphur and 1 part fire clay or equally suitable diluting material.

(*F*) *Curing.*—Immediately after molding, or molding and capping, test specimens shall be stored for 20 to 24 hours in a fog curing room at a temperature of 70° F. (± 2.5° F.) or in a moist closet maintained at a temperature of 70° F. (± 2.5° F.) and a relative humidity of 95 per cent (± 5 per cent). The specimens, stripped of molds, shall thereafter be stored in fog or in clean water at 70° F. (± 2.5° F.) until time of test.

(*G*) *Testing.*—Compression tests shall be made at the age of 7 and 28 days, with the specimens in a moist condition.

The metal bearing plates of the testing machine shall be placed in contact with the ends of the test specimen. An adjustable bearing block shall be used to transmit the load to the test specimen. The diameter of the bearing block shall be the same or slightly larger than that of the test specimen. The upper or lower section of the bearing block shall be kept in motion as the head of the testing machine is brought to a bearing on the test specimen. The load shall be applied uniformly and without shock. The moving head of the testing machine should travel at the rate of about 0.05 inch per minute when the machine is running idle.

The total load indicated by the testing machine at failure of the test specimen shall be recorded and the unit compressive strength calculated in pounds per square inch, using the area computed from the average diameter of the cylinder.

32. Heat of hydration.—The heat of hydration of type A and type B cement shall be determined as follows:

(*A*) *Determination.*—Three hundred grams of the dry cement sample shall be placed in a container and sealed until test. Three hundred grams of cement and 120 grams of distilled water shall be mixed together at a temperature of 70° F., vigorously stirred with a mechanical stirrer for five minutes and placed in four [1] or more containers in approximately equal amounts. The containers shall be sealed immediately, stored at 70° F. (± 1° F.) for one day, then stored at 100° F. (± 1° F.) until test. At each of the ages of 7 and 28 days, the heat of solution of one specimen of the partially hydrated cement in a given acid mixture shall be determined. One determination of the heat of solution of the dry cement in an identical acid mixture shall also be made not later than the date of the 28-day test on hydrated cement. The heat of hydration at the age of 7 days shall be determined by subtracting the heat of solution of the specimen of cement, which has hydrated for 7 days, from the heat of solution of the specimen of dry cement. Similarly, the heat of hydration at the age of 28 days shall be determined by subtracting the heat of solution of the specimen of cement which has hydrated for 28 days from the heat of solution of the specimens of dry cement.

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[1] This number provides for two companion specimens, over and above normal requirements, to allow for rechecking, breakage, etc.

The heat of solution of a cement sample, either dry or partially hydrated, shall be determined by dissolving a known weight of the cement in a dilute nitric-and-hydrofluoric-acid mixture and by observing the resultant temperature rise. Sufficient data shall be obtained to make corrections to the observed temperature rise for all loss or gain in heat due to other causes than heat of solution. From the corrected temperature rise and other necessary data, the heat of solution of the sample in calories per gram of dry, unignited cement shall be computed. The entire testing procedure shall be conducted with such accuracy that two determinations of heat of solution upon companion specimens will each check the other within 3 calories per gram of cement.

(*B*) *Heat of solution test on dry cement sample.*—The equipment to be employed in the heat of solution test shall consist of the following:

(1) A cylindrical copper vessel of not less than 1,200 milliliters' capacity, lined with pure gold, and chromium plated and polished on the outside. This vessel is herein designated as the inner vessel.

(2) A copper cover for the inner vessel, plated and polished on its top surface and covered on its lower surface with beeswax, bakelite varnish, or other material which is not chemically attacked by nitric or hydrofluoric acid.

(3) A cylindrical metal vessel of such size as to completely surround the inner vessel, chromium plated and polished inside and fitted with a removable water-tight cover. This cover shall be provided with such chimneys as are necessary for introduction of cement, for admitting metastatic-thermometer stem or electrical-thermometer lead wires, for admitting heater-coil lead wires, and for housing bearings and a portion of a shaft which is used to drive a propeller in the inner vessel. The size of the outer vessel shall be related to the size of the inner vessel in such manner that when the inner vessel is held in position within the outer vessel an air space of approximately 3 centimeters thickness separates the two vessels.

(4) An electrical heating coil of from 10 to 100 ohms resistance, housed in a metal container which is protected from chemical attack of acid by a surface coating of beeswax, bakelite varnish, or equally suitable material. This coil shall be mounted on the cover of the inner vessel in such position as to be within this vessel when the cover is attached to the vessel.

(5) Means for determining heat energy released by the heater coil during any stage of its operation.

(6) A stirred, water bath of not less than 20 gallons capacity.

(7) Means for maintaining the water bath at a temperature of approximately 25° C. with an hourly variation of not more than 0.01° C.

(8) Means for determining bath temperature with a maximum allowable error of 0.005° C.

(9) Means for determining temperature within the inner vessel with a maximum allowable error of 0.003° C.

(10) Means for determining time intervals with a maximum allowable error of two seconds.

The procedure in making a heat of solution determination on a dry cement sample shall be as follows:

The cement shall be removed from its sealed container and thoroughly rolled, and a representative portion consisting of at least 9 grams shall be placed in a weighing bottle. An amount of 6.000 grams of cement, to be herein designated as the calorimeter sample, is then taken from the weighing bottle, placed in a suitable container, and brought to water-bath temperature. An additional amount of 2 to 3 grams of cement, the exact weight being accurately determined and recorded, shall be removed from the weighing bottle and placed in a platinum crucible for loss on ignition determination.

Into the inner vessel shall be placed 1,200 grams of 2.000 normal nitric acid and 10 milliliters of chemically-pure hydrofluoric acid, the whole being at a temperature at least 1.6° C. below water-bath temperature.

The inner vessel then shall be placed within the outer vessel and the covers placed on the respective vessels. The assembled vessels then shall be placed in the water bath with the chimneys of the outer-vessel cover extending above the water surface.

The rotation of the propeller in the inner vessel then shall be begun and continued for the duration of the test.

By means of the heater coil, the temperature of the acid mixture in the inner vessel shall be raised until it is approximately 1.6° C. below the temperature of the water bath, at which stage the use of the heater coils shall be discontinued. Acid temperatures, water-bath temperatures, and corresponding times shall be observed and recorded at intervals of one minute. When acid temperature has raised to 1.5° C. below water-bath temperature, the calorimeter sample shall be slowly introduced into the acid. While the temperature of the acid rises quite rapidly, observation and recording of temperatures and corresponding times shall be continued at sufficiently frequent intervals to provide data for preparing a chart of the time-temperature relations. The test shall be terminated when the solution of cement is complete as evidenced by a substantially constant rate of cooling of acid.

The rise in temperature of the acid mixture from the time at which introduction of cement was begun, to an arbitrarily chosen time somewhat later than that at which the solution of cement was completed, shall be computed from temperature determinations and designated as the uncorrected temperature rise. The time during which the uncorrected temperature rise occurs is designated as the elapsed time.

The product of elapsed time and mean temperature difference between acid mixture and water bath shall be determined by area measurements on the time-temperature chart.

Making use of the observed rate of heating of the acid before cement has been introduced and the observed rate of cooling of acid after solution of the cement has been completed, coefficients of temperature change due to stirring and due to heat transfer to or from the inner vessel, shall be computed. The former coefficient is to be expressed as degrees centigrade per minute and the latter is to be expressed as degrees centigrade per minute per degree.

Adjustments shall be now made to the observed temperature rise to correct for heat of stirring and heat transfer. The product of elapsed time and coefficient of temperature change due to stirring provides a correction for the temperature rise due to heat of stirring. The product of mean temperature difference between acid mixture and water bath, elapsed time, and coefficient of tempeature change due to heat transfer provides a correction for heat transfer to or from the inner vessel. By applying these corrections to the observed temperature rise, the temperature rise due to heat of solution of the cement shall be obtained.

Having determined by a separate test in which the heater coil is employed, the number of calories of heat which are necessary to raise the temperature of an identical acid mixture under identical conditions by an observed amount, temperature rise due to heat of solution of cement shall be converted into calories of heat. This quantity shall be divided by the weight of the calorimeter sample (6.000 grams), the quotient thus obtained being the heat of solution of the cement in calories per gram.

The water-bath temperatures during a test on a dry cement sample shall be within 0.1° C. of the temperature during a test on a corresponding partially-hydrated sample.

Any heat of solution test shall be disregarded if undissolved material in an amount exceeding 0.2 per cent of calorimeter sample remains in the inner vessel after the test.

(*C*) *Heat of solution test on partially hydrated cement sample.*—The determination of heat of solution of a partially hydrated sample of cement shall be accomplished according to the method specified for dry cement in paragraph 32 (B), with the following exceptions and additions:

(1) The calorimeter sample shall consist of approximately 9 grams of the partially hydrated specimen which has been rapidly ground and passed through a No. 100 sieve.

(2) The quantity of dry, unignited cement contained in the damp calorimeter samples shall be computed from ignition tests on corresponding dry and partially hydrated samples. This quantity shall be used as a divisor in place of the actual weight of the calorimeter sample for computing from the total heat of solution determined in the test, the heat of solution of the partially hydrated cement in calories per gram.

(3) Such auxiliary tests as are necessary shall be made so that corrections may be applied for any extraneous differences which exist between conditions for the tests of the partially hydrated and dry cement.

(*D*) *Changes in testing procedure.*—When approved by the contracting officer, changes or modifications in equipment or procedure for making heat of hydration and heat of solution tests may be permitted. In no case will approval be given to methods of procedure which, in the opinion of the contracting officer, will produce results of lower accuracy than those specified in paragraph 32 (A, B, C) hereof.

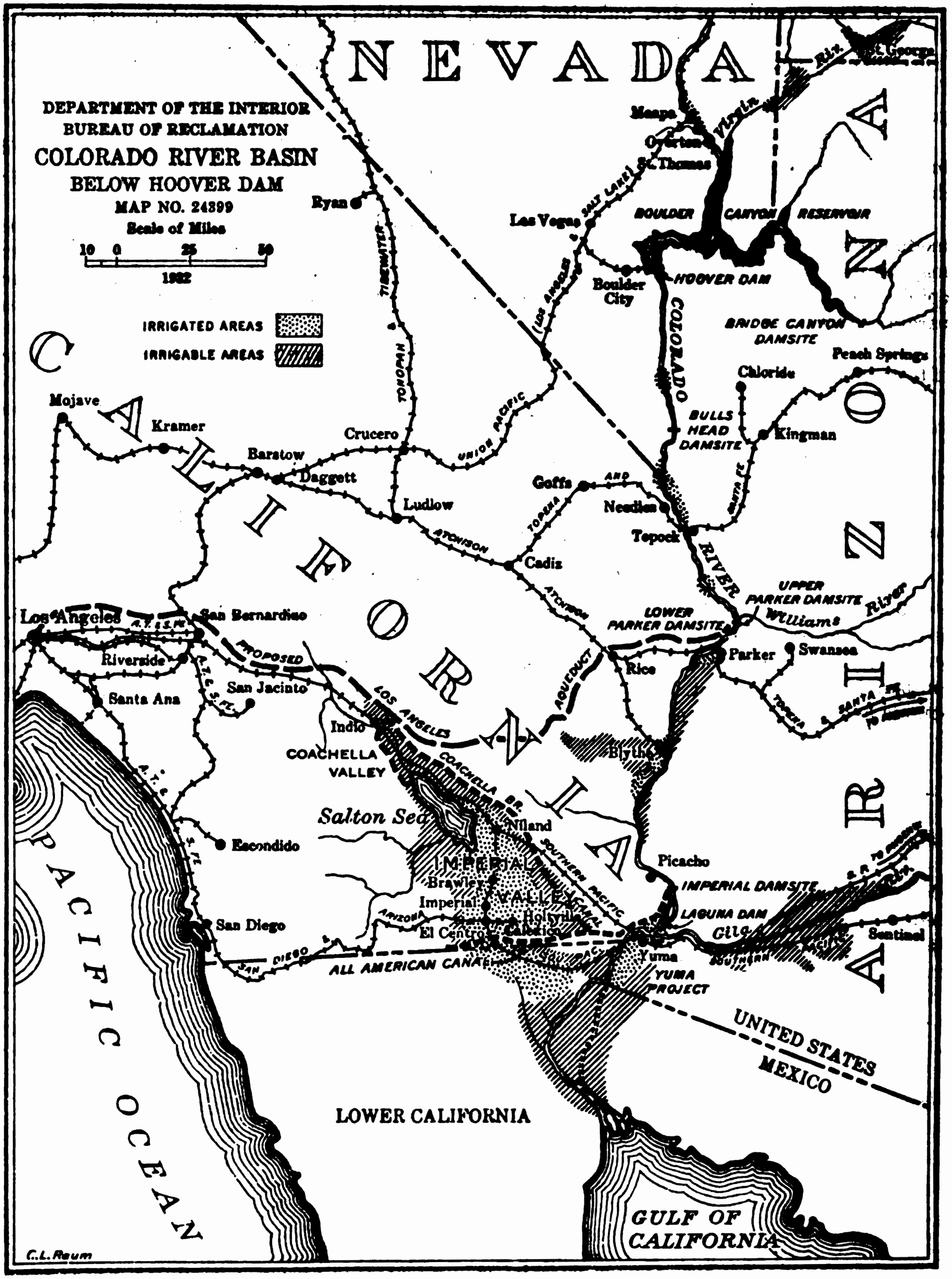
33. Number of tests.—Unless otherwise directed by the contracting officer, the number of tests shall be as follows:

(*A*) *Tests for normal consistency, time of setting, soundness, and fineness.*—Tests shall be made on each test sample.

(*B*) *Tests for chemical composition, compound composition, heat of hydration, and compressive strength.*—Tests shall be made on samples representing each 2,000 barrels of cement. The samples to be used shall be obtained by combining equal amounts, whenever practicable, of the unused portions of cement from the regular 5-pound test samples.

PACKAGING, PACKING, AND MARKING

34. Packaging, packing, and marking.—The cement shall be delivered in packages as specified with the brand and name of the manufacturer plainly marked thereon, unless shipped in bulk. When shipped in bulk this information shall be contained in the shipping advices accompanying the shipment. A bag shall contain 94 pounds net. A barrel shall contain 376 pounds net. All packages shall be in good condition at the time of the inspection.


DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
COLORADO RIVER BASIN
BELOW HOOVER DAM
MAP NO. 24399
Scale of Miles
10 0 25 50
1932
IRRIGATED AREAS
IRRIGABLE AREAS
NEVADA
CALIFORNIA
ARIZONA
Las Vegas
Boulder City
HOOVER DAM
BOULDER CANYON RESERVOIR
BRIDGE CANYON DAMSITE
COLORADO RIVER
BULLS HEAD DAMSITE
Kingman
Chloride
Peach Springs
Needles
Topock
Goffs
Cadiz
Ludlow
Barstow
Daggett
Crucero
Kramer
Mojave
Ryan
UNION PACIFIC
TONOPAH & TIDEWATER
ATCHISON
UPPER PARKER DAMSITE
LOWER PARKER DAMSITE
Williams River
Parker
Swansea
Rice
Blythe
Los Angeles
San Bernardino
Riverside
Santa Ana
San Jacinto
Indio
COACHELLA VALLEY
Salton Sea
Niland
IMPERIAL VALLEY
Brawley
Imperial
El Centro
Holtville
Calexico
Escondido
San Diego
Picacho
IMPERIAL DAMSITE
LAGUNA DAM
Gila
Yuma
YUMA PROJECT
Sentinel
ALL AMERICAN CANAL
PROPOSED LOS ANGELES AQUEDUCT
COACHELLA BR.
SOUTHERN PACIFIC
UNITED STATES
MEXICO
LOWER CALIFORNIA
PACIFIC OCEAN
GULF OF CALIFORNIA
C.L. Reum

PART II : PRELIMINARY OPERATIONS

UNION PACIFIC RAILROAD

During the period of preliminary investigations the officials of the Union Pacific Railway System cooperated with the engineers of the bureau in determining the most feasible route for a railroad to the dam site. Later this company made other location surveys which culminated in an offer to construct a portion of a branch line from Bracken, 7 miles south of Las Vegas, Nev., on the Los Angeles and Salt Lake Railroad, to the summit between the desert plateau and the Black Canyon. After several conferences with the Union Pacific representatives, particularly in regard to freight rates, this company was authorized to construct the railroad. The work, consisting of 22.7 miles of branch line and 5.2 miles of secondary track, was advertised and let by contract to the Merritt-Chapman-Scott Co. by the railroad company. Construction of the line was completed on February 5, 1931, and scheduled train service to Boulder City, which had in the meantime been located near the summit, was commenced on April 17, 1931. The railroad company also constructed approximately 4 miles of yard tracks in the delivery and interchange yard near Boulder City, which are being jointly operated and maintained by the railroad company and the contractor for the dam.

UNITED STATES CONSTRUCTION RAILROAD

The end of the Union Pacific branch railroad at the summit near Boulder City was at elevation 2,500. To reach the dam site, about 6.7 miles distant, involved some difficult location and construction work. The point selected as the end of the line not far from the Nevada rim of the canyon was at elevation 1390, and in order to obtain suitable grades, it was necessary to locate a route about 10.3 miles long. The construction of this line, known as the United States Construction Railroad, was done by contract by the Lewis Construction Co., being commenced on March 1, 1931, and completed early in September, 1931.

The first 6 miles was readily accessible but the remainder had to be built through rough mountainous country, which required the construction of 5 tunnels varying in length from 165 to 415 feet, with a total length of about 1,500 feet, in addition to many heavy rock cuts and fills. Getting to the tunnels was the most difficult part of the entire job and necessitated the construction of 7 miles of construction roads up steep mountain slopes. The longest of these was 2 miles in length and much of it was on a 15 per cent grade. The fills between the tunnels varied from 100 to 140 feet in height. The maximum open cut was 120 feet in depth. The roadbed was graded to a width of 16 feet on fills and 20 feet in cuts. A 6-inch gravel cushion was placed on the roadbed in rock excavation. The track was standard gage, and consisted of 90-pound relay rails fully tie-plated upon untreated fir ties, which was completely ballasted. There are no upgrades toward the dam and the maximum grade from the dam is 3 per cent. The maximum curvature is 10 degrees.

The contract for the construction of the dam provides for the operation and maintenance of this railroad by the contractor and for the hauling materials for the Government at definite prices. The contractor for the dam is also required to furnish the necessary rolling stock and to construct all passing, switching, and spur tracks required for his operations.

BOULDER CITY—HOOVER DAM HIGHWAY

A contract was made with the General Construction Co. for the construction of a highway from Boulder City to the dam site; i. e., to a point near the end of the United States Construction Railroad. This highway is for transportation of workmen and of small equipment and materials to and from the works by trucks during construction, and for the future operation and maintenance of the completed dam and power plant. The stretch of highway, 7 miles in length, was constructed with a roadway width of 22 feet and was gravel-surfaced and oiled. The maximum plus grade toward the dam was 4 per cent and from the dam 6.7 per cent. Construction of this highway was completed on July 30, 1931. The contract for the construction of the dam provided for the extension of this highway by 3,500 feet on the Nevada side of the canyon and about a mile on the Arizona side, which will cross on top of the completed dam and connect with the road to Kingman, Ariz.

CONSTRUCTION POWER

Electrical energy for construction purposes at Hoover Dam is obtained from power plants of the Nevada-California Power Co. and the Southern Sierras Power Co. These power plants are located more than 200 miles from the Hoover Dam site and feed into a substation located at San Bernardino, Calif.

In order to deliver the electrical energy required for construction purposes at Hoover Dam, it was necessary for the Nevada-California Power Co. to construct a transmission line from the San Bernardino substation to the Hoover Dam site. This line has been constructed and is now in operation. After the dam is completed this line will be used to transmit power from the Hoover power plant to San Bernardino and into the power system of the Nevada-California Power Co. for supplying a portion of the light and power to be used in southern California.

The transmission line is single circuit, 3-phase, 60-cycle, and 88,000-volt. From San Bernardino to Victorville, Calif., it crosses the San Bernardino range, reaching an altitude of 5,500 feet at El Cajon Pass, from which point it drops rapidly to a substation near Victorville, then following a northeasterly course crosses 191 miles of desert wastes and rocky foothills, including one mountain pass east of Baker, Calif., to the rim of the Black Canyon above Hoover Dam site.

PROVISIONS FOR SEVERE WINTER WEATHER

The line structures and conductors are subjected to heavy wind and ice loads during the winter months at points where the line crosses the mountain passes, and at such points it was necessary to shorten the span between towers and to use heavier supporting structures. In addition to this protection against heavy loading, it was found desirable to make other provisions for insuring continuous service between San Bernardino and Victorville, where winter conditions are very severe. This was done by providing another available circuit in case the main line should be out of service.

The supporting structures are of galvanized steel, and for additional protection all steel used in footings was treated with a heavy coat of petrolastic asphaltum before erection.

The standard type of structure is an H-frame consisting of two latticed masts each 2 feet square which support a horizontal trussed crossarm 34 feet in length at a height of 52 feet above the ground surface, and terminate at the base in a wedge-shaped spade made of steel plates. The total weight of this type of structure is 2,610 pounds.

Structures used at horizontal angle points in the line, for angles up to 50°, or at other points where additional strength is required, are of the A-frame type. For angles up to 25° a structure weighing 5,775 pounds is used, and for angles between 25° and 50° a structure weighing 6,325 pounds is used. For angles greater than 50° or where exceptional stability is required, the structure is made up of three vertical masts tied together at the top of the horizontal arm. All the masts are guyed and each conductor dead-end assembly is connected direct to the mast top. The bases of the A-frame type towers rest on concrete footings.

All masts of the H-frame type of tower and side members of the A-frame type of tower were shipped to the field in two sections. Field erection consisted of assembling the masts and side members, raising them into position, and connecting them at the top with the trussed cross-arm. No further connection was made between the masts of the H-frame towers, but increased strength and stability was secured for the A-frame towers by the addition of horizontal and transverse lattice frames between the two side members.

On line tangents at least one standard structure in every mile is storm-guyed. Guys are seven-sixteenths inch, high-strength, double galvanized steel strand, and are connected to 1 inch by 10 foot galvanized anchor rods and reinforced concrete anchors.

The line is operated at 88,000 volts. However, it is insulated for 132,000 volts, which is the voltage to be used for transmission of power from the Hoover power plant to San Bernardino after completion of the plant. The line insulation consists of 9 Jeffrey-Dewitt suspension insulator units in suspension strings, and two strings of 10 units each, in parallel, in dead-end assemblies.

The line conductors are 4/0 aluminum cable steel, reinforced, having an ultimate strength of 8,435 pounds and an elastic limit of 5,940 pounds. The stringing tension used conformed closely with that recommended by the California Railroad Commission in General Order 64–A. The total length of the line is 222.26 miles and the average span length is 750 feet. The total weight of the conductors used on this line is approximately 1,250,000 pounds. The line is patrolled by men with patrol cars located at the Hoover Dam substation and near the half-way point at Yucca Grove. Patrol men are also available at Barstow, Victorville, El Cajon, and San Bernardino. Since the line for the most part follows the main highway between Las Vegas and San Bernardino, patrol service is easily maintained.

CONSTRUCTION SUBSTATION

The Hoover Dam construction substation is located on the rim of the Black Canyon. It is 815 feet above the Colorado River and 1,400 feet west of the dam site. This substation consists of an outdoor high-voltage switching and transformer station and an indoor synchronous condenser and low-voltage switching station complete with control room, battery room, etc.

The 88,000-volt line enters the substation through a 132,000-volt automatic oil circuit breaker to an overhead bus from which a bank of three single-phase, 5,000 kilovolt-ampere, 60-cycle transformers are energized. One spare transformer has been provided, and arrangements have been made on both the high-tension and low-tension sides for cutting in the spare unit without moving it from its normal position.

Immediately back of the transformer bank is the substation building, which is 45 feet by 72 feet in plan and of steel frame construction covered with heavy metal lath and a double plaster coat. A 2,300-volt, 3-phase bus is located directly over the oil circuit breaker rooms, which are a portion of the building proper. These rooms contain the control equipment for the synchronous condensers, and connection is made from the overhead bus to the oil circuit breakers through roof bushings just below the bus. Two 7,500 kilovolt-ampere, 2,300-volt synchronous condensers are housed in the main operating room of the building. One of these units has sufficient capacity to maintain satisfactory voltage under normal operating conditions so that the other unit serves as a spare.

At one end of the building a bus room, 18 feet by 45 feet in plan, is reserved for the use of the Six Companies (Inc.) and the Bureau of Reclamation. Two 2,300-volt, 3-phase busses are installed in this room, one for the Six Companies (Inc.), feeders, and the other for the feeders of the Bureau of Reclamation. Electrically operated, frame-mounted, remote-controlled, oil circuit breakers for the eleven 2,300-volt outgoing feeders are installed in this room. Connections between the main outdoor 2,300-volt transformer bus and the two busses are made through the wall of the bus room. The panels and switchboards for controlling the 132,000-volt oil circuit breaker, all 2,300-volt oil circuit breakers, two synchronous condensers, and all auxiliary equipment, are located in one switchboard room.

TELEPHONE LINE

A double circuit telephone line running parallel to the main transmission line has been constructed by the Nevada-California Power Co. to aid in the operation and maintenance of the transmission line. Should an outage occur at any point on the transmission line between San Bernardino and the Hoover Dam construction substation, it is possible by alternately closing the sectionalizing switches located at Victorville, Daggett, Midway, Wind Mill, and State Line, and reporting the results by telephone, to quickly locate the section in which the trouble has occurred.

CONSTRUCTION PROGRESS

The final surveys and preliminary construction of the line were started on October 30, 1930. The entire transmission line and substation were completed 238 days later. On June 27, 1931, Mr. A. B. West, president of the Nevada-California Power Co., closed a switch which, by means of control relays, energized the transmission line.—*Reclamation Era, April, 1932.*

BOULDER CITY, NEV.

General information.—Boulder City has been established by the United States Bureau of Reclamation as the headquarters for the construction of Hoover Dam and appurtenant works and for the operation of the power plant and reservoir when completed. The construction will require approximately 6 years (until 1937) and during this period the residents of Boulder City will include the engineering and clerical employees of the bureau, most of the employees of Six Companies (Inc.), the contractor building the dam, the employees of Babcock & Wilcox, contractor for fabricating steel pipe for outlet tunnels, and business and professional people engaged in their enterprises in this town. After completion of construction, the contractors' forces will vacate, and the population of Boulder City will be composed of the operating personnel and such business and professional inhabitants as are justified in staying by the business then obtainable, augmented by tourists traveling over the transcontinental highway which will cross the Colorado River on Hoover Dam. The present population of the town is approximately 6,000.

The site chosen for the location of the town is 23 miles southeast of Las Vegas, Nev., and 6 miles southwest of Hoover Dam site. The elevation is 2,500 feet above sea level, 1,000 feet higher than the top of the canyon wall at the dam site and 500 feet higher than Las Vegas. The town is located on the divide between the river area and the plain sloping toward Las Vegas. There is a rather sharp descent from the town site to the north, and when Hoover Dam is completed a beautiful view will be had of the 145,000-acre reservoir 4 miles distant.

The temperatures at Boulder City during the year vary from 20° to 120° above zero with a mean temperature of 52° in December and 94° in July, the average temperatures being 7° cooler than at the dam site and 2° cooler than at Las Vegas. The summers are hot and dry, but the winter climate is mild and agreeable.

The town is situated on a branch line of the Los Angeles & Salt Lake Railroad (Union Pacific System) extending from Boulder Junction on the main line 6 miles south of Las Vegas to the town site. An oiled surface highway 22 feet wide and 23 miles in length connects Boulder

City to United States Highway 91 at Las Vegas, Nev. Other highway connections are via Searchlight, Nev., to United States Highway 66 at Bannock, Calif., 78 miles from Boulder City, or by way of a ferry across the Colorado River near Williamsville and a recently improved road to Chloride, and thence to Kingman, Ariz., on Highway 66, a distance of 96 miles from Boulder City.

Construction.—The facilities now provided in Boulder City include complete water and sewer systems, street improvements of paving, curb and gutter and sidewalks, and an electrical distribution and street lighting system. The water supply system consists of a series of pumping plants capable of lifting 1,500 gallons of water per minute from the Colorado River to a 2,000,000-gallon storage tank which is located on a hill at an average height of 150 feet above the town. Water is distributed from this tank to consumers through 10-inch, 8-inch, and 6-inch cast-iron mains connecting with copper service lines of three-quarter inch diameter for residences and of larger diameter for public buildings. The sewer system consists of 4-inch to 6-inch diameter service lines leading to 6-inch and 10-inch mains and by a 12-inch outfall line to a modern sewage disposal plant.

All the principal streets in Boulder City are paved with asphalt concrete and additionally improved with concrete curb and gutter and concrete sidewalks. The residential streets are paved with oil-treated gravel or a gravel surface and further improved with concrete curb and gutter and gravel sidewalks.

The electrical distribution system covers the entire occupied area of the town with single phase 2,300-volt, 60-cycle lines, which for power purposes are supplemented in the business and industrial districts by three-phase lines of the same rating. Transformers are installed in required locations to furnish the consumer with single-phase current at 110 or 220 volts and three-phase current at 220 volts. The street lighting system consists of ornamental steel standards with concrete bases in the business district and along the principal thoroughfares, and bracket lights on poles in other sections of the town. Street lamps are all of 6,000 lumens brilliancy.

Buildings.—Approximately 1,000 buildings have been erected or are in process of erection in Boulder City. Of these, the Six Companies (Inc.) has constructed 681 buildings, which include 10 dormitories of 1,500 persons total capacity; 661 residences of 2, 3, 5, and 6 room size; a mess hall seating 1,300 persons; a laundry, clubroom, and large commissary. The Babcock & Wilcox Co. is building a 79-room dormitory, and a number of 4 to 6 room residences. Persons holding permits for business enterprises in Boulder City have erected nearly 100 commercial buildings or residences, and the Government has completed, or nearly so, a group of 100 residences, administration building, two dormitories, municipal building, and six other structures of various types. The town is adequately protected from fire by two volunteer fire engine companies.

Schools.—A census recently completed in Boulder City lists 851 children, 651 of whom are of school age. The Government has constructed and equipped a modern school building for 12 grades. During the present school year the school will be maintained by contributions from Six Companies (Inc.) who will pay a greater portion of the cost, as the children of its employees are greatly in the majority. The Babcock & Wilcox Co. will also help pay the expenses of operation. The school is operated under the jurisdiction of the city manager, Mr. Sims Ely. Excellent school facilities are also available in Las Vegas, where a high-school building was erected in 1930 at a cost, with equipment, of $250,000. Tuition must be paid by all residents of Boulder City whose children attend school in Las Vegas.

Miscellaneous.—The Catholic, Episcopal, and Latter Day Saints denominations have erected church buildings in Boulder City. A community church has been established, and meetings are held at present in the American Legion Hall. Efficient mail service is provided in

Boulder City by a post-office force of eight persons. The office has recently been moved into the new Municipal Building. The Six Companies (Inc.) has a hospital with 60 beds which is adequately equipped in all details to provide its patients with scientific and modern medical attention.

More than 10,000 trees and shrubs have been planted for landscaping purposes in Boulder City. The Government has a landscape gardener to supervise the planting. Babcock & Wilcox Co., under its contract to furnish and install plate-steel outlet pipes, must locate main field offices and house at least 95 per cent of its employees in Boulder City. The Government operates the water supply and distribution system and furnishes water to consumers through individual meters. The Nevada-California Power Co. supplies electricity to the Government which re-sells it to consumers.

Business establishments.—The principal contractor, following the usual practice in large construction operations, is operating a general store and a laundry, as well as all operations connected with the housing and feeding of its men, and the requisite shops and warehouses used in construction activities. The commissary, operated by a subsidiary organization, the Boulder City Co., is a combined department, grocery, and drug store carrying rather complete lines of most standard articles. Credit books or "scrip" are supplied to its employees which are redeemable only at the company store.

Approximately 50 individuals or firms have constructed buildings under Government permits for concessions in Boulder City. These include 2 wholesale gasoline and oil stations, 2 restaurants, 2 tourist camps, 2 men's clothing stores, dry cleaning shop, building supplies yard, garage and filling station, lodging house, moving-picture theater, bus terminal station, Western Union telegraph office, barber shops, lunch rooms, general store, drug store, beauty shops, laundry, mortuary, electrical appliances store, and several other businesses. Additional applicants are submitting plans for approval and making other preparations toward establishing their enterprises.

Administration of Boulder City.—Boulder City lies in the Boulder Canyon Project Federal Reservation and is entirely controlled and regulated by the United States Government through the Bureau of Reclamation and directly by the construction engineer, Mr. Walker R. Young. A city manager, Mr. Sims Ely, has been appointed for administration of Boulder City, including matters concerning business concessions and all transactions usually performed by a city government. Police powers are vested in Federal rangers operating under the city manager. A committee has been appointed to act in an advisory capacity to the construction engineer and the city manager on all matters relating to the administration of the Federal Reservation and of Boulder City. The members of this committee are Officer Engineer John C. Page and District Counsel J. R. Alexander, of the Bureau of Reclamation, and Mr. J. F. Reis, an official of the Six Companies (Inc.). On March 1, 1932, all offices of the project were moved from Las Vegas to Boulder City. The construction engineer and the field and office engineering and clerical forces employed in supervision of the building of the project occupy the Administration Building. The city manager and his staff of assistants are located in the Municipal Building.

BOULDER CITY WATER SUPPLY

After a decision had been made, for reasons of climate, accessibility, and from the standpoint of health of the workers, to locate the construction camp for Hoover Dam at the present site of Boulder City, Nev., the Government was confronted with the problem of procuring an acceptable water supply for the camp.

Two sources were available—one from artesian wells located in the basin near Las Vegas and the other from the Colorado River. Water from the wells in the Las Vegas plain was clear and free from bacteria, but possessed an average hardness of 633 parts per million. The pressure line to Boulder City from an assured source of adequate supply would be approximately 25 miles in length and pumps would be required to lift the water a difference in elevation of 600 feet.

Colorado River water possessed an average hardness of 367 parts per million, the source of supply was 6 miles from Boulder City, and pumps would be required to lift the water from low river elevation 645 feet to top of storage tank in Boulder City at 2,670, a difference of 2,025 feet in elevation. Additional disadvantages of river water were its high silt content, an average of 6,000 parts per million, and its large bacteria count.

COLORADO RIVER WATER SELECTED

Studies were made of both sources, and it was decided to use the river water principally because the supply was sufficient and determinable, and the estimated cost of the system was nearly $200,000 under that for the artesian supply. There was also grave danger, if the Las Vegas Basin supplied Boulder City as well as the Las Vegas Valley, that the additional water requirement might deplete the underground basin storage to such an extent that a shortage would result.

To obtain acceptable water for domestic use, it has been found necessary to remove the silt from the river water, soften it to approximately 100 parts per million of hardness, and treat it chemically to destroy harmful bacteria. The lift of 2,025 feet from low-water surface at the river to a storage tank in Boulder City is provided by four pumping stations—the first by the intake plant from the river to a presedimentation basin, the second by pumping plant No. 1, which forces the water to pumping plant No. 2, which in turn lifts the water to a receiving tank in Boulder City. From this tank it flows by gravity to the filtration plant and from there it is pumped into the distribution line or to the storage tank.

The location for the intake pumping plant was selected downstream about 3,000 feet from the Hoover Dam site, at the mouth of Water Trail Canyon, where a break in the wall of Black Canyon extends westward toward Boulder City. Sometime in the future the intake will be moved to a point upstream from the dam, after this structure is completed, in order to procure clear water and take advantage of the higher water surface in the reservoir, thus eliminating a certain amount of pumping and the necessity for removal of silt.

INTAKE PLANT

The intake plant consists of three 550-gallon per minute 115-foot head centrifugal pumps, each operated by a 25-horsepower induction motor. The pumps and equipment are mounted on a carriage, which is supported and moved on 4 wheels, running on 45-pound rails, laid 7 feet apart on a 47½° incline. The carriage is raised or lowered by an electrical hoist to suit the stage of the river. A 10-inch diameter cast-iron pipe, with 8-inch laterals at 9½-foot intervals for connection to the discharge side of the pumps, is laid between the rails and leads to a 225,000-gallon concrete presedimentation basin located at the mouth of Water Trail Canyon.

This presedimentation basin is 13 feet high, 55 by 55 feet inside dimensions, and is situated with its base at elevation 734. Approximately 97 per cent of the silt is removed here by a detention period of two and a half hours. The basin is equipped with a traction clarifier and a 94-gallon per minute sludge pump for removal of the settled solids. On a basis of 500,000 gallons of water flowing through the sedimentation tank in 24 hours, the sludge pump will be required to remove nearly 15 tons of solids.

From the presedimentation basin the clarified water flows by gravity to a 30,000-gallon sump tank, from which it is lifted by the three 500-gallons-per-minute, 1,150-foot head centrifugal pumps of plant No. 1, the power being furnished by three 200-horsepower induction motors, through 3.9 miles of steel pipe, the first 1,834 feet of which is 10-inch inside diameter and the remainder 12-inch, to pumping plant No. 2. This line is laid from elevation 726 at the pumps of plant No. 1, to elevation 1,712 at the pumps of No. 2. The trench for the pipe was excavated for more than half the distance in solid rock and the pipe laid by the Wheelwright Construction Co. of Ogden, Utah, during the summer of 1931, when it was necessary that all work be done at night or in the early hours of the morning on account of high temperatures. During the day all steel exposed to the sun would blister the hands when touched and the temperatures in the trenches would rise to nearly 150°.

The profile of the pipe line has three sharp changes in its grade, where automatic air valves are installed, and one summit where an air vent has been placed. Two gate valves have been provided at low points on the line for drainage purposes, and immediately preceding the entrance of the pipe into plant No. 2, a steel tank of 4 feet inside diameter and 95 feet high serves to equalize the flow through the two high-head pumping stations.

Pumping plant No. 2 is equipped with the same type and number of pumps as in plant No. 1 and is likewise housed in a structural steel building. Walls and roof of the building are respectively of tile and metal lath stucco, differing from those of plant No. 1 where the walls and roof are of "Transite," an asbestos fiber composition. The pipe line is protected from surges and water hammer by means of automatic surge suppressors, one of which is installed near the lower end of each section of the pipe line. These surge suppressors open automatically upon a drop in pressure such as that caused by stopping of the pumps upon failure of power supply and they remain open a sufficient period of time to permit the surge to damp itself out after which the surge suppressors close at a very slow rate. All pumps are automatically controlled by means of pressure or float switches.

WATER TREATMENT

Water from pumping plant No. 2 flows through 2.7 miles of steel pipe, the first 3,050 feet of which is 10-inch inside diameter and the remainder 12-inch, to an aerator installed at the top of a 100,000-gallon steel receiving tank in Boulder City. The maximum static lift between these two stations amounts to 824 feet, as the inlet to the aerator is at elevation 2,554.

The aerator consists primarily of a tank 7 feet in diameter, having outlets through U-shaped pipes to the centers of two horizontal circular plates of approximately 36 inches in diameter and equipped with small vertical baffles. The water is aerated in its passage over the vertical baffles to the edges of the circular plates and in its fall of 6 feet or more to the water surface in the receiving tank.

The aerated water flows by gravity from the receiving tank to the filtration plant, where it is submitted to complete clarifying, chemical, and filtering processes, emerging at the end of this treatment perfectly clear, entirely free from harmful bacteria, and with hardness reduced to about 100 parts per million. The manner in which the river water is treated to secure this pure product will be discussed in a future article. Suffice to say that there are now only five of this type of filtration plants in existence, and the water softening features observed here will be found only in those plants that have been designed within the last two years.

The treated water from the clear well of the filtration plant is pumped by three 600-gallons-per-minute pumps, powered by 30-horsepower induction motors, against a maximum static head of 160 feet to a storage tank of 2,000,000 gallons capacity located on a hill northeast of the plant. The storage tank, situated on Water Tank Hill, on the northerly edge of Boulder City, has an inside diameter of 100 feet and a height of 35 feet. Its walls are of 5/16 to 3/8 inch steel plates, the floor is composed of 1/4-inch steel plates resting on a concrete floor slab and sand cushion, and the roof is made up of 10-gage steel plates supported laterally by 10 and 15 inch channels bearing on 15 columns, each constructed of two 12-inch channels.

The water-supply system is placed in operation by starting the pumps at the intake station and the presedimentation tank equipment. The clarified water discharging into the sump tank actuates a float-control switch placing in operation the number of pumps in plant No. 1 that were preset for starting. Water raising in the equalizing tank at plant No. 2 operates a pressure-control switch, when sufficient head has been developed, and places in operation the pumps in plant No. 2, that are in starting position. The equipment at the filtration plant is manually controlled with the exception of the three pumps which force the water from the plant to the storage tank. These are started by three float-controlled switches, located in the clear well. To shut down the system, the intake pumps are stopped and all other stations automatically cease operating as the water supply is cut off.

DISTRIBUTION SYSTEM

A complete distribution system covers the entire occupied area of Boulder City and is so designed and laid out that all mains are in loops and there are no dead ends. The distribution system is supplied by two mains, each consisting of a 12-inch cast-iron pipe from the main storage tank. Cast-iron mains, 4 to 10 inches in diameter, branch from the main supply lines in each intersecting street. Service connections from mains to consumers are ¾ to 1½ inch copper tubing. Fire protection for the town is provided by 89 fire hydrants and by 2-inch and 4-inch stand-pipes in dormitories and public buildings. Nearly 13 miles of mains and more than 15 miles of service lines have been laid to date. The static pressure for the distribution system varies from 90 feet in the buildings at the north side of town to 220 feet at the south, the average being 160 feet, or nearly 70 pounds per square inch.

Water pumped from the river at the present time amounts to approximately 15,860,000 gallons per month, requiring 200,400 kilowatt-hours of electrical power for pumping purposes. All water used in Boulder City is on a metered service. The cost of the supply, treating, and distribution system totaled approximately $470,000.—*Reclamation Era, November, 1932.*

BOULDER CITY SEWAGE DISPOSAL SYSTEM

Realizing the extreme importance of adequate health facilities, and in line with its policy to create a pleasant, modern, and healthful place for the builders and operators of Hoover Dam to live, the Bureau of Reclamation included in its construction of Boulder City an extensive sanitary sewer system covering the entire occupied area and built an efficient sewage disposal plant.

The lines of the sewer system were laid in conjunction with the water-distribution system and preceded the construction of walks, curbs, and street paving. Service lines of 4-inch to 6-inch diameter lead to 6-inch and 10-inch mains and thence by 12-inch outfall to a sewage disposal plant located at the head of a ravine, approximately one-half mile southeast of the town. All sewer mains and laterals are of vitrified tile. Cast-iron soil pipes lead from services outside the house foundations to plumbing fixtures.

The sewage-disposal plant is of the separate sludge digestion type and is designed to afford primary treatment for an average sewage flow of 1,500,000 gallons a day. The structure consists principally of reinforced concrete tanks and chambers, constructed mainly below the ground surface, including a 30-foot clarifier tank of 8-foot side water depth, a digester tank 24 feet square of 13-foot side water depth, and a chamber containing a sludge pump and heating apparatus, all combined in one monolithic reinforced-concrete unit approximately 45 by 61 feet in plan. A 1-story brick building, 27 by 38 feet in plan, has been built over the digester tank, sludge pump, and heating chamber. The roof of the building is of timber construction covered with asphalt composition shingles laid over one layer of asphalt-saturated felt roofing. The concrete roof of the digester tank is supported by structural steel trusses that also partially support the roof of the building.

PLANT EQUIPMENT

The mechanical equipment includes a Dorr clarifier equipped with a scum skimmer, a sludge pump, a Dorr digester tank mechanism, a gas-fired boiler, and a circulation pump, together with the piping system, valves, fittings and specials, electric motors, and operating mechanism.

The raw sewage enters the plant through bar screens of 1-inch openings, to remove the larger particles of indigestible foreign matter from the flow. It is then introduced into the clarifier tank for a subsidence period of two hours at maximum rate of flow to allow the suspended solids to settle to the tank bottom as sludge. Approximately 97 per cent of the suspended solids are removed in this tank.

The clarifier mechanism consists essentially of an arm equipped with scrapers that revolves very slowly, so as to create a minimum of disturbance, around the conical-shaped bottom of the tank. The sludge that settles to the bottom is carried by these scrapers to a small sump in the center of the tank, where it is removed periodically by the sludge pump to the digester. Mounted at the water surface of the clarifier is another arm which revolves with the scraper arm at the bottom. The function of this arm is to convey the scum that constantly forms on the sewage to a sump at the side of the tank. As this sump fills it raises a float which actuates a switch and automatically starts the sludge pump which pumps the scum to the digestive tank. The float stops the pump when the sump is empty. The effluent from the tank, which is practically free from nuisance-forming properties, flows over the weir on the opposite side of the tank from which the sewage enters, through a short outfall sewer to a near-by ravine. The effluent is deficient in dissolved oxygen and is therefore unstable as it leaves the tank. The outfall sewer discharges down a series of concrete steps to permit intimate contact with oxygen from the air, and the effluent is clear and free of obnoxious odors.

The digester is equipped with heating coils and a stirring mechanism to break up the sludge and release the gas which is produced in the process of digestion. The digestion process, consisting of a reduction of all organic solids to inorganic solids, is accomplished by anaërobic bacteria and requires an alkaline reaction of the sewage and a temperature of about 90° F. to secure the best results. The akaline reaction is maintained by the addition of lime when necessary. A maximum of 150 pounds per day is used to prevent foaming during the hot summer months.

The gas produced by action of the bacteria contains approximately 80 per cent methane (CH_4) and has a heat value of approximately 700 B. t. u. per cubic foot. The gas is trapped in a gas dome installed in the tight roof of the digester and is utilized as fuel to heat the water which is circulated through the digested sludge by a system of 1¼-inch coils. The gas not needed for heating purposes passes through a water seal to a stack, opening above the plant. Approximately 6,000 cubic feet of gas are produced daily, and the sludge temperature is maintained near the optimum point for maximum digestion and gas formation without difficulty.

The digester is designed for a 60-day digestion period at 1,500,000 gallons daily of sewage flow. At the present time the flow is approximatly 500,000 gallons a day and digestion is maintained for nearly 90 days. The effluent from the digester flows to a near-by ravine. The digested sludge, an inoffensive, black, nonodorous, inorganic humuslike material, is deposited on drying beds at intervals of approximately six months.

The cost of the sanitary sewerage system in Boulder City was approximately $62,000 and the sewage-disposal plant $25,000, or $87,000 for the entire system. A health and sanitation board, appointed by the construction engineer, maintains general supervision of all sanitation features and makes frequent inspection of the sanitary measures in force in Boulder City and elsewhere on the Federal reservation.—*Reclamation Era, February, 1933.*

SURVEYING IN BLACK CANYON

Inspection of a topographical map of Black Canyon where Hoover Dam is being built reveals many features that are quite unexpected and decidedly unusual in a map of this type. Tracing a contour along the canyon wall, it may merge abruptly with 10 or 20 others and then cross, with a dotted line, a dozen or two of its associates before returning to view as a line of single elevation along a less precipitous part of the canyon.

The sheer walls, overhanging cliffs, and deep water-worn caverns that produce this condition present obstacles to ordinary types of surveying that are not only difficult to surmount but hazardous in the extreme. In addition, a vast amount of time is required to procure exact topographical data on account of the inordinate number of transit shots or observations that are necessary, and by reason of the precipitous canyon walls and large expanse of surface that is covered by a relatively small horizontal area.

As an example of this situation, 4,000 transit shots were taken for a horizontal area of 330 feet by 660 feet on a section of the canyon wall, which is shown on the topographical map. The 660-foot measurement is parallel to the river, and the distance of 330 feet in a horizontal direction away from the river covered a difference in elevation of 600 feet.

Ordinary surveying methods, with triangulation forming the basis for horizontal control and elevations from United States Geological Survey bench marks for vertical control, were used in the early investigations and for all engineering data concerning Black Canyon preceding the year 1930. In conjunction with the examinations by the Bureau of Reclamation of Boulder and Black Canyons during 1920–1923 the topographical survey conducted by the United States Geological Survey of the Colorado River upstream from Boulder Canyon was continued downstream through Black Canyon and a triangulation system established at the latter canyon. At this time more detailed topography was taken at Black Canyon for locating the proposed dam in the most favorable site and for aiding in the design of the dam and its appurtenant works.

After Congress had passed the Boulder Canyon project act, thus assuring construction of the dam, and the Colorado River Board had approved the site in Black Canyon, surveys in the canyon were renewed. Many new triangulation points were set; permanent bench marks were established; the town site for the construction camp at Boulder City was laid out; location and quantity surveys were made for United States construction railway, Boulder City-Hoover Dam Highway, transmission line from Nevada-California substation to the dam site, a telephone line from Boulder City to the dam site, and other construction features.

PHOTOTOPOGRAPHICAL SURVEYS

The area of 50 square miles over which construction activities would extend was much too large to be adequately covered by ordinary surveying methods within a limited period, and other measures and methods were required in order not to delay commencement of construction. Contracts were awarded for ground and aerial phototopographical surveys of areas adjacent to the dam site, and for making an aerial photographic controlled mosaic map of the entire area in the vicinity of the dam site, which would be covered by project activities. A contour interval of 5 feet was required and a horizontal scale of 400 feet to the inch for aerial surveys and 50 feet to the inch for ground phototopography.

Brock & Weymouth Co., of Philadelphia, was awarded the contract for the aerial survey, and the Aerotopograph Corporation of America, Washington, D. C., for the ground phototopography. Both companies started work in July, 1930, and completed the field work in August. The aerial mosaic was completed and forwarded to the project office on November 29, the ground phototopography on December 2, and the aerial topographic map on January 22, 1931. The mosaic covered an area of more than 96 square miles, the aerial topography about 18.5 square miles, and the ground phototopography 7,400,000 square feet, projected on a vertical plane.

A Fairchild monoplane and Brock aerial plate magazine mapping camera were the principal equipment used for the aerial survey. All aerial photographs were required by specifications governing the contract to overlap at least 50 per cent in the direction of the line of flight and at least 20 per cent between parallel flights. Ground control was procured by marking points of known location, and generally of unknown elevation, with 12 by 12 feet white sheets or by painting 12 by 12 feet squares with whitewash on the ground surface. The contractor built a triangulation system by measuring a base line 7,138.57 feet in length and extending this by a system of triangles and quadrilaterals to include Bureau of Reclamation triangulation stations, significant points in connection with the aerial survey, and finally tying the network to the "Gyp-River Mountain" line of the triangulation system of the Metropolitan Water District of Southern California, which is in turn tied into the Texas-California arm of primary triangulation of the United States Coast and Geodetic Survey.

The underlying principles of both ground and aerial photographic surveys are essentially the same, differing chiefly in the position of the camera when pictures are taken. For aerial views the plate of the camera should be in a horizontal position and all pictures taken from a definite height above the ground, dependent upon the focal length of the camera and the required scale for the map. This height is maintained by the plane's barometer, which is checked for elevation on the flying field at the beginning and end of each flight. Photographs for ground surveys should preferably be taken with the plate of the camera in a position parallel to the ground surface, which may be nearly vertical when there are large differences in elevation in the landscape being surveyed.

MAKING THE MAPS

The topographical map from the aerial survey was prepared by stereoscopic scrutiny and by means of equipment similar to the "aerocartograph" and coordinatograph, a description of which may be found in an article, Photographic Surveys of Hoover Dam Site in "Civil Engineering" for April, 1931.

Prints from 171 negatives, covering an area of more than 90 square miles, were assembled on a network of accurate control, established by triangulation, field traverse, and graphic triangulation of the photographs, to form the completed mosaic. These prints had been rephotographed from the originals, after the originals had been adjusted in the reproducing machine to correct for tilt of the camera, different heights of the plane above the ground and other factors.

In Black Canyon where the steeply sloping walls, numerous caverns, and overhanging cliffs preclude the use of aerial photography, the survey was conducted by means of ground photography, using a phototheodolite. Greater detail was also required in this section, where the dam was to be located, and, as stated previously in this article, the maps from this survey were required to be made on a scale of 1 inch equaling 50 feet.

The phototheodolite is built in the same fashion as a transit, practically the only difference being that a camera is mounted in place of the telescope. The plate holder of the camera can be removed and an eyepiece with cross hairs inserted in its place. The camera lens then becomes the objective lens of the transit, or the theodolite, and the optical axis becomes the line of colimation. The details of this survey are described in the article mentioned in a previous paragraph.

From the enlargement of the aerial mosaic to a wall map 8 by 20 feet in size, the relationship of various project features could be discerned at a glance. The topographic maps aided in locating structures and furnishing approximate estimates of the amount of yardage that would be removed in excavations for the dam, power plant, and other features in Black Canyon and adjacent areas.

Owing to the unemployment situation, the contract for construction of Hoover Dam was awarded in March, 1931—six months ahead of the time originally planned. Six Companies (Inc.), of San Francisco, to whom the contract was awarded, commenced work from many places and the requirements for surveying rapidly increased. Under the demands for locations of numerous features, rapid but accurate work was required to be accomplished under extreme stress.

SURVEYORS ENCOUNTER DIFFICULTIES

The work was severely fatiguing, as well as exceedingly hazardous. Ladders were built to reach some locations, but others were found inaccessible except by lowering men by ropes. To ascend or descend the canyon walls by ordinary means usually required long hikes over trails that were few and far between.

The winds of the springtime, causing discomfort and danger by carrying sharp sand particles and dislodging pebbles and rocks along the canyon walls, were succeeded by the severe high temperatures of the summer. During July, the mean temperature in the shade was 107.4°. On two days the maximum temperature was 128°, and for two-thirds of the month the thermometer at some time during the day registered above 120°. In the sun, thermometers broke at 140°, rocks and metal burned the hands, and the canyon walls reflecting the sun's rays created an inferno in the canyon below. All accurate measurements required temperature corrections for chaining, surveying instruments had to be shaded, and heat waves made reading of record or point impossible for any except short distances. Surveying was started at 2 o'clock a. m. and stopped at 11 o'clock a. m. The men worked with practically no clothing, only shoes, trousers, and helmets.

Reflecting the loyalty of the men to their organization and indicating the careful manner in which the work was performed, it is of interest to note that none of the men quit work on account of its arduous character, none were discharged, and none were killed or seriously injured.

The contractor, starting at a few locations, soon extended these to a dozen as tunneling got under way, then to twice this number as the tunnels were widened to the full 56-foot diameter. With the starting of excavations for spillways, intake towers, trash-rack structures, connecting tunnels, and adits, the number was further increased until in March, 1932, the contractor was proceeding with 15 distinctly different operations in Black Canyon at 36 locations. Thirteen Government survey parties, totaling 48 men, and two parties of the Six Companies (Inc.), were required for location and quantity surveys. Some of their duties were to locate all structures and give line and grade for subsequent operations, cross section all sites for structures, measure quantities of material removed in their excavation, and to outline the tunnel section with white paint after each blast in driving diversion tunnels. Considerable ingenuity was exercised in obtaining some of these measurements, particularly for the completed 56-foot diameter tunnel section, the outlining for excavation for canyon wall structures and the measurement of excavation removed.

CANYON WALL SURVEYS

As the preceding surveys were not sufficiently accurate and complete for all purposes, a survey was instituted in December, 1931, of the walls of Black Canyon in the area of the dam site. The map prepared from the readings obtained is plotted on a scale of 20 feet to the inch and with 10-foot intervals between contours.

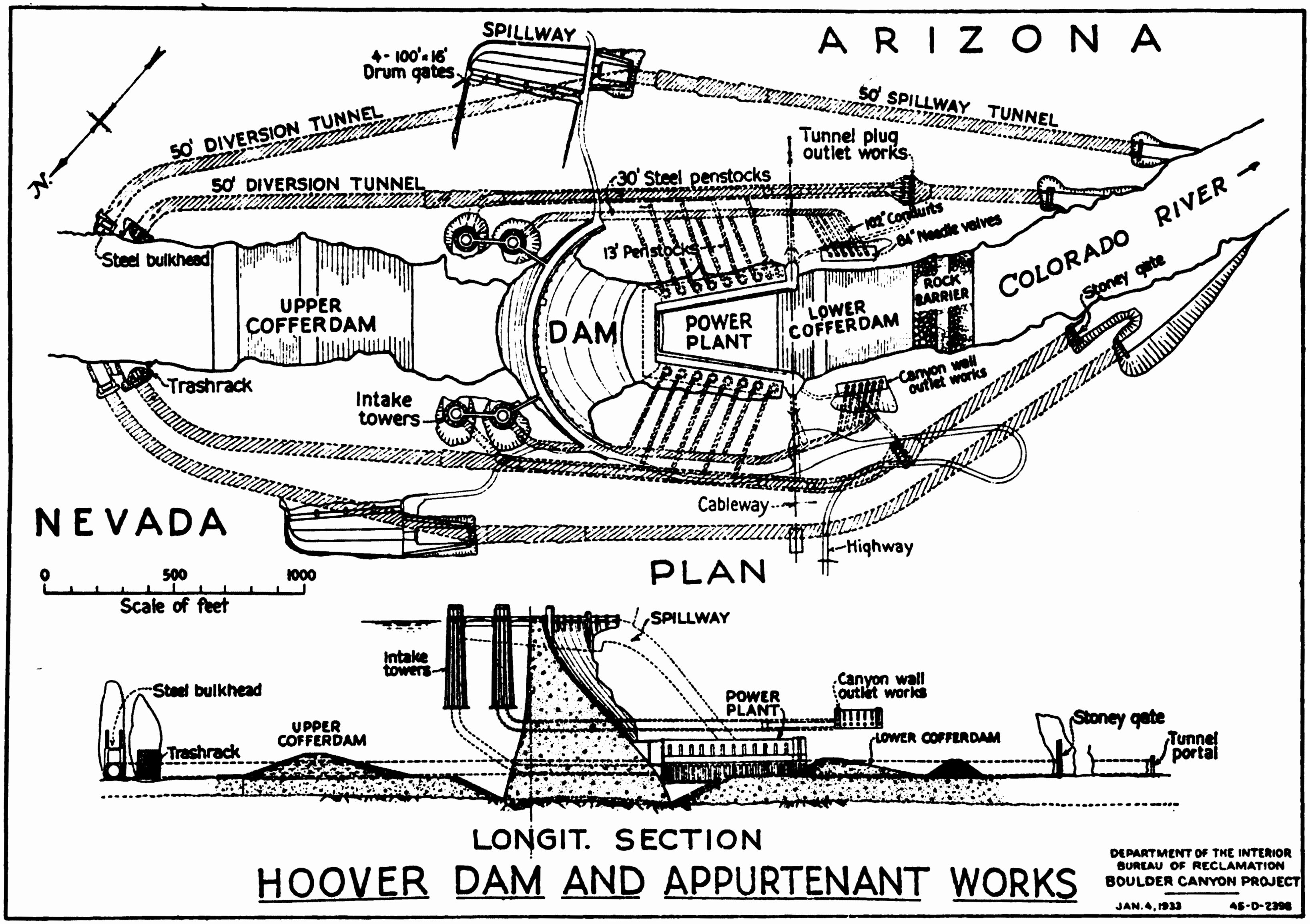
For this canyon wall survey two transits were located at points of known locations and elevations on a wall of the canyon and oriented by backsighting on each other. The rodman, termed in this instance a "rigger," descended from the opposite canyon rim in a vertical line to the river's edge, stopping at points required for accurately delineating the canyon wall surface. Horizontal and vertical angles were read at both transits for each designated point. Over most of the area surveyed, the rigger was lowered by ropes in order to reach otherwise inaccessible places. A 15-foot pole with flag attached at one end was used to reach the back of caves or below overhanging cliffs, but in many instances it was necessary for the rigger to swing himself inward as a pendulum in order to secure readings under high overhanging cliffs.

The survey crew for these operations consisted of 11 men. An assistant engineer acted as crew chief and was assisted by 2 transitmen, 2 recorders, 2 riggers, 2 ropemen for lowering the riggers, 1 man stationed in the canyon below to warn workmen of rocks that would be dislodged by the operations above, and 1 signalman who was stationed between the transits to establish communication between the transitmen and the rigger. The rigger was lowered by three-quarter-inch rope snubbed around two drills driven securely into crevices in the canyon rim. When he reached the river's edge, he removed the rope and returned by trail and ladders to the top. While one was returning, another was being lowered at a different location.

The data secured from this survey are plotted by drawing the intersecting lines according to the recorded horizontal angles of the transits and scaling on the map the distances from transits to the point of intersection. The elevation of the point is then calculated from this scaled horizontal distance, the vertical angle recorded by the transits and the known instrument elevations.

Surveying is never slow or monotonous in Black Canyon. The contractor is creating records in the rapid removal of large quantities of excavated material and the speed with which unusually large structures are being built. Accurate location and quantity surveys must precede all operations and be carried along with them. Responsibility for maintaining surveys in precedence of the contractor's undertakings rests upon the field engineer who is in charge of field work for the Government and upon an associate engineer who is directly in charge of field surveys.

The work of the surveyor is ordinarily taken as a matter of course, is seldom mentioned in reports of construction activities and is soon forgotten when the structure is completed. It is well to remember when viewing or reading of some masterpiece of the constructor's art that its design was founded on the surveyor's data, its foundations were laid under the surveyor's directions, and the structure was built in accordance with the surveyor's measurements. His work is done in an unobtrusive manner, but its importance is of first-order value.—*Reclamation Era, October, 1932.*



HOOVER DAM AND APPURTENANT WORKS

PART III : PROJECT FEATURES—DETAILS OF DESIGN

REPORT OF CONSULTING BOARD

The board of consulting engineers on Hoover Dam, comprising W. F. Durand, D. C. Henny, Louis C. Hill, and A. J. Wiley, made the following report on April 20, 1931:

"Your board has been furnished with copies of the contract and specifications covering the plans for the design and construction of the Hoover Dam, and the members have individually and in conference, given careful cosideration to the same. They have furthermore been in contact, since their organization as a board, with many of the chief problems involved in this undertaking and have therefore approached this study with the advantage of these earlier contacts.

"From this study we are of the opinion that these plans and specifications provide for the construction of a safe and efficient structure and we hereby express our approval of the same for contract purposes.

"The contract designs and plans, following usual practice, have been made general and must naturally be supplemented by numerous detail designs and considerations relating to matters of secondary importance. We are of the opinion that the terms of the contract provide adequately and fully for such developments and variations in detail as further study may suggest or changing conditions require."

DAM

The Hoover Dam will be of the massive concrete arch-gravity type, in which the water load is carried by both gravity action and horizontal arch action, with a crest length of 1,180 feet and a height of 730 feet above the lowest point of the foundation. It will be 45 feet thick at the top, 650 feet thick at the base of the crown section, and will have an upstream horizontal projection of 110 feet at the crown section. The curvature of the top of the dam will be on a radius of 500 feet. The volume of concrete in the dam will be about 3,400,000 cubic yards. Hoover Dam will be the highest in the world and will raise the water surface of the Colorado River about 584 feet, and 30,500,000 acre feet or 10,000,000,000,000 gallons can be stored in the reservoir.

CONTRACTION AND RADIAL JOINTS

Plans for the dam provide circumferential contraction joints in addition to the usual radial joints. The contraction joint system will divide the concrete into blocks or columns approximately 50 by 50 feet in plan, the upstream and downstream faces being laid out on chords parallel to the axis of the dam. The other faces will vary from parallel to the river in the lower part of the dam to radial in the upper portion. The circumferential contraction joints thus formed by the columns, will be broken by staggering the columns, but the radial joints will be continuous through the dam.

The radial joints will be formed to provide interlocking vertical keys 5 feet 12 inches in section with the ends beveled to prevent shearing of the corners due to shrinkage of the concrete. Circumferential joints will be provided with horizontal keys. The total area of circumferential and radial contraction joints will be about 3,800,000 square feet.

All contraction joints will be equipped with small metal pipes and fittings, installed in separate systems or units. After the concrete in each system has been placed and the setting heat dissipated, the joints will be filled with cement grout forced through the pipes under pressure. Copper expansion strips will be placed across the joints a short distance back of the faces of the dam and at other locations as required by the separate grouting systems. Construction of the joint grouting system will require about 820,000 feet of standard steel pipe, ranging from ½ to 1½ inch diameter, about 400,000 pipe fittings, 140,000 conduit box covers and 150,000 linear feet of copper expansion strips.

GROUT AND DRAINAGE SYSTEM

Percolation of water through the foundation will be lessened by a concrete cut-off and by drilling and pressure grouting the rock formations below the cut-off. Grout holes will be spaced at 5-foot intervals in a single line and will vary in depth from a minimum of 20 feet near the ends of the dam to about 150 feet at the sections of greatest height. Alternate holes will be only two-thirds the depth of adjacent holes. Geological investigations have indicated unusually good foundation conditions, from which it appears that the grouting will be required primarily for sealing fine seams and joints.

A drainage system is provided to handle leakage. The drainage gallery will be parallel to the axis of the dam, with the upstream wall of the gallery at a horizontal distance of 6 feet downstream from the axis of the dam. In elevation the gallery will follow generally the profile of the canyon, rising by steps at the abutments of the dam. Spiral stairways will be provided in the vertical sections of the gallery.

Drainage holes, varying in depth from about 15 feet in the abutments near the crest of the dam to a maximum of about 100 feet at the lowest part of the foundation, will be drilled into the foundation from the drainage gallery. These holes will be spaced at 5-foot intervals, will have bottom diameters not less than 2 inches, and will not be drilled until all adjacent grout holes within a minimum distance of 150 feet have been drilled and grouted. The portions of these holes through the concrete of the dam will be formed by 3½-inch steel pipe as the concrete is poured. Porous concrete tile drains will be placed vertically on 10-foot centers in the concrete near the upstream face of the dam and each of these will have a direct outlet into the drainage gallery. The collecting trench in the bottom of this gallery will connect with radial drainage conduits discharging at the toe of the dam.

In addition to the drainage gallery, an extensive system of shafts and galleries will be formed in the dam for inspection purposes. Two elevators, with adits at the elevation of the generator floor of the power house, will provide transportation between the power house and the top of the dam and will provide means of access to all galleries. The vertical travel of each elevator will be about 580 feet, equal approximately to that required for a 50-story building.

CONCRETE COOLING SYSTEM

The rapid placing of so large a mass of concrete in a structure having such large dimensions in its vertical and stream directions called for a plan of cooling the concrete. If cooling were not provided, a large proportion of the setting heat of the concrete would remain in the dam for years, and the gradual loss of the excess temperature would result in concentration of stresses, cracking, and leakage, thereby impairing the safety and shortening the life of the structure. Studies were made of various methods of cooling, all based upon the mathematical theory of heat conduction. From these studies a method was evolved of running cooled water through a system of embedded 2-inch metal pipes. The pipes will be placed circumferentially parallel to the axis of the dam with spacings of 10 feet vertical and 11.55 feet horizontal.

In order to test the workability of the cooling plans a similar experimental system was installed in the Owyhee Dam, recently completed on the Owyhee project in eastern Oregon. One-inch diameter pipes were placed in each of seven consecutive 4-foot lifts of concrete. The initial temperature of the concrete was 118° F. By pumping water at 64° F. through the pipes the mean temperature of the concrete was reduced to 84° F. in two weeks, the computed and observed values of the concrete temperature differing by less than 2°.

The specifications provide that after any portion of the concrete in the dam and tunnel plugs has set for a minimum period of 6 days, it shall be cooled by removing the excess heat above 72° F. The general contractor shall furnish, install, and operate a complete refrigeration plant for removing the excess heat. This plant shall have a capacity sufficient to reduce from 47° F. to 40° F. the temperature of a flow of 2,100 gallons per minute. The average temperature rise due to setting of concrete is approximately 40° F. above placing temperature. There will be embedded in the concrete a system of pipes containing 800,000 feet (150 miles) of pipe through which cooling water from the refrigeration plant will be circulated.

DIVERSION WORKS

During construction of the dam and power plant the Colorado River is to be diverted around the site by a temporary earth and rock-fill cofferdam through four 50-foot diameter tunnels, excavated to 56 feet and lined with 3 feet of concrete. These tunnels, two on each side of the river, are driven through the rock of the canyon walls. They will carry over 200,000 second-feet of water and have a total length of 15,934 feet or 3 miles. The upstream cofferdam is located 600 feet below the diversion tunnel portals. This dam is 90 feet high and 70 feet thick at the top, with steel sheet piling driven 40 to 50 feet to rock at the upper toe. On the upstream face there is 6 inches of reinforced concrete paving, and on the downstream face there is a layer of dumped rock. This cofferdam contains 568,000 cubic yards of earth and 157,000 cubic yards of rock. A similar cofferdam will be built just below the power plant site, which will be 60 feet high and will be protected downstream by a rock barrier 53 feet in height.

On November 13, 1932, at 11.30 a. m., the Colorado River, which for centuries past has flowed undisturbed through Black Canyon, was turned from its course and diverted around the dam site through diversion tunnel No. 4 on the Arizona side. Just before noon a mighty blast was fired which tore a hole in the barrier in front of the tunnel. A few hours later, entrance to the No. 3 (Arizona) tunnel was effected, allowing river water to enter a second of the mammoth tubes. These two tunnels can accommodate the Colorado's flow during the winter of 1931–32. Work was immediately started on the cofferdams. The concrete lining in the two Nevada tunnels will now be finished, and before the 1933 flood waters come down from the upper basin in May or June all four tunnels will be ready for diversion.

OUTLET WORKS

Outlet works will be installed on each side of the river. Each division will consist of two separate systems, each system being regulated by two welded plate-steel cylinder gates, one placed near the bottom at elevation 894, and the other near the middle at elevation 1045, in a reinforced concrete intake tower about 390 feet high and 75 feet in average diameter. There are four towers, two for each system, located above the dam, and about 165 feet apart in a direction parallel with the river. Each tower will control one-quarter of the supply of water for the power plant turbines.

At the upstream intake tower the water will discharge through the cylinder gate into a 30-foot diameter steel conduit constructed in the inner diversion tunnel below the upstream tunnel plug. Below the tunnel plug four 13-foot diameter penstocks will branch off to the power plant, and then 102-inch diameter steel conduits, in separate tunnels, will lead off to the six 84-inch needle valves of the canyon wall outlet works.

These valves will discharge into the river at elevation 820, which is about 180 feet above river level. Below the junction with the 102-inch conduits a 25-foot diameter steel conduit, located in the large tunnel, will lead to six 72-inch needle valves in the downstream tunnel plug.

At the downstream intake tower, the water will discharge through the cylinder gate into a 30-foot diameter steel conduit, to be constructed in a 37-foot diameter tunnel at elevation 820. This conduit will serve in turn four 13-foot diameter power penstocks, and then the 6 valves of the canyon wall outlet works. Reservoir outflow will be controlled in all outlet works by internal differential needle valves, each of which will be protected by emergency slide gate placed just above the needle valve.

The valves located in the canyon wall structures will not be used except under emergency or flood conditions because of the undesirable spray conditions which will result from discharges of this character. Discharge through the valves in the tunnel plugs, together with the flow from the power-plant draft tubes, will provide for irrigation water demands in the river section below, with occasional release through the lower canyon wall outlets when the demand for power is low.

Because of the high hydrostatic heads it was not considered advisable to depend upon concrete lining and the rock cover for resistance to internal water pressure. Hence, the pressure conduits in all tunnels will be of steel construction with sufficient outside clearance in the tunnels for assembling and welding. The steel conduit sections will be brought in through adits constructed for this purpose, which will afterwards serve as entries for inspection and drainage outlet conduits. Concrete tunnel lining will provide protection to the steel conduits from rock-falls and cave-ins. In the branch tunnels leading to the valves the space between the smaller diameter steel conduits and rock will be solidly filled with concrete.

The main outlet pipes will be 30 feet in diameter and will have a total length of about 4,500 feet. Made of welded plate-steel with a maximum thickness of almost three inches, they will be the largest ever constructed. One length of this pipe 12 feet long will be made from three plates, and one erection-section comprising two lengths welded together will weigh 150 tons, heavier than many types of railroad locomotives. Smaller outlet pipes vary in size from 25 feet down to 8½ feet. About 110,000,000 pounds of steel plates and castings will be required for the outlet pipes.

SPILLWAYS

The maximum known flood of the Colorado River appears to have occurred in 1884 and is estimated to have reached a peak discharge of between 250,000 and 300,000 second-feet at the dam site. It is desirable to limit the reservoir discharge for a flood of this order of magnitude—estimated to occur about once in 200 years—to 75,000 second-feet, which would correspond to about 62,000 second-feet in the delta region. Making allowance for power plant discharge and assuming all other outlets to be closed, the required spillway capacity at the top of flood storage, i. e., at elevation 1229, will be 63,000 second-feet. In view of the comparative shortness of the period of flood records and consequent uncertainty of the maximum discharge to be expected, the low freeboard allowed, and the magnitude of the works, the designs have been prepared for a spillway discharge of 335,000 second-feet with reservoir water surface at the top of flood storage, or 400,000 second-feet with water surface 3 feet higher; i. e., at the elevation of the top or roadway surface of the dam.

Two spillways will be constructed; one on each side of the river. These will be essentially alike in their general features. Each will consist of a concrete-lined open channel about 650 feet in length, 150 feet wide, and 120 feet deep, with the side next the river formed into an ogee-shaped crest. Each channel will discharge through an inclined shaft 50 feet in diameter and 600 feet long into the outer diversion tunnel on the same side of the river. Each spillway crest will be divided into four 100-foot openings by three concrete piers, and will be provided with a structural steel drum gate 16 feet high. An operating chamber will be formed in the crest below each gate.

The drum gates will be made of steel skin plates, carried on transverse plate steel girder frames spaced 28 inches on centers. They will be hinged to the upstream lip of the operating chambers throughout their lengths; and their upstream faces will be so shaped that when lowered they will form continuity of surface with the concrete spillway crest.

The gates may be controlled either automatically or manually. It is planned to install and operate them so that up to the discharge of 63,000 second-feet for all gates no movement of the gate will be required. Should this discharge prove insufficient to hold the reservoir water surface at elevation 1229, the gates may be set to automatically lower so that when completely down 335,000 second-feet may pass without a rise in the reservoir water surface. The spillways will then have uncontrolled crests and additional rises in the reservoir water surface will result in corresponding increases in discharge.

The two spillways will require 625,000 cubic yards of rock excavation. The maximum velocity in the spillway tunnels will be about 175 feet per second.

POWER PLANT

The proposed power plant will be a U-shaped structure forming in fact two independent plants, one on each side of the river, joined together by a section of building across the downstream toe of the dam. The physical characteristics of the site lend themselves to this arrangement as a rock shelf of sufficient width to accommodate practically all of the building lies at about the elevation of the draft tube floor on each side of the river. The two wings of the U also diverge sufficiently to provide good hydraulic characteristics for the tailrace. The building will be of steel and reinforced concrete with a heavy fill of rock on the roof to protect against rocks falling from the canyon walls. Access to the building from the upstream side will be by means of two elevators in the dam as mentioned before. Railroad track from a cableway landing below the plant will be provided for handling heavy equipment.

The building layout provides for the installation of fifteen 115,000-horsepower and two 55,000-horsepower vertical hydraulic turbines, 15 main generators of 82,500-kilovolt-ampere-capacity each and two main generators of 40,000-kilovolt-ampere capacity each. Eight of the larger units are located on the Nevada side of the river. The weight of the rotating parts of these units and the handling of other machinery and equipment will require the installation of four 300-ton and one 100-ton electric overhead traveling cranes.

Transformers for stepping the voltage up to 220,000, or such other transmission voltage as may be selected, will be located on a platform on the tailrace sides of the building. Each platform will also support a railroad track for handling equipment. These tracks will lead into the portion of the building across the toe of the dam where machine shops, control rooms, storage and other rooms will be located.

A high-voltage switch yard for controlling the outgoing transmission lines will be located on a comparatively flat space back of the rim of the canyon on the Nevada side. The necessary oil circuit breakers, control equipment, control-house, and other equipment will also be located at this point.

Based on past records of river flow and considering future depletion by upstream irrigation and other consumptive uses, it has been estimated that a firm power output of approximately 494,000 kilowatts, or 667,000 horsepower, will be available at the dam in the year 1938. This will allow a firm power output of 4,330,000,000 kilowatt-hours per year. It is also estimated that further developments in upstream consumptive uses will decrease this amount by 8,760,000 kilowatt-hours per year each year thereafter for a period of 50 years, or until 1988, which was the period studied in connection with the financial operation of the project. In years of more than average run-off there will be large amounts of dump power available in addition to the above firm power.

The larger of the power plant units are the largest yet manufactured, exceeding in size the 83,000-horsepower turbines and 76,500-kilovolt-ampere generators in the Dnieprostroy plant in Russia. On March 1, 1933, bids were opened at Denver for furnishing the initial installation of turbines, five 115,000-horsepower, and two 55,000-horsepower units. Approximately $17,000,000 will be spent for power plant machinery and equipment. The turbines will operate under a maximum head of 590 feet and an average head of 530 feet. The installed capacity of the power plant will be 1,835,000 horsepower (rated) which is three times the amount of power that can be developed at Muscle Shoals (Wilson Dam) and is four times that developed at Niagara Falls on the American side. The estimated cost of the Hoover Dam power development is $38,200,000.

PERMANENT CABLEWAY

At the downstream end of the power plant an electrically operated 2-speed cableway, with a capacity of 150 tons and a span of about 1,200 feet, will cross the canyon. It will be used for transporting 30-foot diameter steel pipe sections, power-plant machinery, gates, valves, and other machinery and materials to or from a loading platform at elevation 1,262 from or to two landing platforms on each canyon wall, the upper platform on each side being at elevation 799, and the lower platform on each side at elevation 670. The cableway consists of a track made up of a number of steel wire cables placed in a horizontal plane, supported on a structural steel tower on the Nevada side, and on a saddle on the Arizona side, connected at both ends to I-bars embedded in concrete anchors. The hoisting machinery is installed in a hoist house located between the tower and the anchor on the Arizona side.

The carriage will be operated at a speed of approximately 240 feet per minute, with provision for acceleration and deceleration, the total travel being approximately 1,050 feet. The load speed for hoisting and lowering will be approximately 30 feet per minute when raising loads of from 40 to 150 tons or lowering loads of from 50 to 150 tons, and 120 feet per minute for raising or lowering smaller loads. Provision will be made for creeping speeds when conveying and inching speeds when hoisting or lowering. Five control stations are required, control station No. 1 being located on the tower for the chief operator, who will direct the conveyance of the load to a point over each of the other four stations. The control will then be transferred to the desired station at one of the landing platforms, where an operator will direct the lowering or raising of the load, with ability to convey the load at creeping speed within a restricted zone. Direction of operations by the chief operator will be by means of a telephone connected to all stations. Transfer of control between stations will be made with all equipment deenergized, and resumption of operation made by means of a definite interlock to the station assuming control. The control apparatus will be so arranged that all operations, including hoisting, lowering, and conveying, can be controlled at control station No. 1 by means of a change-over switch located in the hoist house. Signal lights will be provided at each station, showing by means of green and red lights which station is energized. Operation and control will be by direct current supplied by motor-generator sets.

The first four years of service will consist principally of the lowering of fabricated sections of welded steel pipes, the principal sections of which will be 30 feet in diameter and from 12 to 23 feet in length. Approximately 46,000 tons of these pipe sections will be lowered from the canyon rim and deposited on landing platforms at the entrances to two adits on each side of the river. There will be a total of approximately 38,000 tons of maximum-size pipe sections to be

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handled during the 4-year period. Beginning with the second year of operation of the cableway, it will be used for lowering generating machinery for the power plant, and gates and valves and other miscellaneous machinery for the outlet works, for which the heaviest piece will weigh 80 tons, and will be used for that purpose and for general maintenance purposes thereafter. In addition to the service described above, the cableway will be used for general purposes, handling miscellaneous materials in loads from 1 ton to the maximum, as construction, operation, and maintenance needs at Hoover Dam may require, but with no specific duty schedule.

REPORT OF COLORADO RIVER BOARD

The following report was submitted to the Secretary of the Interior under date of November 19, 1932, by the Colorado River board, consisting of Daniel W. Mead, acting chairman; Charles P. Berkey, secretary; Warren J. Mead; and Robert Ridgway:

The Colorado River board has the honor to make the following report covering questions pertaining to plans and designs for the Boulder Canyon project, which have arisen since November 6, 1931, the date of its last report.

The major question submitted to the board at this time was presented by Acting Chief Engineer S. O. Harper, under date of November 11, 1932, as follows:

> The board has been called together at this time for final consideration of the general plan and cross section of the dam. The contractor will soon be ready to start abutment excavations and definite approval of the design of the dam is needed so that these excavations can be staked.

Several additional matters bearing only indirectly on the design of the dam proper, but vitally pertinent to certain subordinate works and to the success of the project, which were considered by the board and discussed with the engineers in charge, are, at the request of Chief Engineer R. F. Walter, also treated in this report.

The board greatly regrets the absence, through resignation, of General Sibert, chairman since its organization in 1928, and the consequent loss of his wise counsel and sound judgment.

The remaining four members spent several days during the past week at the dam site under the personal guidance of Chief Engineer R. F. Walter and Construction Engineer Walker R. Young. Particular attention was given to the relations of the natural features of the site to questions before the board, in the light of information now so well disclosed by the work in progress. Both the natural physical conditions at the site and the general conduct and execution of the work appear to the board as thoroughly satisfactory.

Additional time has been spent with the engineers in charge of design and research in Denver. The board is impressed with the progress made in those studies and with the thoroughness, care, and ingenuity with which these investigations are carried on.

DESIGN OF THE DAM

The board approves the plan and maximum section of the dam as shown in drawing No. 45-D-2080 of study No. 37, dated September 22, 1932. It is understood that such design is subject to possible minor changes, such as the substitution of a straight instead of a curved downstream profile in the lower part of the dam and of such additional fillets on the upstream profile and at the arch abutments as continuing studies of these features may indicate as advisable.

ADDITIONAL PROBLEMS

Abutment excavation.—It is obvious that the best possible seating of the dam against the canyon walls is essential and that every precaution must be taken to attain that end. The rock of the abutments is of such excellent quality and so much superior in strength to the concrete which would replace any excess removal that excavation should be limited to the requirements of proper abutment stress design.

Despite the superior quality of the rock, it can be materially weakened by heavy blasting. The board is informed that these possibilities are appreciated by the engineers of the Reclamation Bureau.

Information disclosed by tunneling operations.—The excavation of the four great 50-foot diversion tunnels has now been completed.

These tunnels have explored the side walls of the canyon back of the abutments of the dam and have shown the rock condition and quality in detail and in a wholesale manner. It is now a matter of record that the rock behavior during tunneling operations has been exceptionally good. Only in rock formations of the highest quality can tunneling on such a scale be done in safety. It is in general to be expected in driving large tunnels that zones of weakened rock requiring roof support will be encountered, that falls of rock from the roof will occur, and that there will be a certain amount of overbreak due to the weakened condition of the rock. Here, however, in 16,000 feet total length of finished bore, not a single place required support and the excavation was carried remarkably true to the specified cross sections. No element of weakness or of questionable behavior was developed in the four diversion tunnels around and back of the abutments of the dam.

The thoroughly dependable character of the walls of the canyon, a matter wholly of judgment and interpretation when this site was selected, therefore, is now fully proven. There is no doubt of the satisfactory quality and condition of the rock formation which is to support and hold the dam.

Tunnel No. 1 outlet.—The outlet portal of the spillway tunnel on the Nevada side (tunnel No. 1) is of necessity so located as to require a deep side cut over 600 feet long, the wall of which turns slightly toward the river. For part of this distance the excavation cuts a zone of fractured rock not occurring elsewhere in the immediate vicinity of the dam site. The rock slope of the excavation through this section is so unstable as to appear to require protection from heavy spillway discharge to obviate the hazard of undercutting the canyon wall. This could be avoided by extending a concrete conduit downstream from the portal 400 feet or more, but the cost would be excessive. It is believed that adequate protection can be afforded also by a properly designed concrete wall. Some such provision should be made if experience during the construction period, while the tunnel is used for diversion of the river flow, indicates the necessity of it.

The upper cofferdam.—The board has observed with much satisfaction the suitable character of the foundation, the excellent quality of the material being used in the fill, and the acceptable manner in which the work is being done on the upper cofferdam.

In the portion of the river bed exposed in the westerly half of the cofferdam now under construction, after the removal of some 20 feet or more of silt and loose gravel, a fairly uniform bed of compact and well-assorted gravel was encountered furnishing better foundation for this structure than was orginally anticipated. The material for the dam which is being placed on this foundation is obtained from the Hemenway Wash and, when wetted and properly rolled in place, is a dense, fairly impervious mass well suited to the purpose.

The steel sheet piling so far as placed in its final position at the time of the visit of the board, had been set in a concrete footing in open excavation to bedrock and back filled by puddle on both sides. The compact and relatively impervious and stable nature of the river fill as disclosed in the excavations and the manner in which construction work is being carried on promise a thoroughly successful structure for protection of the work of excavation and the construction of the lower portion of the main dam. No difficulties are anticipated provided that no unusual flood occurs during the early stages of the cofferdam construction.

River fill and its behavior.—One of the elements of greatest uncertainty in the beginning and through the whole period of development to very recent date has been the river fill. Normally the gorge is filled to a depth of more than a hundred feet with sand, gravel, and bowlders, the exact physical character and behavior of which could not be predicted. It was realized from the beginning that great difficulty and expense might have to be met if this material should prove to be loose and pervious and inclined to slump and ravel when the excavation for the dam is made, whereas all these difficulties would be greatly simplified if the river fill should prove to be stable and comparatively tight.

On this matter there is now considerable additional information. The excavation made for the westerly half of the upper cofferdam has exposed this river-bed material to a depth of over 30 feet. Its quality with respect to physical structure and stability and its relatively low permeability are both more satisfactory than originally anticipated. Not only does the material exposed at the site of the cofferdam furnish an eminently suitable foundation for that structure but it stands well in the excavation walls and yields surprisingly little water. The amount of inflow from the immediately adjacent river into an excavation over 700 feet in length and about 30 feet below the river level, covering half the width of the river trench, is so small as to be almost negligible in handling the work.

This is new and very important information. There is good reason to believe that similar conditions will be encountered in the excavation for the main dam, and, although much variability in character of material as well as increase of seepage with increase of head to be expected in a deposit of this kind and of such great depth, there is now little doubt about its general stability and comparative freedom from costly and dangerous behavior.

The excavation to be made for the main dam will furnish a unique opportunity to determine the structural detail of the river fill of this great gorge of which advantage should be taken to make a complete descriptive and graphic record. Such a record will be of use not only in case of additional developments on the Colorado River but will be of future value on other rivers of similar history.

Spillway geology and treatment.—Sufficient variation in quality of foundation rock has been encountered in both the Nevada and the Arizona spillway excavations to warrant making special provision for the foundation of the weirs and preventing undesirable water seepage. In each case the proposal to excavate for the foundation of the weir at least as low as the excavation for the spillway channel at the particular places where more broken and porous rock have been disclosed, is a suitable treatment of the situation and there is no doubt of the safety of the structure when adequately grouted and drained.

The Arizona spillway exhibits somewhat special geologic conditions. The so-called spillway breccia is made up of a mixed lot of volcanic débris filling an ancient volcanic vent up through which hot vapors continued to issue for a long time after the accumulation had completely filled the crater and the site had been covered with later deposits. It is because of this history that the material is so variable in make-up and in physical condition. Certain portions have more open texture and are more porous and more modified than other portions of the same mass, and it is one of these more porous portions of the vent that has been encountered in the excavation.

This ground introduces no particular difficulty or danger and affords and adequate foundation for the spillway structures. The deeper excavation proposed in the most porous rock near the center of the foundation of the weir is undoubtedly an advisable precaution for securing stable foundation, but it is not necessary to carry the rest of the excavation to equal depth. The whole spillway excavation requires heavy concrete protection backed up by thorough grouting and adequate drainage.

Structural material.—The material as developed in the Arizona gravel deposit is admirably suited for the concrete aggregate and it is doubtful if material of a better quality and grading for the purpose could be found. The stripping of the deposit is light, and the material is so well graded that there is little waste and there appears to be a sufficient quantity for all demands.

Observation tunnel beneath the river.—A tunnel intended to serve as a drainage sump for the foundation excavation has been driven by the contractor beneath the floor of the gorge. At the present stage this tunnel does not reach beneath the deepest notch in the floor and it ends at a point some distance downstream from the toe of the dam. For its original purpose little more may be required, but the usefulness of this tunnel is not confined to its service as a sump.

Already it has added materially to the accuracy of knowledge concerning the quality and condition of the rock floor beneath the dam. It is especially encourgaing to note that the tunnel thus far has encountered only sound rock. At the time of the board's inspection this tunnel was inaccessible, but reports indicate that there is virtually no leakage into the tunnel under the river.

The opportunity for obtaining other kinds of information, however, is of greater importance. Advantage should be taken of it to carry a branch tunnel of small cross section for observation purposes, entirely across the river beneath the toe of the dam. Such a tunnel would explore the remaining portion of the rock beneath the deepest section of the gorge and is fully warranted even for that purpose alone. It would make possible in addition a series of important direct observations bearing on matters now necessarily treated wholly on theoretical lines.

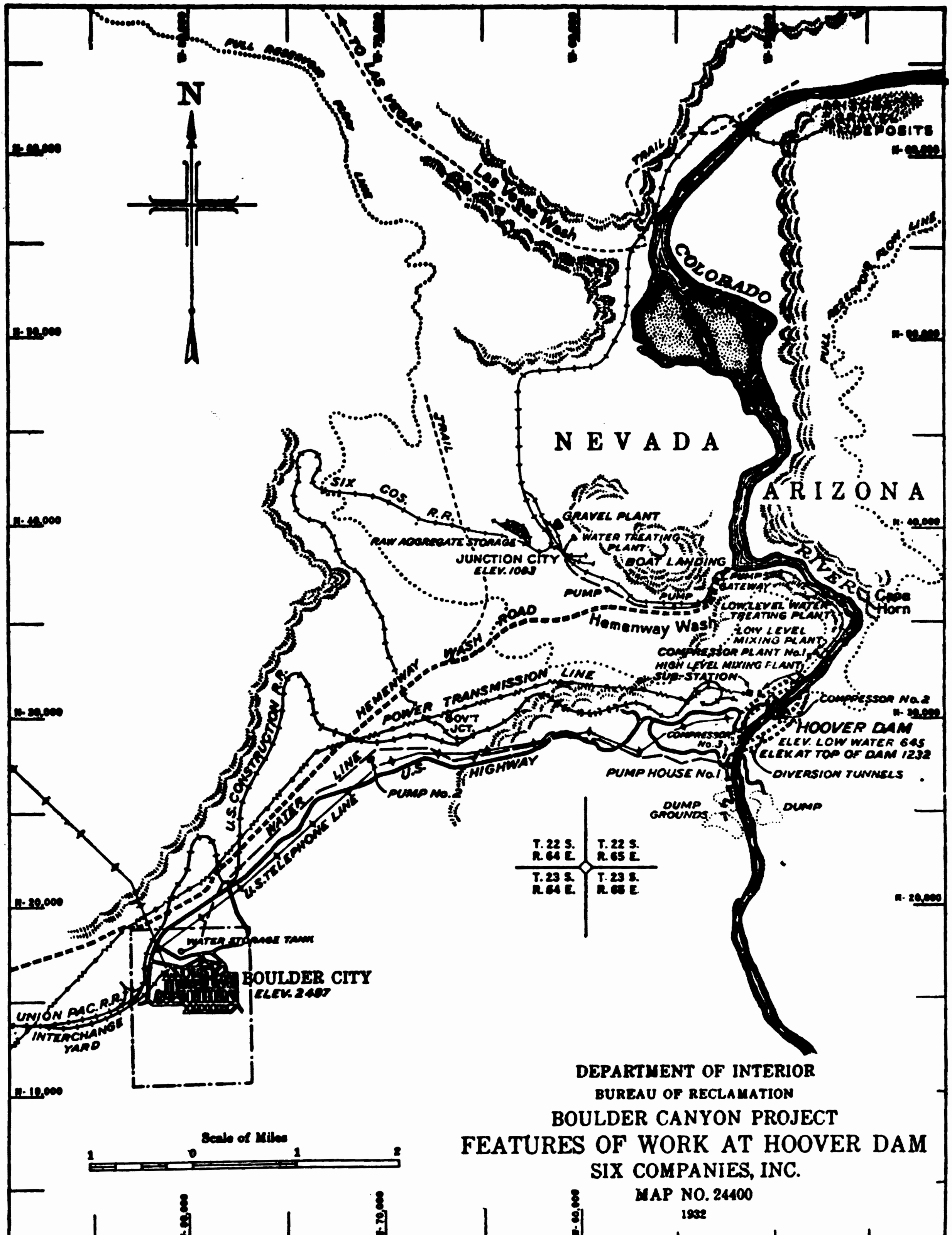
Measurements can be taken of the strain conditions now existing in the rock beneath the gorge and it is desirable that these measurements be continued during and following the construction of the dam. It would give unique opportunity to measure the effect of loading this rock foundation with the dam itself and the additional effect of filling the reservoir.

This is a most important service and the opportunity should not be lost for gathering whatever data may be furnished by the extraordinary conditions imposed by the new structure at this place. The tunnel should be kept open and should be fitted with whatever devices are necessary to secure reliable data.

Research and publication.—The unprecedented nature of this great work has created the necessity of extensive research in order to secure information necessary to the solution of many problems that have not hitherto been of equally vital importance. In this connection there have been developed new methods of procedure and an unusual refinement of technique not ordinarily possible in work of lesser magnitude. The magnitude of the structures and the importance of utilizing every advantage in the proper control of the immense forces to be imposed, together with the severe conditions under which operations must be conducted, have led to refinements in methods of analysis and design which had not been previously developed.

This vast amount of valuable information which is accumulating during the design and construction of the work should be published in order that the advances made in methods of study and design may not be buried or lost. This information would then be available for future similar work, eliminating duplication of the effort and expense which in work of lesser magnitude would be impossible.

A large amount of important and valuable geological information is being brought to light by the numerous and extensive surface and underground operations. As a matter of good engineering practice it is important that the geological features be accurately noted and recorded. This information can best be obtained during the progress of the work, and provision should be made for it as one of the contributions,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RAW AGGREGATE STORAGE
JUNCTION CITY
ELEV. 1063
BOAT LANDING
PUMP
PUMPS
GATEWAY
LOW LEVEL WATER TREATING PLANT
LOW LEVEL MIXING PLANT
COMPRESSOR PLANT No.1
HIGH LEVEL MIXING PLANT
SUB-STATION
Cape Horn
Hemenway Wash
HEMENWAY WASH ROAD
POWER TRANSMISSION LINE
GOV'T JCT.
COMPRESSOR No.2
HOOVER DAM
ELEV. LOW WATER 645
ELEV. AT TOP OF DAM 1232
COMPRESSOR No.3
PUMP HOUSE No.1
DIVERSION TUNNELS
DUMP GROUNDS
DUMP
U.S. HIGHWAY
PUMP No.2
WATER LINE
U.S. TELEPHONE LINE
U.S. CONSTRUCTION R.R.
WATER STORAGE TANK
BOULDER CITY
ELEV. 2487
UNION PAC. R.R.
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DEPARTMENT OF INTERIOR
BUREAU OF RECLAMATION
BOULDER CANYON PROJECT
FEATURES OF WORK AT HOOVER DAM
SIX COMPANIES, INC.
MAP NO. 24400
1932

PART IV : PROGRESS OF CONSTRUCTION

CONTRACT WITH SIX COMPANIES (INC.)

AWARD OF CONTRACT

In order to assist in relieving unemployment conditions existing in 1930, Secretary Wilbur requested the Bureau of Reclamation to speed up preparation of plans and specifications for the Hoover Dam and appurtenant works, so that a contract for construction could be awarded at the earliest possible date. The engineers of the Denver office responded by having the specifications printed in December, 1930, or 6 months ahead of the original program. Bids were opened at Denver, Colo., on March 4, 1931, and three regular bids were received. Six Companies (Inc.), of San Francisco, Calif., submitted the low bid of $48,890,995. This concern is made up of the Utah Construction Co., Ogden, Utah; Henry J. Kaiser & W. A. Bechtel Co., Oakland, Calif.; McDonald & Kahn (Ltd.), Los Angeles, Calif.; Morrison-Knudsen Co., Boise, Idaho; J. F. Shea Co., Portland, Oreg.; and the Pacific Bridge Co., Portland, Oreg.

The contract was awarded to the Six Companies (Inc.), on March 11, 1931, one week after the opening of bids. The contractor was notified to proceed with the work on April 16, 1931, and in a few days workmen had established a temporary camp and the project was under way. Frank T. Crowe is general superintendent for the contractor.

The contractors were obliged to build the roads and railroads necessary to their operations, beyond those built by the Union Pacific and the Government. The difficult nature of the country made this a costly undertaking and involved the construction of 30 miles of hard-surfaced highway and 25 miles of standard-gage railroad. The railroad connects the dam with the gravel pits located about 8 miles up the river on the Arizona side. Excavation of the four tunnels was the first important task undertaken by the Six Companies.

EXCAVATION OF DIVERSION TUNNELS

Four diversion tunnels, each 56 feet in diameter, having an average length of 4,000 feet, and a combined capacity sufficiently large to carry the entire flood flow of the Colorado River, have recently been excavated as an integral part of the construction of Hoover Dam.

Two of these bores have been driven through the walls of Black Canyon around the dam site on the Arizona side of the river and the other two through the walls on the Nevada side. After lining with concrete to an inside diameter of 50 feet and making connections to other structures, these tunnels will be used for diversion of water around the site of the dam and power plant during the construction period, and upon their completion will form component parts of the spillway and power house features.

Preceding the driving of the tunnels and in conjunction with the usual preparatory work of building roads to the tunnel portals, installing compressor stations and moving construction equipment into position, the walls of the canyon were stripped of loose rock above all tunnel portals. For this latter work, men were lowered by ropes from the tops of the sheer cliffs and barred or blasted loose all rocks that might become dislodged and fall into the canyon below.

ADITS AND PILOT BORES

Underground work was commenced during May, 1931, in two 10 by 12 foot adits which were driven, one on each side of the river, into the abutments of the dam to intersect the diversion tunnels. When the adits penetrated to the intersections, at distances varying between the limits of 363 to 826 feet from the adit portals, pilot bores as top headings 12 by 12 feet in section were started in both upstream and downstream directions. After the diversion-tunnel portals had been excavated to their approximate position, 12 by 12 foot top headings were also started from these locations. During September, 1931, operations were in progress at 14 headings, in which month 3,300 linear feet of pilot tunnel were excavated, removing 20,000 cubic yards of rock. Altogether, 14,637 linear feet of 12 by 12 foot tunnels were driven, excavating 84,815 cubic yards of rock and using approximately 765,000 pounds of 40 per cent powder, an average of about 9 pounds of powder for each cubic yard of excavation. Tunnel procedure and equipment were similar to those in modern usage, 50-horsepower Conway mucking machines, 8-ton storage-battery locomotives, compressed-air drifter drills, and 2-cubic-yard mine cars comprising the principal equipment.

Headings, consisting of the top 41 feet to the full 56-foot diameter, were started from diversion-tunnel portals during October, 1931, and by January, 1932, were progressing from the inlets and outlets of all tunnels. The procedure for these excavations differed radically from ordinary tunnel methods, the principal difference being in the size of equipment that was used efficiently in these large bores.

DRILLING JUMBO

After a vertical face was secured at the portals, the wings on both sides of the pilot tunnel were blasted outward to the 56-foot diameter section and to a depth along the tunnel of at least 25 feet. A "drilling jumbo," consisting primarily of a steel frame and two decks supporting five horizontal bars on which were mounted as many as 30 drifter drills, the whole carried on a 10-ton truck, was backed into position against the tunnel face at one side of the heading. After blocking the truck to retain its position, air and water lines were connected, drills inserted, and drilling commenced.

A total of 48 holes were drilled to depths as great as 20 feet and the jumbo was then moved to the opposite side of the tunnel, where the operations were repeated. Only two set-ups of the jumbo were required for drilling the face. Holes were spaced as shown on the accompanying diagram, with the two higher rows drilled upward toward the floor of the top headings and wing sections. Loading was done as the holes were drilled, in all cases allowing at least one drilled hole to remain between the loading and drilling operations. Dynamite of 40 per cent strength was used, requiring approximately 1,800 pounds for each round. After drilling and loading were completed, all men and machinery were moved to a safe distance and the round was fired electrically in 15 delays, the number by each hole on the accompanying diagram indicating the sequence of the firing. The face was advanced an average of 16 feet at each round, breaking approximately 1,000 cubic yards of rock, or an average of 1.8 pounds of powder per cubic yard. To maintain the top heading in advance of the main heading, the wing sections on both sides of the pilot tunnel were blasted simultaneously with the 56-foot face.

After the smoke and fumes had been cleared by blowers of capacities between 34,000 to 120,000 cubic feet per minute, installed near the adit entrances to pilot tunnels, a 30-horse-power caterpillar tractor equipped with a bulldozer emerged from the pilot tunnel and pushed the broken rock from the top leading on to the bench below. After a "60 cat." bulldozer had cleaned up the bottom, an electrically operated 3½ cubic yard power shovel moved to the face, followed by a fleet of 7 to 10 cubic yard trucks to commence mucking operations. After all rock was removed, Government engineers outlined the tunnel periphery on the face of the heading and the drilling jumbo reentered to continue the cycle of operations.

Tunnels of the 41 by 56 foot section were excavated for a combined length of 6,848 feet during the month of January, 1932, removing 454,335 cubic yards of rock. A record was established for one day when, in three shifts on January 20, 256 linear feet were excavated, breaking 17,000 cubic yards.

After the 41 by 56 foot headings were holed through, the remaining 15 feet in the invert section of the tunnel was removed in a manner similar to that for the section above. For this operation, the top deck of the drilling jumbo was taken off and bars shaped to the invert were added on both sides of the drill carriage. The entire invert heading was drilled from one set-up of the jumbo, 25 holes being drilled to depths of 20 feet. Approximately 750 pounds of 40 per cent dynamite were used for each round, breaking 320 cubic yards of rock.

TRIMMING OPERATIONS

Reaming the tunnels to the specified cross section was accomplished from a "trimming jumbo" for the 41 by 56 inch section and by gantry crane, truck, skip, and power shovel in the invert. The trimming jumbo consisted essentially of two parallel steel trusses, each shaped to the periphery of approximately a 35-foot section of a 50-foot diameter circle, which were placed about 9 feet apart and connected by a steel framework. The structure was mounted on car wheels and propelled on parallel rails located for line and grade with respect to the tunnel by Government engineers. A triangular plate, having at its center of gravity a small ring or other contrivance for fastening a steel tape, was affixed to the jumbo by three cables, each equipped with turnbuckles and so arranged that the plate was held near the center line of the tunnel. When the jumbo was set up, Government engineers adjusted the plate so that the ring was accurately placed at the tunnel center line, and workers, operating from the timber platforms, took measurements with a steel tape from the ring to the tunnel roof and walls to determine which projections should be removed. These they barred down or blasted loose.

Trimming the invert was done immediately in advance of tunnel-lining operations. Skips were loaded by hand or power shovel and were transported to the dumping ground directly by truck or, where necessary, first by a gantry crane, installed for concreting operations, and thence by truck.

The ingenuity and skill that the principal contractor for building the Hoover Dam and power plant displayed in driving these tunnels are worthy of commendation. Starting the work on May 14, 1931, it was carried forward through a summer when the temperatures in the canyon reached 128° in the shade. During August, operations were halted for one week by labor troubles and in February for 10 days by an unexpected rise of the Colorado River. Despite all obstacles, the work progressed rapidly, and the last section of tunnel was holed through on May 23, 1932, a year and nine days from the starting date. In the 12-month period 1,500,000 cubic yards of rock were removed, all of which, by reason of the contract specifications, were required to be dumped out of reach of the Colorado River at all stages of its water height. This latter requisite necessitated removal of excavated material a distance as much as 1 mile from the tunnel portals.—*Reclamation Era, September, 1932.*

CONCRETE AGGREGATES

The concrete which was poured on March 5, 1932, in the foundation for the 100-foot high trash rack at the inlet portal of the Nevada inner diversion tunnel was the first concrete to be poured under the contract for construction of Hoover Dam, power plant, and appurtenant works.

This operation was the commencement of concreting which will continue until approximately 4,400,000 cubic yards have been poured. It also marked the culmination of the investigations and studies that have been conducted since 1929 for the location of a deposit of suitable concrete aggregates, the building of a railroad for transportation of these aggregates, the construction of a screening plant for segregation and classification of sand and gravel, and the building of a mixing plant capable of manufacturing, in the required quantities, the quality of concrete designated in the specifications of 2,500 pounds per square inch compressive strength for mass concrete and 3,500 pounds per square inch for thin sections.

Aggregates of sand and gravel for the concrete are taken from the Arizona deposit by a 5-cubic-yard electric dragline, dumped into 50-ton side-dump cars, transported across the Colorado River on an 850-foot pile-trestle bridge and then over 6 miles of railway to the screening plant. Here the aggregates are dumped into bunkers, thence transported by a series of lateral belt conveyors to rotary and vibrating screens which separate the pit material into sand and four sizes of gravel, and then by another series of transverse conveyors deposit each in a separate stock pile. Sand and each size of gravel are loaded by belt conveyors into separate railroad cars and transported 4.7 miles to a concrete mixing plant located in Black Canyon approximately 1 mile upstream from the Hoover Dam site. The sand and gravel are dumped from the cars into their respective bins below the track and then elevated by belt conveyors to storage at the top of the concrete plant. The sand, gravel, and cement are conveyed to batchers and to the mixers where water is added. Mixing of each batch is carried on for a minimum of two and one-half minutes in 4-cubic-yard mixers. The concrete is then dumped into an agitator drum mounted on an 8-ton truck and transported to the site for pouring.

ARIZONA GRAVEL DEPOSIT

The Arizona deposit, from which all aggregates for the construction in Black Canyon will be obtained, is located on the Arizona side of the Colorado River 6 miles by air line north of the Hoover Dam site. The deposit lies along the river, covers an area of more than 100 acres, and, from investigations by test pits, has an average depth of more than 30 feet. It is expected that not more than 3 feet of this depth will be discarded by surface stripping or removal of silt pockets; thus there will remain approximately 4,500,000 cubic yards of aggregates available for use in the dam, all of which will be needed. This deposit was chosen after extensive search had been conducted of the region for 50 miles in all directions from the dam site and tests had been made of aggregates from more than 20 different deposits.

An electrically driven dragline equipped with a 5-yard bucket is used for stripping and for loading aggregates. The pit is operated with three shifts daily, and at present an average of one hundred and fifty to two hundred 50-ton cars are shipped to the screening plant each 24 hours. The aggregates are transported in side-dump cars pulled by 90-ton locomotives. The railroad line from the deposit to the screening plant is 7 miles in length and was constructed by the Six Companies (Inc.), contractors on the dam.

SCREENING PLANT—GENERAL DESCRIPTION

The location of the screening plant is in the flat area at the lower end of Hemenway Wash, about 2 miles west of the river and 2¼ miles by air line northeast of the Hoover Dam site. It is situated at Three-Way Junction on the contractor's railroad, from which point one line leads to the Arizona deposit, another to the concrete plant in Black Canyon, and the third to the United States construction railroad connecting with Boulder City.

The screening plant essentially consists of a scalping station with its attendant crusher, four classification towers, sand washer, sand shuttle conveyor, four live storage piles east of the classification towers, and sand storage piles across the gravel loading tracks west of the towers. The aggregates from the Arizona deposit are either dumped at a raw storage site adjacent to the screening plant or into bunkers at the north end of the plant.

A 42-inch belt conveyor running in a concrete tunnel beneath the bunkers receives the aggregates through gates and hoppers installed in the roof of the tunnel and transports the material to the scalping station, dumping the aggregates into a 20-foot cylindrical revolving screen. This screen allows all material less than 9 inches in size to pass through its perforations, and dumps cobbles above this size onto a transverse conveyor leading to a gyratory crusher. After going through the jaws of the crusher, the broken cobbles are conveyed by belt to the 42-inch principal conveyor and return through the scalping station.

From the scalping station the material less than 9 inches in size is conveyed by a 36-inch belt conveyor to the first classification tower, which is equipped with two vibrating screens. The first screen allows aggregates less than 3 inches in size to pass and dumps the 3 to 9 inch material onto a traverse conveyor which transports it to the stock pile. The second screen allows all sand less than ¼ inch in size to pass through its perforations and dumps all gravel onto a lateral conveyor leading to the second classification tower. In a similar manner the vibrating screen and traverse conveyor at this second station remove the ¾ to 3 inch gravel to a stock pile and the lateral conveyor transports the material less than 1½ inches in size to the third tower. Here gravel of ¾ to 1½ inch size is removed to a stock pile and all materials passing through the screen are conveyed laterally to the fourth tower, where a transverse conveyor transports this gravel of ¼ to ¾ inch size to its stock pile.

SAND WASHING

The sand removed by the vibrating screens in the first classification tower is chuted to a series of mechanical sand washers or classifiers. Water is added to the sand after it leaves the screen, and the sand and wash water enter the lower end of a mechanical sand washer consisting of drag blades installed on eccentrics. This arrangement, by reciprocating action, moves the sand progressively up the sloping bottom of the washer tank and out over the end to a chute through which the sand is conveyed by water to a second washer of the same type. The water and silt separated from the sand in the tanks overflows at the lower end of the sand washer to a flume and thence to a sedimentation tank equipped with a traction clarifier and sludge pump. From this clarifier the water runs to a sump tank and is then pumped to a sedimentation tank located on a hill southeast of the plant for reuse. The sand after passing the second sand washer is transported by a belt conveyor through a concrete tunnel underneath the railroad tracks to a conveyor running parallel to the tracks. This conveyor connects with a tripper equipped with two transverse conveyors, all of which are mounted on a framework and rails supported by a steel trestle. This arrangement for sand storage permits piling the sand into stock piles, one on each side of the lateral supply conveyor and parallel to the railroad tracks.

Five railroad tracks have been laid for efficient loading of sand and gravel from the plant. Between the classification towers and the sand stock piles, there are three tracks—one for gravel loading, the next for sand loading, and the third, adjacent to the sand piles, for the operation of a railroad crane. On the west side of the sand piles are two tracks, the first for the railroad crane and the other for sand loading. The sand is loaded into cars by the crane, equipped with a clamshell bucket.

A concrete tunnel, 11 feet in height and 9 feet wide inside, is constructed beneath all gravel stock piles, and has contained therein a 24 or 30 inch conveyor belt which leads to screens in the lower part of the classification towers. The gates installed in the roof of the tunnel are opened from inside, allowing the gravel to drop into a hopper from which it is fed to the loading conveyor belt.

The belt dumps the gravel into a vibrating reclassifying screen, which passes all gravel of a size less than that supposed to be in the stock pile, dropping this smaller material onto a lateral conveyor which returns it to the scalping station. The material remaining on the screen flows from its lower end to a hopper and a 48-inch shuttle conveyor and thence to bottom-dump railroad cars. The gravel is kept continuously wet by sprinklers installed at the top of the stock pile and is washed by water jets as it is dumped from the reclassifying screen onto the loading conveyor.

The capacity of the plant with its present installations is more than 500 tons per hour. Four 50-ton cars can be loaded out every 16 minutes. Present construction allows for storage in stock piles of 1,700 tons of cobbles, 1,500 tons of each size of gravel, and 22,000 tons of sand. By increasing the speed of the conveyor belts and making slight alterations, principally by extension of the transverse conveyors and the tunnels beneath the stock piles, the plant can be increased to a capacity of 1,000 tons per hour.

The plant is run by electrical power, requiring more than 50 induction motors for all operations. The supply conveyor and the conveyor to the first classification tower are run by 60-horsepower motors, the others by 10 and 20 horsepower, and most of the screens by 5-horsepower motors. The supply conveyor is 220 feet long, the lateral conveyors are 1,160 feet in total length, the transverse conveyors 710 feet, and the loading and shuttle conveyors 670 feet. The plant contains a 5-foot diameter, 20-foot long scalping screen, and 13 vibrating screens, 11 of which are 10 by 4 feet in size and 2 are 12 by 4 feet.

The plant is controlled from a central switching station located in the top of the scalping tower. Thirty-four sets of pushbutton switches electrically control all units of the plant, and one switch can stop all operations. At this same station the nine gates in the bottom of the supply bins are regulated by rheostat control, thus governing the supply of aggregates to the primary conveyor and the output of the entire plant. The conveyors are all operated at a constant speed regulated by the gearing from the driving motors. The speed of the lateral conveyors vary from 150 to 350 feet per minute, the transverse conveyors from 150 to 225 feet, and the loading conveyors from 225 to 300 feet.

Water for washing purposes in the plant is pumped from the Colorado River by stages through 2 miles of 12-inch pipe line against a static head of 415 feet to a sedimentation tank located on the hill southeast of the plant. The character of the silt in the river water is such that 98 per cent of it can be removed by a detention period in the tank of three hours. Water from the river contains an average of 6,000 parts per million of silt, and water sent to the screening plant is required to contain not in excess of 500 parts per million. The presedimentation tank, constructed of reinforced concrete, is 150 feet in diameter and 15 feet in height. It has a capacity of 800,000 gallons of water and is equipped with a Dorr traction clarifier. Sludge is removed by gravity.

Construction of the screening plant was started in November, 1931, and it was first operated on January 9, 1932, when S. O. Harper, assistant chief engineer of the Bureau of Reclamation, closed the switch to commence the initial operation. More than 385 tons of structural steel were used in the construction, and the cost of the plant amounted to approximately $450,000.—*Reclamation Era, May, 1932.*

CONCRETE MIXING

Gravel and sand loaded into bottom-dump cars at the screening plant are transported over four miles of railroad to the contractor's concrete mixing plant in Black Canyon. This plant is situated on the Nevada side of the river at the base of the high wall of the canyon and less than a mile upstream from Hoover dam site.

Aggregates from the screening plant are dumped from the cars into separate compartments in the bunkers beneath the railroad tracks, and when required are separately transported an average distance of 450 feet by two 42-inch belt conveyors up a 16° incline to the tipple at the top of the concrete plant. Hoppers with movable spouts receive the material and drop it onto shuttle conveyors which transport it to the designated bin.

DESCRIPTION OF PLANT

The dimensions of the concrete plant are 78 feet by 118 feet in plan, 88 feet in height from truck-loading platform to top of storage bin, and 120 feet to top of tipple. A heavy concrete foundation supports the four 4-cubic yard Smith mixers and is extended westward beneath the structural steel framework of the plant. The top of the foundation for the mixers is at elevation 735, 15 feet above the truck-loading platform. Above the mixers is the control deck and above this the conveyor and batcher floor. The bottom of the 33-foot high storage bins is 9 feet above the batcher floor and the tipple rises about 30 feet above the bins.

The bins at the top of the plant are 6 in number, 3 of which are for gravel, 1 for cobbles, another for sand and the sixth for cement. All are 78 feet wide, and from front to back of the plant 30 feet of the total length of 118 feet is used for cement, 16 feet for 3 to 9 inch cobbles, 16 feet each for coarse, intermediate, and fine gravel, and 24 feet for sand. The bins are of steel frame construction with laminated timber sides and partitions. The walls are of 3 by 8 inch to 3 by 12 inch planks and the floor of 3 by 16 inch planks. The cement bin is covered and is waterproofed on the inside with tar and felt.

Bulk cement, transported by rail from the place of manufacture to Boulder Junction on the Los Angles & Salt Lake Railroad south of Las Vegas, to Boulder City over the Union Pacific branch line, to the concrete plant, via the United States Construction Railroad and the contractor's line, is elevated to the bins through 6-inch steel pipe by air pressure, the unloading machine resembling a large vacuum cleaner.

Water for the plant is pumped from the Colorado River to a 50-foot diameter Dorr clarifier located on the canyon wall approximately one-quarter mile up-stream from the mixing plant. All silt above 500 parts per million is settled out in this tank, and the water flows by gravity to a 125,000-gallon storage tank situated in a side canyon above the mixing plant.

CONTROL OF AGGREGATE QUANTITIES

When the plant is placed in operation, the sand and different sizes of gravel from ¼ to 3 inches are each dropped through an automatically controlled gate into a batch hopper, termed a "batcher," located below each bin. Doors in the bottom of the batchers are opened in rotation by air-controlled electrically operated devices, the hopper nearest the mixer opening last, and the aggregates are spread in thin layers on a 48-inch belt conveyor leading to a mixer hopper installed above and back of a mixer. When the 3 to 9 inch cobbles are used, they are allowed to pass through a door in the bottom of the cobble bin to an automatically controlled steel belt conveyor and to the cobble batcher. A chute connects this batcher directly with the mixer hopper.

For each mixer, cement runs from the cement bin through four chutes to an automatically controlled double screw conveyor cement feeder placed at the top of the cement batcher. The gate in the bottom of the cement batcher is just above a chute which leads to the throat of the mixer hopper. Water from the storage tank on the hill back of the plant flows to a water batcher through an automatic valve which shuts off the water when the batcher has received its designated weight. The outlet from the batcher leads to the mixer through a discharge valve which is manually controlled.

The automatic controls referred to in the above paragraphs are operated in all cases by the weight of the batcher and its load. The batcher is mounted on the end of a dial scale which connects by a series of levers and balancing weights to mercoid cut-off controls. At the scale, weights are added, dependent on the amount of material desired to be included in each batcher load.

The mercoid controls, installed on the weight end of the system, are electrical switches operated by change in position of a glass capsule containing a globule of mercury. The electrical circuit is broken at two projections inserted at one end of the capsule and the circuit may be closed by lowering the end of the capsule containing the projections, thus allowing the electrical current to flow through the mercury globule. One of the controls is termed the "main flow cut-off" and the other the "final balance cut-off." When the weight of aggregates in the batcher reaches about 95 per cent of the predetermined weight, the swing of the beam on which the controls are mounted, causes the mercury globule in the main flow cut-off to move away from the two projections, thus breaking the electrical circuit and by means of electromagnetic coils, closing the gate in the bottom of the aggregate batcher by compressed air. The electrical current operating through the mercury globule in the final balance cut-off, by means of a small motor and air valve, alternately quickly opens and closes the gate to allow small amounts of material to dribble into the batcher until the predetermined weight is acquired, at which time the adjusted position of the cut-off beam breaks the contact in the final balance cut-off.

In the system of balance levers, there is a connection by rods to a recorder which registers on a 20-inch dial the visual record of the weighing. Connection is also made from the system to a graphic recording device consisting of a pen tracing on a time constant operated paper roll which is graduated in intervals of weight. The consistency of the concrete and the length of time it was mixed are also recorded on this roll by a hookup with a wattmeter which measures the power used in operating the mixer in question. As the power for rotating the mixer drum varies as the amount of water in this mix, this arrangement indicates the consistency and at the same time shows graphically the period of mixing after all materials were in the mixer. The chart gives a visual image of all operations of the plant and as well furnishes a permanent record of the weight of all materials that are placed in each batch of concrete. Similar visual and graphical recording instruments are employed for measuring the amount of water used, these devices also being operated by weight.

MIXING OPERATIONS

For actual mixing of the concrete, water from the water batcher is started into the revolving mixer. After approximately five seconds, the mixer hopper and the cement batcher gates are opened, allowing aggregates and cement to flow into the mixer drum; thus water, aggregates, and cement enter the mixer together. After all materials have entered, mixing is continued for a minimum period of 2½ minutes and the concrete is then dumped by tilting the mixer drum.

The concrete pours from the mixer plant through a chute into 4½-yard agitator drums mounted on trucks, or into 2-yard buckets carried by trucks. The agitator is in effect a mixer, which is rotated at intervals as the concrete is being transported in order to retain its consistency and uniform density. The buckets, two of which are transported by each truck, are of bottom-dump type. Rails, set in concrete to provide a smooth roadway for trucks, have been laid below the mixers for later transportation of concrete by railroad cars. At the present time all concrete for lining the diversion tunnels is transported by 10-ton trucks, and rail transportation will probably not be started until pouring has commenced for the dam and power-plant structures.

While one batch of concrete is mixed, another has been discharged into the mixer hopper and the cement and water batchers have been loaded. Thus under capacity operation, using all four mixers, 16 cubic yards of concrete can be manufactured by the plant in 3½ minutes. On this basis, the theoretical capacity of the plant over a 24-hour period would be 6,600 cubic yards.

PLANT EQUIPMENT

The concrete plant contains 1,493 feet of conveyors, four 4-cubic yard Smith mixers, two batchers each for water, cobbles, sand and each of the three grades of gravel, and four batchers for cement. Sixteen visual gages and two plant-operation recorders have been provided. Eight hundred tons of structural steel were used in construction, and the cost of the plant amounted to $351,000 of which sum $103,000 was paid for equipment. The principal power equipment consists of 75-horsepower motors for each mixer and 200-horsepower motors for each of the supply conveyors.

The capacity of the bunkers under the track is 1,500 cubic yards, or 300 cubic yards in each compartment. The two supply conveyors will together transport 1,500 tons of aggregates per hour. The storage bins have a total capacity of 5,400 cubic yards of aggregates and 14,800 barrels of cement.

The aggregate proportions in the concrete depend upon the type of construction for which the concrete will be poured and the amount of moisture present in the aggregates. As an illustration, one mix that has been used has a ratio of 2,000 parts of cement, 4,200 of dry sand, and 9,400 of dry gravel by weight. The gravel in this particular case was composed of 32 per cent of ¼ to ¾ inch, 32 per cent of ¾ inch to 1½ inches, and 36 per cent of 1½ to 2¾ inches. Cobbles will be used when mass concrete is manufactured for the dam or similar structures.

It is contemplated that concrete for the dam will be transported from the present plant by railroad in 8-cubic yard buckets. These buckets will be filled directly by the mixers and upon arrival at the dam site will be picked up by a 20-ton cableway and transported to position, and there dumped by trip line. It is anticipated that the dam will be poured to elevation 900 or 935 from the present plant, and that the plant will then be moved to a site on the canyon rim near the end of the United States construction railroad for pouring the remainder of the dam.—*Reclamation Era, July, 1932.*

CONCRETE LINING IN DIVERSION TUNNELS

The type of conveyance used for transporting concrete from mixing plant to pouring site depends upon the means adopted for placing the concrete in its final location. Trucks loaded with two 2-yard bottom-dump steel buckets are employed when the concrete is conveyed from trucks to pouring site by gantry crane, and the agitator drum, mounted on truck, is used when it is possible to pour concrete directly into place or into a chute leading to a hopper, where it is transferred to the steel buckets.

The inlets of all diversion tunnels have been excavated to the portals and a concrete arch cofferdam built around each portal for protection from floods. A rock fill nearly to the top of the cofferdam has been made between these structures and the river, and as a result trucks can not be driven directly into the tunnels at these portals.

The present procedure for pouring the 3-foot lining in the diversion tunnels is to transport the concrete from the mixing plant to the inlet portals in 4-cubic-yard agitator drums. Upon arrival at the tunnel portal the concrete is dumped into a chute leading to a steel hopper, from which it is dumped into the steel buckets as desired. These buckets, two of which are loaded on each 10-ton truck, are then conveyed to the pouring site, where a 10-ton gantry crane lifts the buckets from the truck and moves them to the pouring position.

Lining diversion tunnels is performed in three operations—the invert section, comprising the lower 74° of the tunnel, is poured first; this is followed by pouring side walls, 88° on each side; followed in turn by pouring the remaining 110° in the roof or crown of the tunnel. All sections are poured for the same linear distance, so that a transverse construction joint is secured around the entire periphery of the tunnel. At present this section is 40 feet in length for all tunnels except in the portions of the two outer tunnels, which will later be used for spillway purposes, where the construction joints are placed 26⅔ feet apart.

PRELIMINARY OPERATIONS

Following the excavation of a tunnel to its full 56-foot average diameter, the first operation preliminary to lining is the pouring of a concrete gantry rail base on both sides of the tunnel. The top of this foundation is 3.1 feet in height above the finished tunnel invert, and its inside corner is accurately poured to line and grade at a distance of 15 feet 9½ inches from the center line of the tunnel, with the result that the corner is located 24 inches from the finished face of the concrete lining, the 24 inches being the specified minimum thickness of lining. On each of these bases, which have an average width of 2½ feet, is placed a 6 by 12 inch timber, to which is spiked a 90-pound rail. On these parallel rails is then mounted the 10-ton gantry crane, which is capable of traveling along the tunnel at the rate of 300 feet per minute. The transverse traveler of the crane, equipped with two hooks of 5 tons' capacity each and operated by a 10-horsepower electric motor, has a traveling speed of 125 feet per minute and a hoisting speed of 100 feet per minute.

Longitudinal steel side forms 2 feet high, made up in sections 10 feet long, are set in position on the concrete foundation and held rigidly in place by bolting the form to the gantry rail concrete foundation and to the timber rail base. Transverse steel forms 2 feet wide, approximately 32 feet long, and spaced 26⅔ or 40 feet apart, are bolted to the longitudinal forms and braced against the rock floor of the tunnel. The space between the form and the floor is filled with a 2-inch timber bulkhead. Both transverse and longitudinal forms are constructed of 10-gage steel plate, smooth inside, supported by 2-inch angle top flanges and 2 by 3 inch stiffeners. Keyways between abutting sections of concrete, 1½ by 10 inches in transverse forms and 6 by 12 inches in longitudinal forms are provided by grooves of these shapes in the steel plates.

LINING THE INVERT

The shape of the invert is procured by a device consisting primarily of two steel screeds supported on car wheels which run on the inside bottom flanges of two I beams. The beams, shaped to the invert and separated by an approximate distance of 11 feet, are connected at each end by a steel framework and supported by pairs of car wheels which run upon the upper flanges of the longitudinal forms.

Each of the screeds has a horizontal upper deck mounted on the screed plate, which itself is shaped to the radius of curvature of the finished tunnel section, which is 50 feet in diameter. The screed plate is approximately 11 feet long and 4 feet wide. On the upper deck is mounted a hand winch operating two cables, each of which is fastened through single sheaves to the framework connecting the I beams, so that by winding the winch the screed is moved upward across the invert toward the side forms.

For concreting operations the winch on the screed is unwound, allowing the two screeds to meet at the center of the tunnel. The gantry crane picks up the two buckets of concrete from the truck and transports them to the pouring site. Concrete pouring through the bucket gate, which is opened or closed manually by a large removable handwheel, is dumped on the tunnel wall side of each screed and puddled into place beneath. When the space is filled the screeds are pulled toward the tunnel walls, leaving behind them the molded shape of the invert. This process is repeated until the screeds arrive at the side forms.

To move the screeds and their track framework lengthwise of the tunnel, screw jacks installed on the axles of the wheels, which run on the side form, raise the framework slightly, allowing it to be pushed manually to its next position, or, if the distance to be moved is of great length, the gantry crane picks up the framework bodily and moves it to the desired location.

The surface of the invert is finished by men working from a movable timber platform supported just above the concrete by curved I beams placed 5 feet apart. The I beams are connected at each end by a steel framework which contains double-flanged wheels running on the gantry-crane track.

After the concrete in the invert has been finished, sand is dumped on it for a depth of approximately 3 feet on the center line of the tunnel, to act as a roadway for operation of trucks.

SIDE-WALL SECTIONS

In preparation for pouring the side wall and crown sections, a concrete shelf 1½ feet wide is poured along each side of the finished invert as a foundation for 90-pound rails which are placed 11½ feet from the center line of the tunnel. These rails are the track for the side-wall jumbo, an 80-foot long and 50-foot high structural steel framework weighing 385 tons, which supports the ¼-inch steel skin plate for forming the walls.

This jumbo is equipped with chutes, a traveling crane, and other mechanism for placing the concrete in designated position, and a series of screw jacks and ratchets used for distribution of hydrostatic pressure of green concrete and for the adjustment of position of the wall forms for pouring, or for moving the jumbo to a new position. Because of unequal lengths of walls on curves the jumbo is made up in five panels, three of 20 feet and two of 10 feet length. Each of these sections is equipped as a unit with supporting double-flanged wheels, rectangular chutes, and "coffin" chutes. Screw jacks and steamboat ratchets are mounted at the top of the section and bear against the rock crown to resist the upward pressure of green concrete. Other jacks are installed in the ends of the horizontal struts connecting the forms on each side of the tunnel and bear against the arch beams holding the steel form face. On curves, wooden gores are built between the steel sections.

A 5-ton bridge crane, equipped with two steel hooks and powered by a 10-horsepower motor, runs on a pair of 50-pound steel rails carried on a longitudinal 10-inch H beam, which is in turn supported by the vertical struts on each panel. The bridge has a traveling speed of 300 feet per minute and the transverse traveler a hoisting speed of 100 feet and a traveling speed of 125 feet per minute.

The concrete chutes from the interior face of the jumbo to the faces of the forms are spaced from 4 to 6 feet vertically at the form face and are from 8 to 16 feet in length. Six of the chutes are of ordinary type, 12 inches deep and 30 inches average width, made of ¼-inch plate and 2-inch angles. The opening in the form face at the lower end of the chutes is closed when desired by a 12 by 24 inch steel door pushed into position, flush with the form face and bolted in place. The uppermost chute, termed the "coffin," is, in effect, a hopper 3 feet 3 inches deep at the end next the tunnel center line, 12 inches deep at the form face, and 4 feet wide. This chute is hinged at the form face, and concrete is dumped over the top of the form by raising the loading end by means of a cable connected through sheaves to a compressed-air winch located at the base of the jumbo. This "coffin" is made and operated in the manner designated to permit pouring the top 4 feet of wall, which otherwise could not be poured by gravity on account of its proximity to the roof of the tunnel.

POURING THE CONCRETE

Pouring operations consist of lifting the 2-cubic-yard bucket from the truck which has been driven to the section of the form designated for pouring, hoisting the bucket to the chute where the concrete is required, moving the bucket so that the hooks on the bucket gate are above a 3-inch round tripping iron bar over the chute; then by lowering the bucket slightly the tripping bar opens the bucket gate, pouring the concrete into the chute. When emptied the bucket is disengaged from the bar, lowered to the truck, and the other bucket is lifted, moved to the opposite side of the tunnel, and poured in a similar manner. An inspector and five to seven laborers are behind each form to puddle the concrete into place. A timber bulkhead, framed to provide a 1½ by 10 inch keyway similar to that in the invert concrete, is placed at the center or one-third point of the 80-foot length of forms, and each of these 40 or 26⅔ foot sections is poured to the top of the form before the adjacent section is started. As the top of the section is completed, carpenters remove the lower part of the bulkhead, continuing this removal as concrete rises in the section. Obviously, concreting is started at the lower level of chutes, and the doors at the ends of these are closed before pouring is started through the chutes above. A longitudinal keyway, approximately 2 by 10 inches, is formed or cut in the top of the side-wall concrete, against which the crown concrete will abut.

At present 34 hours are required for pouring an 80-foot section of wall on each side of the tunnel. After the 80-foot section has been poured the forms are required to remain in place for 12 hours. When this period has elapsed the timber bulkhead, erected at that end of the form which does not abut on a previously poured wall section, is removed, the jacks and ratchets are loosened, and the form moved to a new position. Moving the jumbo is accomplished by means of a block and tackle attached to the rails ahead and rigged to air winches installed on the jumbo at its base. Each 80-foot section of side wall requires approximately 60 hours per cycle.

CROWN SECTIONS

A structural steel jumbo is used for pouring concrete in the crown section of the diversion tunnels. Essential parts of this jumbo are a concrete gun carriage, pipe carrier, traveler, and arch-form support. All these parts are supported on flanged wheels traveling on the 90-pound steel rails laid for the side-wall jumbo.

The gun carriage, approximately 45 feet long and 47 feet high, is equipped with a 2-drum electric hoist and two pneumatic concrete guns, with their receiving hoppers and concrete conveyors of 8-inch wrought iron and rubber hose. A 25-horsepower motor is used to move the carriage on its track. Its maximum speed is 100 feet per minute in a forward direction, or 20 feet per minute in reverse. The hoist for raising the buckets of concrete is powered by a 50-horsepower motor and has a lifting speed of 300 feet per minute.

The pipe carriage and traveler serve to support the 8-inch pipe through which the concrete is forced into the space above the crown forms. The pipe carriage in pouring position is connected to the gun jumbo, while the traveler may be moved to a position between the pipe carriage and the arch-form jumbo to support the conveyor pipe.

The arch form jumbo is made up in 10-foot and 20-foot panels, each panel of which is built of structural steel and equipped with jacks to place the face of the form in correct position for pouring, or to lower the form face away from the finished concrete. Trusses at 7-foot 4-inch maximum intervals, having lower chords 33 feet 4 inches long, support the center 88° of the crown section. The ¼ inch form face and its supporting beams for the lower 11° on each side of the center is connected at one end to the truss and supported at its opposite and exterior end by screw jacks bearing on the framework of the jumbo. Bulkheads are placed to secure transverse construction joints at 40 feet or 26⅔ feet, in manner similar to those for the invert and sidewall sections.

For pouring, the electric hoist installed on the gun carriage lifts the 2-yard buckets from the truck and dumps them into the gun hopper. The gun, by air pressure, forces the concrete through the 8-inch pipe to the center of the arch form. From here it flows to its final position through a 90° elbow and continuation of the conveyor pipe, or by a chute and baffle arrangement running down the arch form. Pouring is started at the end of the form farthest removed from the gun, and the conveyor pipe and its appurtenant placing device are pulled lengthwise on the forms as concreting progresses.

All concrete in the tunnels is sprinkled as soon as the forms are removed and is kept continuously wet for 14 days thereafter. Pipes with jet sprays are installed along the walls and a film of water is permitted to run uninterrupted over the concrete surface. This water is pumped from sumps dug near the ends of the tunnel portals, the water being comparatively clear, as the silt is removed by the filtering action of the loose excavated material.

The lining of diversion tunnels constitutes a prominent part of the concrete-pouring program for Hoover Dam and serves to give an impression of the magnitude of the work and the efficient methods the contractor is using to gain the desired results. Lining the inclined spillway tunnels, the spillway open cuts, the pressure tunnels, penstocks, and pouring concrete for the intake towers and the main structure, a 727-foot dam and its attendant power plant will present special problems, each of which will be solved in different manner.—*Reclamation Era, August, 1932.*

STEEL GATES FOR DIVERSION TUNNELS

The four diversion tunnels for Hoover Dam have been excavated to their 56-foot average diameters, three have been lined with a 3-foot thickness of concrete, lining is 90 per cent completed in the other, and since November 13, 1932, the two tunnels on the Arizona side have been carrying the entire flow of the Colorado River.

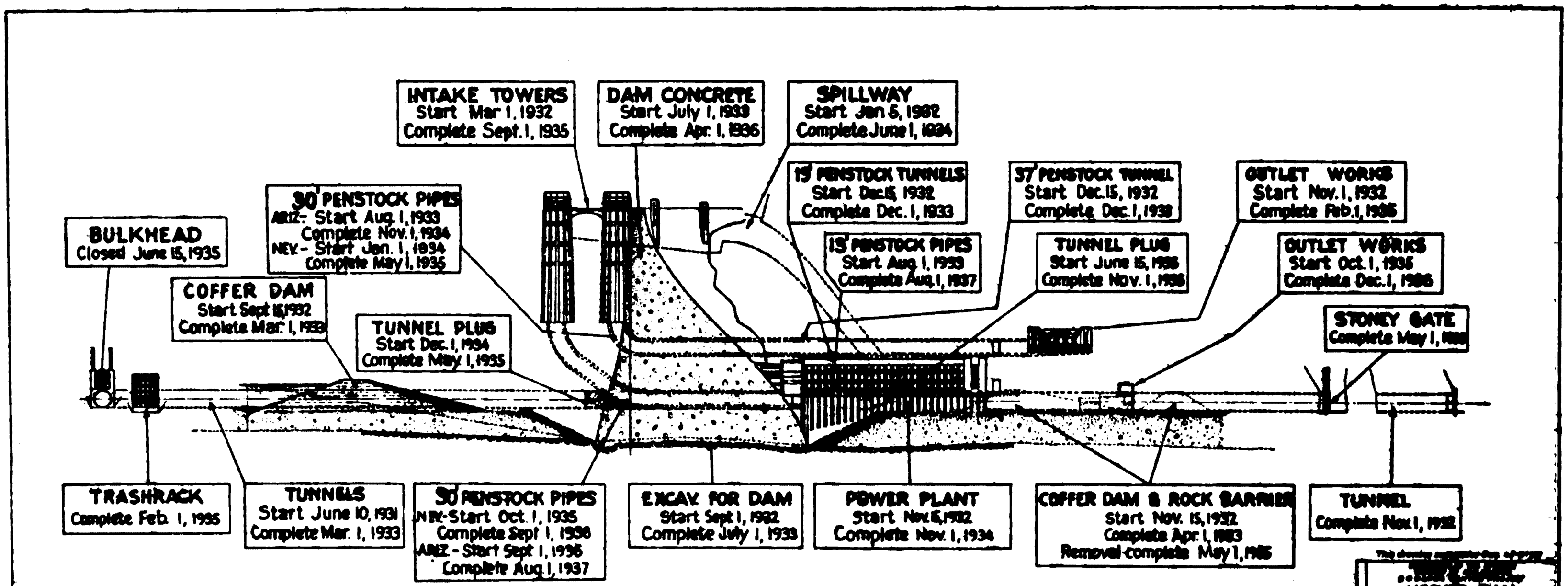
Reinforced concrete structures that have been built or are under construction at the portals of the tunnels comprise transition sections and portal structures at the inlets and outlets of all four tunnels; trash-rack foundations at the inlets and Stoney gate structures at the outlets of the two tunnels nearest the river (the inner tunnels); and bulkhead gate structures at the inlets of the two tunnels farthest from the river (the outer tunnels).

The necessity for the bulkhead and Stoney gates during the construction period is best explained by a review of the general construction program. It is contemplated that the diversion tunnels will be lined, cofferdams built, gates erected, excavation for the dam structure finished, and pouring concrete in the main structure started by the fall of 1933. Excavation and lining of the 37-foot diameter penstock header tunnels connecting with intake towers and the 18-foot diameter branch penstocks leading from header tunnels to power house are to be completed by January, 1934. Placing the 30-foot diameter steel headers in the 37-foot diameter tunnels will then be started, and it is expected these will be installed on the Arizona side by December, 1934, by which time the spillways will be completed, power house structure finished and installation of power machinery started.

The inner tunnels will then be closed, possibly one at a time, by temporary dams around the inlets and Stoney gates at the outlets. The upstream plugs and gates will be placed in these tunnels and trash racks installed at the inlets. The canyon wall outlet works are to be completed soon after, as well as the installation of the 30-foot header pipes in the Nevada 37-foot penstock tunnels.

After the plugs in the inner tunnels have been completed and gates installed therein, the Stoney gates will be lifted, the temporary dams at the inlets will be removed, and water allowed to flow through the inner tunnels. The bulkhead gates at the entrances to the outer tunnels will be dropped when the flood stage has reached such a point as is judged will provide water for power purposes by September, 1935. The water will then, under control of the gates in the plugs in the inner tunnels, start rising back of the partially completed dam.

By the late fall of 1935 the contractor proposes to finish the intake towers and the plugs in the outer tunnels at the intersection with the inclined spillway tunnels. Within the following 18 months it is expected that the main structure of the dam will be completed, the 30-foot steel penstock headers placed in the inner tunnels, penstock connections made through the 18-foot tunnels to the powerhouse, and that all of the power machinery required at this time will be installed.



CONSTRUCTION PROGRESS PICTORIAL DIAGRAM

The Stoney and bulkhead gates have been shipped to the project and are being erected in their final positions. Each Stoney gate is 50 feet wide by 35 feet high and consists of seven horizontal structural steel girders, unequally spaced from 3 feet 3 inches at the bottom to 10 feet 5 inches at the top of gate, connecting the vertical girders at the sides and covered on the river or downstream face by 5/16-inch steel skin plates.

The steel cross girders are 51 feet 6 inches long, and 6 feet 2 inches wide at center, and 3 feet 7½ inches at the vertical girder connections. Vertical girders are approximately 37 feet long, and 3 feet 7½ inches in width. Two carbon steel ear plates extend beyond the upper ends of the vertical girders to form connections for the operating hoist chains. Twenty vertical lattice-work trusses equally spaced are designed to stiffen the gate.

The concrete structure for the gate contains the counter-weight wells; the gate recesses, equipped with guide plates; a rail-protected inspection platform 56 feet above the tunnel invert; a hoist house extending across the entire width of the structure, with its floor elevation 99 feet above the tunnel invert; and a spiral stairway connecting the inspection platform and hoist house.

The gate is raised and lowered by two hoists, each hoist consisting of a sprocket driven through gears from a lined shaft which is connected through a worm gear to a 10½ horsepower slip ring induction motor.

A water seal is maintained by seal pipes of 3½-inch heavy brass tubing, one on each side of the gate. The seal pipe bears against a bronze plate on the outside corner of the gate recess and against the skin plate of the gate.

The operating chains, each 82 feet 10 inches in length, run from the gate up and around the hoist sprocket to counterweights and are constructed of 5-inch diameter bronze pins and 19 by 9 inch link units of high carbon steel plates. Motor control is secured by a drum-type reversing controller with limit switches for upper and lower ends of gate travel.

Each of the two counterweights for a gate is composed of a steel hanger and nine 11,200-pound precast concrete blocks, and is connected by earpieces to the hoist chain.

The suspended weight of each Stoney gate and chain, with gate down, is approximately 261,000 pounds and that of the counterweights and chains 215,500 pounds. Frictional losses in pins and sprocket bearings are estimated at 44,000 pounds. The gross lifting capacity of the motor and hoists is 212,000 pounds; thus a surplus lifting effort of 122,500 pounds is provided. The normal hoisting speed is 0.891 foot per minute and the total lift of the gate is 58 feet.

The 50 by 50 foot steel bulkhead gates are of much heavier construction than the Stoney gates, being designed to withstand a hydrostatic head of 295 feet at the gate seat and closure under a maximum head of 60 feet, while the maximum head for a Stoney gate will be with water at its top, and operation of the gate always will be under balanced head. Except for testing purposes, it is not contemplated that the bulkhead gates will be lifted after once being lowered. Therefore, the gate operating mechanism was designed for controlled and sealed closure rather than for recurrent operation.

Each bulkhead gate consists of 19 horizontal structural steel girders connected to a vertical girder on each side. The horizontal cross girders are 55 feet 3 inches long and 12 feet 6½ inches wide, and the vertical girders are 50 feet 5½ inches long and 10 feet 6½ inches wide. Connections to the stems of hydraulic cylinders, which control the gate operations, are obtained by extensions of the web plates of vertical girders.

On the upstream side of the gate is a cover plate unit 47 feet 0 inches wide and 50 feet 6 inches high of 1-inch thick plates riveted to cross girders, and on the exterior face of this unit are nineteen ⅞-inch plates, one for each cross girder. Skin plate units of 1¼-inch thickness are placed between cross girders at a location 10 feet 7½ inches from the upstream face of gate.

The concrete structure for the gate is 119 feet high and contains structural steel guides, brackets, roller tracks embedded in the gate recesses, and cast-steel stationary wedges fastened to the embedded brackets. An assembly recess is located above the tunnel entrance, reaching from 56 to 119 feet above the tunnel invert, and a foundation and platform is provided above the assembly recess for two large hydraulic cylinders and a control board for gate operations.

The gate is erected in raised position in the assembly recess supported there by steel I-beams until time for closure, when the means of support is shifted to lock nuts at the upper ends of hydraulic cylinder stems. When the gate is to be lowered, water will be introduced in the cylinders, the lock nuts will be removed, and by means of a suitable arrangement of piping and valves the water will be released gradually from the under sides of the pistons by an automatic equalizing device lowering the gate slowly into the closed position.

The hydraulic cylinders are constructed of steel castings, are 69 feet in height and 7 feet 7 inches inside diameter. The pistons and cylinder heads are cast steel and the piston rings are of cast manganese bronze. Maximum piston stroke is 62 feet 5 inches. Each piston stem is a 19-inch outside diameter tube with 1⅞-inch thickness of walls. The cylinders have been designed to withstand a pressure of 290 pounds per square inch.

Six roller trains of caterpillar type are installed on each side of the gate to reduce the operating friction. The carriages are attached to cross girders and the rollers travel upon a high carbon steel seat plate set in the concrete structure. The rollers are 14½ inches long by 8 inches diameter cylinders of Meehanite (a chilled cast-iron alloy) and their axles are of 1½-inch diameter rolled manganese bronze pins.

To insure tight closure of the gate and to transmit water pressure directly to the gate structure, freeing the rollers, a movable wedge is provided on each side of the gate for its full height, contacting with the stationary wedge fastened to the gate frame. The stems of the hydraulic cylinders are connected to toggle mechanisms operating the movable wedges so that overtravel of the stems, obtained by introduction of water pressure on the top of the cylinders, causes the toggles to force the wedges downward. Both stationary and movable wedges are constructed of cast steel and have a taper of ⅜-inch in 1 foot. Nickle steel was used for the parts of the wedge mechanism.

A corner filler is placed in each lower corner of each gate recess to keep rocks or other obstructions from accumulating in the recess, thus preventing complete closure of the gate. This filler consists essentially of three reinforced concrete slabs laid on a filling of clean sand. The slabs are locked in position and at the time of gate closure wlll be removed by releasing the locks and pulling the slabs upward and outward from their seats by wire ropes fastened to the slabs. The sand will be jetted from the recess by two jet pipe layouts.

Cooling sprays are provided to reduce the temperature of the metal in the gate, before lowering, to a value as near that of the river water as is practicable. The spray systems consist of three 1¼-inch diameter pipe lines; one placed horizontally above the gate with jets set to spray on the tunnel side of the gate; and the other two lines running vertically within the gate between the upstream cover plate and the skin plate.

Sprays and jets will be operated at a pressure of 100 pounds per square inch. This same force is available for seating wedges and the cylinders can be filled under 220 pounds per square inch pressure. It is estimated that the total amount of water required for lowering each gate will be approximately 98,000 gallons and that the maximum quantity required at one time will be 660 gallons per minute. The cylinders can be filled in 75 minutes and the gate lowered in 45 minutes.

The gate will be sealed in position by a rubber and a bronze seal at the downstream sides and top of the gate and a babbitted seal at the base. The bronze seal is attached by retainers to the cross girders, extends the full height of the gate at its sides and around the top and is held against the gate frame by a series of coil springs which bear against the seal retainer.

Each of the bulkhead gates weighs 2,180,000 pounds and the weight of the gates, hydraulic cylinders, wedges, and steel frame amounts to 3,065,000 pounds. More steel is used in this gate than is ordinarily required for erection of a 12-story office building. Forty-two railroad cars were required for transporting each gate to the project; one girder was loaded to a car, and as the girders extended beyond the length of the cars, empty flat cars had to be inserted between alternate girders. The average weight of a horizontal or vertical girder was 66,000 pounds.

Bolts and rivets required for field erection of a bulkhead gate weighed 29 tons and included 35,300 pounds of 1-inch diameter rivets. Construction of the two cylinders for each gate required 15 tons of stud bolts, each bolt weighing 35.4 pounds.

Exclusive of erection charges, the cost of the two Stoney gates, frames, and hoists was approximately $64,000 and of the two bulkhead gates, frames, and hydraulic hoists, approximately $266,000.—*Reclamation Era, March, 1933.*

CONSTRUCTION OF COFFERDAMS

The construction of diversion works, to leave dry the river channel where the main structure of Hoover Dam will be built, is rapidly nearing completion. The four 50-foot diameter tunnels that carry the water around the dam site have been excavated and soon will be completely lined for their aggregate length of more than 3 miles. A temporary dam was thrown across the river downstream from the inlets of the diversion tunnels, and on November 14, 1932, the entire flow of the river was turned through the two tunnels on the Arizona side. Two-thirds of a million yards of earth and rock fill were placed in the upstream cofferdam during the months of November, December, 1932, and January, 1933, and work is now concentrated on the construction of a similar structure downstream from Hoover Dam site.

The cofferdams have been designed of sufficient mass and height to turn a river flow of 200,000 cubic feet per second, the probable maximum discharge of the river during construction of the project. The flow of the Colorado River at Black Canyon usually ranges between 3,500 and 150,000 second-feet, although a discharge of 200,000 cubic feet per second may occur in unusual years. The four 50-foot diameter diversion tunnels have a fall of 14 feet from inlet to outlet and will carry 200,000 cubic feet per second with a water surface elevation at the inlets of 707, 17 feet above the tunnel roofs, and at elevation 683 at the outlets, 7 feet above the tunnels. The crest elevation of the upper cofferdam was, therefore, established at 720, giving a minimum freeboard of 13 feet; and the lower cofferdam at 690, 7 feet above the maximum water surface. The axis of the upper cofferdam is approximately 600 feet downstream from the inlets of the diversion tunnels and 850 feet upstream from the axis of Hoover Dam; the lower cofferdam is 800 feet upstream from tunnel outlets and 1,340 feet downstream from axis of the dam.

The principal mass of the upper cofferdam is composed of a central section of earth fill 98 feet in height, crest width of 70 feet and slopes of 3 to 1, containing over one-half million cubic yards of material. The slopes are protected by a rock blanket and the upstream face is paved with a 6-inch thickness of reinforced concrete. The dam is 480 feet wide, 98 feet in height, and 750 feet thick.

Percolation of water through the upper cofferdam is prevented by the face paving, a steel piling cut-off driven generally to bedrock across the upstream toe, three concrete cut-offs on each canyon wall reaching from base to crest, and rubber fabric seals on both sides and the lower edge of the face paving.

The lower cofferdam is also an earth fill which has its upstream face protected by a rock blanket. The dam will be approximately 360 feet wide, 500 feet thick, and 66 feet high. The crest width will be 50 feet, the downstream slope is to be 5 to 1 and upstream slope 2 to 1. The dam will contain approximately 230,000 cubic yards of earth and 63,000 cubic yards of rock. Two concrete cut-offs from base to crest are to be placed at each canyon wall to lessen percolation between dam and cliffs. The downstream face is not covered by a protective surfacing, since a barrier of 127,000 cubic yards of rock placed downstream from the cofferdam will act as a buffer against eddy action from the backwash of the river.

To prevent flooding of partially completed work and consequent repetition of construction, it is necessary to build the cofferdams during a single season of low-river flow and, as construction of the dams involves the placing of over a million cubic yards of earth and rock, with flash floods causing possible delays, commencement of construction was advisable at the earliest date. Therefore, when the river flow diminished following the flood of early September, construction operations were immediately instituted. A fill of tunnel muck was advanced from the Nevada side of the canyon to the center of the stream, downstream, and back to the Nevada side inclosing half of the upper cofferdam site and forcing the river toward the Arizona side. The inclosed area was pumped dry, a 5-cubic yard electric dragline was brought down from the Arizona gravel deposit, three 3½-cubic yard electric shovels and a fleet of trucks were moved to the site and removal of the silt and sand was started to uncover a consolidated formation suitable for the dam foundation. This formation was discovered at elevation 622, 18 feet below the river bed and 98 feet below the dam crest.

A pile trestle bridge was built across the river immediately downstream from the inlets of diversion tunnels and as soon as tunnel No. 4 was opened for river flow, trucks commenced hauling rock and dumping into the river on both sides of the bridge. Within 30 hours after initial diversion, the temporary dam thus constructed had risen sufficiently high that all water was flowing through the Arizona diversion tunnels except a small amount of seepage through the hastily constructed fill. To cut off the seepage and to prevent flooding the cofferdam site by possible flood, the temporary dam was then heightened and widened, using muck from the cofferdam excavation.

Soon after the temporary dam was completed above the upper cofferdam, a similar fill was finished immediately upstream from the outlets of the diversion tunnels. The water in the river channel, thus inclosed, was pumped out and excavation of the upper cofferdam extended to the Arizona wall. The excavated material was hauled by 8 and 10 yard trucks to the railroad and used for widening the railroad bench along the river, or unloaded at a dump ground near the mouth of Hemenway Wash. The excavation for the upper cofferdam was started on September 25 and finished on December 5. Approximately 212,872 cubic yards of sand and gravel were removed at an average rate of 5,200 cubic yards a day.

Desirable material for the earth fills had been located by test holes in Hemenway Wash. Pits were opened with 3½-cubic-yard electric shovels, railroad track laid to the pits from the Black Canyon line of Six Companies (Inc.), and the material loaded into side dump cars for transportation to the cofferdams. Arriving at the unloading site, the earth was dumped from a trestle, reloaded into trucks by 3½-cubic-yard shovels and hauled to the cofferdam fill. Here it was dumped by the trucks, spread by bulldozers installed on 30-horsepower caterpillar tractors, the correct amount of water sprinkled on the material, and the mixture rolled by 6-ton Rohl rollers pulled by 30-horsepower tractors.

Approximately 510,000 cubic yards of material were placed from October 31, 1932, to completion of the fill on January 1, 1933. More than 420,000 cubic yards of earth were deposited in the fill during December, 18,000 cubic yards or 4,000 truck loads of material being placed in many 24-hour periods of that month. Three 3½-cubic-yard electric shovels were used at the pit for loading the trains and two or three shovels of the same capacity for loading the fleet of 35 trucks at the trestle near the cofferdam. For hours at a time each shovel was loading, swinging, and dumping a shovelful in less than 30 seconds.

Steel sheet piling at the upstream toe of the upper cofferdam was driven by air hammers, except near the Nevada canyon wall where an unusual number of large bowlders was encountered. A trench was excavated at this location and the piling placed on a concrete footing resting on bedrock. The 5-cubic-yard dragline with its 80-foot boom was used to set sheet piling in position and for holding the air hammer when the piling was driven. Each pile is of the arch-web type, 16 inches wide and 40 to 55 feet long.

The concrete cut-offs at the canyon wall near the center of the dam were formed and poured as the earth fill progressed upward. The concrete was hauled from the mixing plant in 4-cubic-yard agitators, and the agitators were lifted from trucks to the pouring site by the 5-cubic-yard drag line.

The rock blankets on the slopes were placed after the earth fill was nearly finished. The rock was secured from the stripping operations or excavations on canyon walls, requiring 151,000 cubic yards for the slope facings.

The reinforced concrete paving on the upstream slope is poured in 16-foot sections running from a concrete curb at the sheet piling cut-off to the crest of the dam. This work was started on December 20, 1932, and was approximately 60 per cent completed at the end of the following January. When finished, the paving will contain 3,500 cubic yards of concrete and almost 4 miles of ⅝-inch reinforcement bars.

The site of the rock barrier has been excavated and more than 80,000 cubic yards of rock have been dumped therein. This fill when completed will have a thickness of 210 feet, a height of 54 feet, and will contain approximately 127,000 cubic yards of rock.

Construction of the lower cofferdam has been delayed by stripping of canyon walls and the excavations at the sites of the outlet works. The earth fill for the dam probably will be secured from Hemenway Wash. The railroad will be extended downstream, and end at a trestle erected near Hoover Dam site, where the material will be dumped, reloaded, and hauled to the cofferdam site and the fill constructed in manner similar to that for the upper cofferdam.

All four diversion tunnels will be completely lined and both cofferdams are expected to be completed before the high water of the spring and summer of 1933. The low stage of the river from October to January and the respite from flash floods have materially aided the uninterrupted progress of construction.

The cofferdams are only to serve a temporary purpose until Hoover Dam is built above the entrances to outlet tunnels at the bases of intake towers; then the bulkhead gates will be closed at the inlets of the outer diversion tunnels, the flow of the river temporarily controlled by slide gates installed in the inner diversion tunnels, and the upper cofferdam will be overtopped and inundated by the reservoir back of Hoover Dam. The lower cofferdam and rock barrier will be removed from the river channel to clear the tailrace for efficient operation of the power plant.—*Reclamation Era, April, 1933.*

CONTRACT WITH BABCOCK & WILCOX CO. FOR PENSTOCK PIPES

Bids were opened at Denver, Colo., on June 15, 1932, under Specification No. 534 for furnishing, erecting, and painting plate-steel outlet pipes with branch connections, Y branches, and manifolds on concrete-lined tunnels at the Hoover Dam. The Babcock & Wilcox Co., of New York City and Barberton, Ohio, submitted the low bid of $10,908,000 and was awarded the contract. A performance bond of $6,000,000 was required to fully protect the Government against any possible loss resulting from suit for patent infringement.

The main header pipes are 30 feet in diameter, reducing to 25 feet, and branch pipes have diameters of 13 feet, 8 feet 6 inches, and 7 feet 2 inches. The contractor is now erecting a fabricating plant at Bechtel, 1 mile from the dam site, where the steel plates will be rolled and the pipe sections fabricated. The Government will transport the pipe sections from the fabricating plant to landing platforms at entrances to tunnel adits. From there the contractor will transport the pipes into final position in the tunnels.

LIST OF PRINCIPAL CONTRACTS

Work or material	Contractor	Contract price	Date of contract	No. of specifications
Power for construction purposes	Nevada-California Power Co. and Southern Sierras Power Co.	$1,730,000.00	Oct. 28, 1930	486-D.
Boulder City - Hoover Dam Highway.	General Construction Co	329,917.15	Jan. 23, 1931	517.
United States Construction Railroad.	Lewis Construction Co	455,509.50	Jan. 28, 1931	518.
Hoover Dam, power plant and appurtenant works.	Six Companies (Inc.)	48,890,995.00	Mar. 11, 1932	519.
Grading, surfacing, paving sidewalks, curbs, gutters, sewer and water systems, Boulder City.	New Mexico Construction Co	273,972.00	July 27, 1931	521.
Bulkhead and Stoney gates and hoists.	Consolidated Steel Corporation, (Schedules 1 and 2).	233,200.00	June 11, 1932	533.
	Hardie-Tynes Manufacturing Co., (Schedule 3).	60,395.00	May 20, 1932	
	Reading Iron Co., (Schedule 4)	32,500.00	May 20, 1932	
Plate-steel outlet pipes for Hoover power plant and appurtenant works.	Babcock & Wilcox Co	10,908,000.00	July 9, 1932	534.
Cement (335,000 barrels)	Riverside Cement Co., California Portland Cement Co., Southwestern Portland Cement Co., Monolith Portland Cement Co.	428,800.00	Feb. 10, 1932	3333-A.
150-ton permanent cableway	Lidgerwood Manufacturing Co	172,110.00	Oct. 10, 1932	537.
Hydraulic apparatus for Hoover power plant.				540.
Cylinder gates and entrance liners for intake towers.	Goslin-Birmingham Manufacturing Co. (item 1).	56,000.00		541.
~~Cement blending plant~~	Westinghouse Electric and Manufacturing Co. (item 2).	334,737.00		

PART V : ALL-AMERICAN CANAL

SUMMARY OF GAULT REPORT

The All-American Canal, authorized for construction under the Boulder Canyon project act, will be 80 miles in length, and the branch canal to the Coachella Valley 130 miles long, according to a report on "All-American Canal Investigations" by H. J. Gault, dated May, 1931. These investigations have been carried on since May, 1929, by the Bureau of Reclamation in cooperation with the Imperial irrigation district and the Coachella Valley County water district.

GENERAL DESCRIPTION

It is planned to divert from the Colorado River at a point about 5 miles above the Laguna Dam of the Yuma (Federal) irrigation project, in section 9, T. 15 S., R. 24 E., S. B. M. The proposed diversion dam will be of the floating or Indian weir type, with a crest 1,700 feet long, providing floodway capacity of 170,000 second-feet without overtopping the gate structure. Total flood capacity of the works would be 259,000 second-feet, besides the canal diversions. Six desilting basins are provided, any five of which are to be used for diversion to the canal, while the sixth basin is being sluiced. The dam will raise the river water surface about 22 feet.

Capacity assumed for the main canal is 15,000 second-feet from the dam to Siphon Drop on the reservation division of the Yuma project, where 2,000 second-feet are diverted for this project; 13,000 second-feet from Siphon Drop to Pilot Knob, and 10,000 westward from Pilot Knob for the Imperial and Coachella Valleys. The Coachella Canal would carry 2,000 second-feet at the head and 1,000 where it enters Coachella Valley. It is estimated that the diversion dam, desilting works, All-American Canal, and Coachella Canal can be built for something less than $34,000,000. The Imperial Dam—Siphon Drop section of the All-American Canal—will have a bottom width of 130 feet, a water depth of 22 feet, and will carry an amount of water equal to 70 per cent of the aveage flow of the Colorado River at the Hoover Dam.

CANAL LOCATION

The route of the canal follows the river closely to Laguna Dam and then parallels the present Yuma main canal to the Siphon Drop. Several washes must be crossed by culverts or siphons. From the Siphon Drop to Pilot Knob the canal follows the foothills, and bridges for the Southern Pacific Railroad, the Inter-California Railroad, the State highway, and county road will be required. Beyond Pilot Knob, at three different points and for a total distance of 14.8 miles, the canal is located near to and parallel with the international boundary.

For 10½ miles the canal line passes through the sand hills, a region covered with dunes except for a few bare spots. The deepest cut in the sand-hill area is over 100 feet and the dune sand is about 80 feet in depth. Instead of lining the canal with concrete in this sand-hill area, it appears advisable to leave it unlined and prevent sand blowing into the canal as much as possible, and to remove the sand by suction dredges if necessary. The canal section through the sand hills is designed with a mean velocity of 4.5 feet per second at full capacity, which is intended to be nonscouring and nonsilting. Portions excavated in finer sand for the water section and liable to scour are to be overexcavated to a depth of 1½ feet and the space refilled with screened gravel to form a scour-resisting lining. Means of preventing sand from being blown into the canal may be by one or more of the following methods: (*a*) Growing vegetation on the sand in a zone on each side of the canal by irrigation from small pipe lines; (*b*) spraying the sand with crude oil;

(*c*) covering the dune sand with material from the canal excavation in the mesa formation which is too coarse to be blown by the wind; (*d*) excavating a berm 15 feet wide on each side of the canal at the mesa floor level. By adopting these methods in operation it is expected that the quantity of sand blown or drifted into the canal will be small.

From the sand hills the canal line runs west across the east mesa to the present East High Line canal of the Imperial district distribution system, and then through the extreme southern portion of the Imperial Valley, where it crosses 17 principal ditches and passes through the town of Calexico before it reaches its terminus, the present West Side main canal. Here the water surface is −6.7, and at this point the canal has capacity sufficient to supply lands under the West Side canal and also to furnish water for additional lands on the West Side mesa.

COACHELLA CANAL

About 16 miles west of Pilot Knob the Coachella branch canal will take out of the All-American Canal and run in a northwesterly direction across the east mesa. The location crosses the Southern Pacific Railroad near Iris, passes east of the Salton Sea and the Coachella Valley to a point near the town of Coachella, where it again crosses the Southern Pacific and runs southwesterly across the valley, and then south to the Riverside-Imperial county line. There are more than 160 washes crossing the Coachella Canal line, ordinarily dry, but at times of heavy rains or cloudbursts, carrying floods of short duration, heavily loaded with sand and silt; these must be crossed with siphons or culverts. By combining these washes in groups by the use of training levees and diversion channels, the number of structures can be reduced to about 90. The last 47 miles of the canal will be lined with concrete.

SURVEYS

Soil surveys of 1920 in the Imperial Valley have been reviewed and a soil reconnaissance was made of the Pilot Knob mesa, lying east of the sand hills. The lands within the present Imperial irrigation district have been classified. Topography was taken of a zone along the All-American Canal covering a width of 1,000 feet and along the Coachella Canal of a zone 800 feet wide. The following additional field work is necessary: (1) Completion of topography along the Coachella Canal; (2) relocation of first 10 or 15 miles of Coachella Canal; (3) studies and surveys of minor revisions of location; (4) studies for wasteways, surveys of washes, and location of training levees. Final location of turnouts for new lands can not be made until the lateral ditches are located, which in turn should follow topographic mapping and investigations of the irrigable areas.

The Imperial irrigation district, comprising 512,000 acres, is supplied with a complete system of lateral ditches, with about 425,000 acres in cultivation. In the Coachella Valley about 16,300 acres are now under cultivation, being supplied by pumping from wells. There is no general canal or lateral system in the Coachella Valley. The east and west mesas, the Dos Palmas area east of the Salton Sea, Pilot Knob mesa, and the greater part of the Coachella Valley are desert lands with no improvements. It is contemplated that the boundaries of the Imperial irrigation district will be extended to include lands in the Coachella Valley irrigable from the canal when constructed.

The accompanying table shows the irrigable lands west of Pilot Knob as determined by the Imperial irrigation district.

These areas may be materially changed after irrigable area surveys have been made.

There are opportunities for development of power at Pilot Knob and at several points on the canals, but such development must be financed by the irrigation district and other interested agencies. Where canal drops are planned for power development, chute drops will be built by the Government, but it is expected that power plants will eventually be constructed by the district. Before any money is appropriated for construction of this canal a repayment contract must be made with the irrigation district, and negotiations are now under way. This contract will provide for the delivery of stored water from the Hoover Reservoir and the Colorado River in accordance with allocations yet to be made.—*Reclamation Era, July 1931.*

All-American Canal project—Summary of irrigable lands west of Pilot Knob

Lands	Acres gravity	Acres under pump lifts					Total
		50 feet	100 feet	150 feet	200 feet	235 feet	
Imperial irrigation district	521, 600						521, 600
East mesa	195, 432			950	1, 484		197, 866
Dos Palmas	10, 450						10, 450
Coachella	115, 025		27, 315	2, 200	8, 500		153, 040
West mesa		29, 500		85, 289		11, 000	125, 789
Total, west of sand hills	842, 507	29, 500	27, 315	88, 439	9, 984	11, 000	1, 008, 745
Pilot Knob mesa					22, 334		22, 334
Grand total	842, 507	29, 500	27, 315	88, 439	32, 318	11, 000	1, 031, 079

NOTE.—Pumping lifts are approximate for the various areas and are representative of maximums.

STANDARD GOVERNMENT FORM OF CONTRACT

(CONSTRUCTION)

DEPARTMENT OF THE INTERIOR AND SIX COMPANIES (INC.)

Contract for construction of Hoover Dam power plant and appurtenant works.
Amount, $48,890,995.50.
Place, Boulder Canyon project, Arizona-California-Nevada.

This contract, entered into this 11th day of March, 1931, by the United States of America, hereinafter called the Government, represented by the contracting officer executing this contract, and Six Companies (Inc.), a corporation organized and existing under the laws of the State of Delaware, and of the city of San Francisco, in the State of California, hereinafter called the contractor, witnesseth that the parties hereto do mutually agree as follows:

ARTICLE 1. *Statement of work.*—The contractor shall furnish labor and materials, and perform all work required for construction of Hoover Dam power plant and appurtenant works, as covered by items Nos. 1 to 119, inclusive, of the Schedule of Specifications No. 519, Boulder Canyon project, Arizona-California-Nevada, for the consideration of forty-eight million eight hundred ninety thousand nine hundred ninety-five and 50/100 dollars ($48,890,995.50) in strict accordance with the specifications, schedules, and drawings, all of which are made a part hereof and designated as follows:

Specifications No. 519, amended as provided in notices to bidders, dated February 17 and 21, 1931.

The work shall be commenced, and shall be completed within the time provided in paragraph twenty-four (24) of the specifications: *Provided,* That the contract period of time is exclusive of any time that may intervene between the effective date of orders of the Government to suspend operations on account of weather (or other) conditions and the effective date of orders to resume work.

ART. 2. *Specifications and drawings.*—The contractor shall keep on the work a copy of the drawings and specifications and shall at all times give the contracting officer access thereto. Anything mentioned in the specifications and not shown on the drawings, or shown on the drawings and not mentioned in the specifications shall be of like effect as if shown or mentioned in both. In case of difference between drawings and specifications, the specifications shall govern. In any case of discrepancy in the figures or drawings, the matter shall be immediately submitted to the contracting officer, without whose decision said discrepancy shall not be adjusted by the contractor, save only at his own risk and expense. The contracting officer shall furnish from time to time such detail drawings and other information as he may consider necessary, unless otherwise provided. Upon completion of the contract the work shall be delivered complete and undamaged.

ART. 3. *Changes.*—The contracting officer may at any time, by a written order, and without notice to the sureties, make changes in the drawings and (or) specifications of this contract and within the general scope thereof. If such changes cause an increase or decrease in the amount due under this contract, or in the time required for its performance, an equitable adjustment shall be made and the contract shall be modified in writing accordingly. No change involving an estimated increase or decrease of more than five hundred dollars shall be ordered unless approved in writing by the head of the department or his duly authorized representative. Any claim for adjustment under this article must be asserted within 10 days from the date the change is ordered, unless the contracting officer shall for proper cause extend such time, and if the parties can not agree upon the adjustment the dispute shall be determined as provided in article 15 hereof. But nothing provided in this article shall excuse the contractor from proceeding with the prosecution of the work so changed.

ART. 4. *Changed conditions.*—Should the contractor encounter, or the Government discover, during the progress of the work, subsurface and (or) latent conditions at the site materially differing from those shown on the drawings or indicated in the specifications, the attention of the contracting officer shall be called immediately to such conditions before they are disturbed.

The contracting officer shall thereupon promptly investigate the conditions, and if he finds that they materially differ from those shown on the drawings or indicated in the specifications, he shall at once, with the written approval of the head of the department or his representative, make such changes in the drawings and (or) specifications as he may find necessary, and any increase or decrease of cost and (or) difference in time resulting from such changes shall be adjusted as provided in article 3 of this contract.

ART. 5. *Extras.*—Except as otherwise herein provided, no charge for any extra work or material will be allowed unless the same has been ordered in writing by the contracting officer and the price stated in such order.

ART. 6. *Inspection.*—(*a*) All material and workmanship (if not otherwise designated by the specifications) shall be subject to inspection, examination, and test by Government inspectors at any and all times during manufacture and (or) construction and at any and all places where such manufacture and (or) construction are carried on. The Government shall have the right to reject defective material and workmanship or require its correction. Rejected workmanship shall be satisfactorily corrected and rejected material shall be satisfactorily replaced with proper material without charge therefor, and the contractor shall promptly segregate and remove the same from the premises.

(*b*) The contractor shall furnish promptly without additional charge, all reasonable facilities, labor, and materials necessary for the safe and convenient inspection and test that may be required by the inspectors. All inspection and tests by the Government shall be performed in such manner as not to unnecessarily delay the work. Special, full size, and performance tests shall be as described in the specifications. The contractor shall be charged with any additional cost of inspection when material and workmanship are not ready at the time inspection is requested by the contractor.

(*c*) Should it be considered necessary or advisable by the Government at any time before final acceptance of the entire work to make an examination of work already completed, by removing or tearing out same, the contractor shall on request promptly furnish all necessary facilities, labor, and material. If such work is found to be defective in any material respect, due to fault of the contractor or his subcontraactors, he shall defray all the expenses of such examination and of satisfactory reconstruction. If, however, such work is found to meet the requirements of the contract, the actual cost of labor and material necessarily involved in the examination and replacement, plus 15 per cent, shall be allowed the contractor and he shall, in addition, if completion of the work has been delayed thereby, be granted a suitable extension of time on account of the additional work involved.

(*d*) Inspection of material and finished articles to be incorporated in the work at the site shall be made at the place of production, manufacture, or shipment, whenever the quantity justifies it, unless otherwise stated in the specifications; and such inspection and acceptance, unless otherwise stated in the specifications, shall be final, except as regards latent defects, departures from specific requirements of the contract and the specifications and drawings made a part thereof, damage or loss in transit, fraud, or such gross mistakes as amount to fraud. Subject to the requirements contained in the preceding sentence, the inspection of material and workmanship for final acceptance as a whole or in part shall be made at the site.

ART. 7. *Materials and workmanship.*—Unless otherwise specifically provided for in the specifications, all workmanship, equipment, materials, and articles incorporated in the work covered by this contract are to be of the best grade of their respective kinds for the purpose. Where equipment, materials, or articles are referred to in the specifications as "equal to" any particular standard, the contracting officer shall decide the question of equality. The contractor shall furnish to the contracting officer for his approval the name of the manufacturer of machinery, mechanical and other equipment which he contemplates installing, together with their performance capacities and other pertinent information. When required by the specifications, or when called for by the contacting officer, the contractor shall furnish the contracting officer for approval full information concerning the materials or articles which he contemplates incorporating in the work. Samples of materials shall be submitted for approval when so directed. Machinery, equipment, materials, and articles installed or used without such approval shall be at the risk of subsequent rejection. The contracting officer may require the contractor to dismiss from the work such employee as the contracting officer deems incompetent, careless, insubordinate, or otherwise objectionable.

Art. 8. *Superintendence by contractor.*—The contractor shall give his personal superintendence to the work or have a competent foreman or superintendent, satisfactory to the contracting officer, on the work at all times during progress, with authority to act for him.

Art. 9. *Delays—Damages.*—If the contractor refuses or fails to prosecute the work, or any separable part thereof, with such diligence as will insure its completion within the time specified in article 1, or any extension thereof, or fails to complete said work within such time, the Government may, by written notice to the contractor, terminate his right to proceed with the work or such part of the work as to which there has been delay. In such event, the Government may take over the work and prosecute the same to completion by contract or otherwise, and the contractor and his sureties shall be liable to the Government for any excess cost occasioned the Government thereby. If the contractor's right to proceed is so terminated, the Government may take possession of and utilize in completing the work such materials, appliances, and plant as may be on the site of the work and necessary therefor. If the Government does not terminate the right of the contractor to proceed, the contractor shall continue the work, in which event the actual damages for the delay will be impossible to determine and in lieu thereof the contractor shall pay to the Government as fixed, agreed, and liquidated damages for each calendar day of delay until the work is completed or accepted the amount as set forth in the specifications or accompanying papers and the contractor and his sureties shall be liable for the amount thereof: *Provided,* That the right of the contractor to proceed shall not be terminated or the contractor charged with liquidated damages because of any delays in the completion of the work due to unforeseeable causes beyond the control and without the fault or negligence of the contractor, including, but not restricted to, acts of God, or of the public enemy, acts of the Government, fires, floods, epidemics, quarantine restrictions, strikes, freight embargoes, and unusually severe weather or delays of subcontractors due to such causes: *Provided further,* That the contractor shall within ten days from the beginning of any such delay notify the contracting officer in writing of the causes of delay, who shall ascertain the facts and the extent of the delay, and his findings of facts thereon shall be final and conclusive on the parties hereto, subject only to appeal, within thirty days, by the contractor to the head of the department concerned, whose decision on such appeal as to the facts of delay shall be final and conclusive on the parties hereto.

Art. 10. *Permits and care of work.*—The contractor shall, without additional expense to the Government, obtain all required licenses and permits and be responsible for all damages to persons or property that occur as a result of his fault or negligence in connection with the prosecution of the work, and shall be responsible for the proper care and protection of all materials delivered and work performed until completion and final acceptance.

Art. 11. *Eight-hour law—Convict labor.*—(*a*) No laborer or mechanic doing any part of the work contemplated by this contract, in the employ of the contractor or any subcontractor contracting for any part of said work contemplated, shall be required or permitted to work more than eight hours in any one calendar day upon such work at the site thereof. For each violation of the requirements of this article a penalty of five dollars ($5) shall be imposed upon the contractor for each laborer or mechanic for every calendar day in which such employee is required or permitted to labor more than eight hours upon said work, and all penalties thus imposed shall be withheld for the use and benefit of the Government: *Provided,* That this stipulation shall be subject in all respects to the exceptions and provisions of the act of June 19, 1912 (37 Stat. 137), relating to hours of labor.

(*b*) The contractor shall not employ any person undergoing sentence of imprisonment at hard labor.

Art. 12. *Covenant against contingent fees.*—The contractor warrants that he has not employed any person to solicit or secure this contract upon any agreement for a commission, percentage, brokerage, or contingent fee. Breach of this warranty shall give the Government the right to terminate the contract, or, in its discretion, to deduct from the contract price or consideration the amount of such commission, percentage, brokerage, or contingent fees. This warranty shall not apply to commissions payable by contractors upon contracts or sales secured or made through bona fide established commercial or selling agencies maintained by the contractor for the purpose of securing business.

Art. 13. *Other contracts.*—The Government may award other contracts for additional work, and the contractor shall fully cooperate with such other contractors and carefully fit his own work to that provided under other contracts as may be directed by the contracting officer.

The contractor shall not commit or permit any act which will interfere with the performance of work by any other contractor.

ART. 14. *Officials not to benefit.*—No Member of or Delegate to Congress, or Resident Commissioner, shall be admitted to any share or part of this contract or to any benefit that may arise therefrom, but this provision shall not be construed to extend to this contract if made with a corporation for its general benefit.

ART. 15. *Disputes.*—Except as otherwise specifically provided in this contract, all disputes concerning questions of fact arising under this contract shall be decided by the contracting officer or his duly authorized representative, subject to written appeal by the contractor within thirty days to the head of the department concerned, whose decision shall be final and conclusive upon the parties thereto as to such questions of fact. In the meantime the contractor shall diligently proceed with the work as directed.

ART. 16. *Payments to contractors.*—(*a*) Unless otherwise provided in the specifications, partial payments will be made as the work progresses at the end of each calendar month, or as soon thereafter as practicable, on estimates made and approved by the contracting officer. In preparing estimates the material delivered on the site and preparatory work done may be taken into consideration.

(*b*) In making such partial payments there shall be retained 10 per cent on the estimated amount until final completion and acceptance of all work covered by the contract: *Provided, however*, That the contracting officer, at any time after 50 per cent of the work has been completed, if he finds that satisfactory progress is being made, may make any of the remaining partial payments in full: *And provided further*, That on completion and acceptance of each separate building, vessel, public work, or other division of the contract, on which the price is stated separately in the contract, payment may be made in full, including retained percentages thereon, less authorized deductions.

(*c*) All material and work covered by partial payments made shall thereupon become the sole property of the Government, but this provision shall not be construed as relieving the contractor from the sole responsibility for the care and protection of materials and work upon which payments have been made or the restoration of any damaged work, or as a waiver of the right of the Government to require the fulfillment of all of the terms of the contract.

(*d*) Upon completion and acceptance of all work required hereunder, the amount due the contractor under this contract will be paid upon the presentation of a properly executed and duly certified voucher therefor, after the contractor shall have furnished the Government with a release, if required, of all claims against the Government arising under and by virtue of this contract, other than such claims, if any, as may be specifically excepted by the contractor from the operation of the release in stated amounts to be set forth therein.

ART. 17. *Additional security.*—Should any surety upon the bond for the performance of this contract become unacceptable to the Government, the contractor must promptly furnish such additional security as may be required from time to time to protect the interests of the Government and of persons supplying labor or materials in the prosecution of the work contemplated by the contract.

ART. 18. *Definitions.*—(*a*) The term "head of department" as used herein shall mean the head of the executive department or independent establishment involved, and "his representative" means any person authorized to act for him.

(*b*) The term "contracting officer" as used herein shall include his duly appointed successor or his duly authorized representative.

ART. 19. *Alterations.*—The following changes were made in this contract before it was signed by the parties hereto: The words "other than the contracting officer" have been deleted from paragraph (*a*) of article 18 hereof.

ART. 20. *Approval.*—This contract shall be subject to the written approval of the Commissioner of the Bureau of Reclamation and the Secretary of the Interior, and shall not be binding until so approved.

In witness whereof, the parties hereto have executed this contract as of the day and year first above written.

THE UNITED STATES OF AMERICA,
By R. F. WALTER,
Chief Engineer, Bureau of Reclamation.
SIX COMPANIES (INC.), *Contractor.*
By W. H. WATTIS, [SEAL.]
President, 510 Financial Center Building, San Francisco, Calif.

Approved April 11, 1931.

ELWOOD MEAD,
Commissioner, Bureau of Reclamation.
RAY LYMAN WILBUR,
Secretary of the Interior.
Two witnesses:
PAUL S. MARRIN.
SAMUEL S. STEVENS.

I, Charles A. Shea, certify that I am the secretary of the corporation named as contractor herein; that W. H. Wattis, who signed this contract on behalf of the contractor, was then president of said corporation; that said contract was duly signed for and in behalf of said corporation by authority of its governing body, and is within the scope of its corporate powers.

CHARLES A. SHEA. [SEAL.]

I hereby certify that, to the best of my knowledge and belief, based upon observation and inquiry, ---------------------------------- who signed this contract for the ------------- had authority to execute the same, and is the individual who signs similar contracts on behalf of this corporation with the public generally.

—— ——,
Contracting Officer.

This contract is authorized by the act of December 21, 1928 (45 Stat. 1057), known as the Boulder Canyon project act, and acts amendatory thereof or supplemental thereto.

DIRECTIONS FOR PREPARATION OF CONTRACT

1. This form shall be used for every formal contract for the construction or repair of public buildings or works, but its use will not be required in foreign countries.

2. There shall be no deviation from this standard contract form, except as provided for in these directions, without prior approval of the Director of the Bureau of the Budget obtained through the Interdepartmental Board of Contracts and Adjustments. Where interlineations, deletions, additions, or other alterations are permitted, specific notation of the same shall be entered in the blank space following the article entitled "Alterations" before signing. This article is not to be construed as general authority to deviate from the standard form. Deletion of the descriptive matter not applicable in the preamble need not be noted in the article entitled "Alterations."

3. The blank space of Article 1 is intended for the insertion of a statement of the work to be done, together with place of performance, or for the enumeration of papers which contain the necessary data.

4. If it is deemed necessary to include an article on Patents the Invitation to Bidders shall so state and the following article be used:

> ARTICLE ----. *Patents.*—The contractor shall hold and save the Government, its officers, agents, servants, and employees, harmless from liability of any nature or kind for or on account of the use of any patented or unpatented invention, article, or appliance furnished or used in the performance of this contract, excepting patented articles required by the Government in its specifications, the use of which the contractor does not control.

5. Where only one payment is contemplated, upon completion of the contract, all except paragraph (*d*) of Article 16, "Payments to Contractor," must be stricken out.

6. If approval of the contract is required before it shall become binding, the following article must be added:

ARTICLE ----. *Approval.*—This contract shall be subject to the written approval of ------------------------------ and shall not be binding until so approved.

Contracts subject to approval are not valid until approved by the authority designated to approve them, and the contractor's copy will not be delivered, nor any distribution made, until such approval. All changes and deletions must have been made before the contract is forwarded for approval.

7. The number of executed copies and of certified copies, designation of disbursing officer, statement of appropriation, amount of bond, designation of place of inspection, as well as other administrative details, shall be as directed by the department to which the contract pertains.

8. All blank spaces must be filled in or ruled out. The contract must be dated, and the bond must bear the same or subsequent date.

9. An officer of a corporation, a member of a partnership, or an agent signing for the principal, shall place his signature and title after the word "By" under the name of the principal. A contract executed by an attorney or agent on behalf of the contractor shall be accompanied by two authenticated copies of his power of attorney, or other evidence of his authority to act on behalf of the contractor.

10. If the contractor is a corporation, one of the certificates following the signatures of the parties must be executed. If the contract is signed by the secretary of the corporation, then the first certificate must be executed by some other officer of the corporation under the corporate seal, or the second certificate executed by the contracting officer. In lieu of either of the foregoing certificates there may be attached to the contract copies of so much of the records of the corporation as will show the official character and authority of the officer signing, duly certified by the secretary or assistant secretary, under the corporate seal, to be true copies.

11. The full name and business address of the contractor must be inserted, and the contract signed with his usual signature. Typewrite or print name under all signatures to contract and bond.

12. The contracting officer must fill in the citation of the act authorizing the contract as indicated at the end of the last page of the contract.

13. The Invitation, Bid, Acceptance, and Instructions to Bidders are not to be incorporated in the contract.

14. The specifications should include a paragraph stating the amount of liquidated damages that will be paid by the contractor for each calendar day of delay, as indicated in Article 9 of the contract.

Specifications No. 519

UNITED STATES

DEPARTMENT OF THE INTERIOR

RAY LYMAN WILBUR, Secretary

BUREAU OF RECLAMATION

ELWOOD MEAD, Commissioner

SPECIFICATIONS, SCHEDULE, AND DRAWINGS

HOOVER DAM, POWER PLANT
AND
APPURTENANT WORKS

BOULDER CANYON PROJECT

ARIZONA–CALIFORNIA–NEVADA

Bids will be received at the office of the Bureau of Reclamation, Denver, Colorado, until 10 o'clock a. m., March 4, 1931.

UNITED STATES DEPARTMENT OF THE INTERIOR,
BUREAU OF RECLAMATION,
OFFICE OF THE COMMISSIONER,
Washington, December 15, 1930.

Memorandum for the Secretary.

Herewith is transmitted specifications and schedule of drawings of Hoover Dam, power plant, and appurtenant works. As soon as these are approved, bids will be invited.

The estimates show that the work can be completed within the limits fixed by the authorization in the Boulder Canyon act. The pressure for action on this matter, as a means of furnishing employment and encouraging a revival of business is, as you know, very great. It is proposed, if these can be approved within the next day or two, to fix the date for opening bids as March 4, 1931.

ELWOOD MEAD, *Commissioner.*

Approved: December 17, 1930.
RAY LYMAN WILBUR,
Secretary.

PLATE I

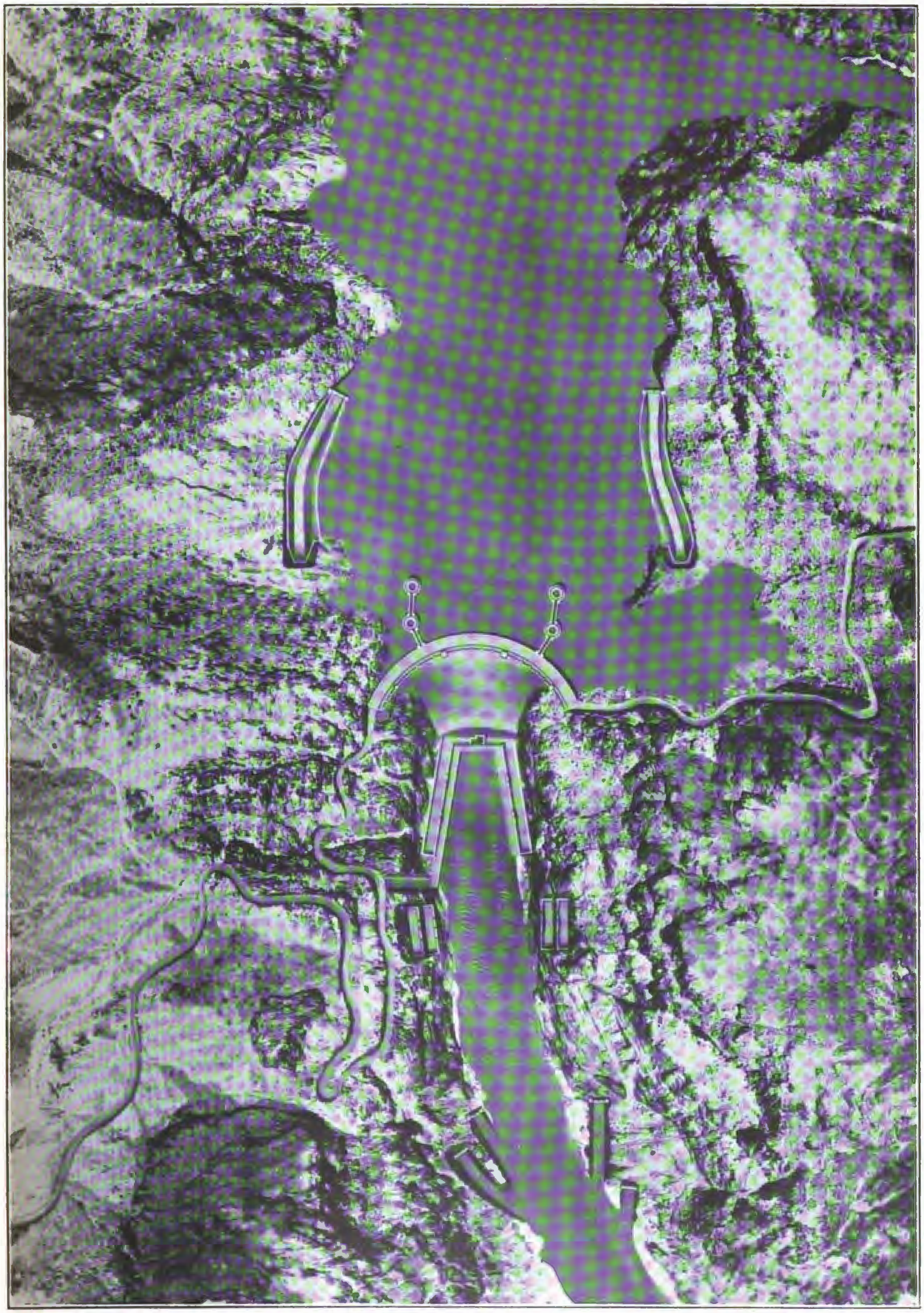
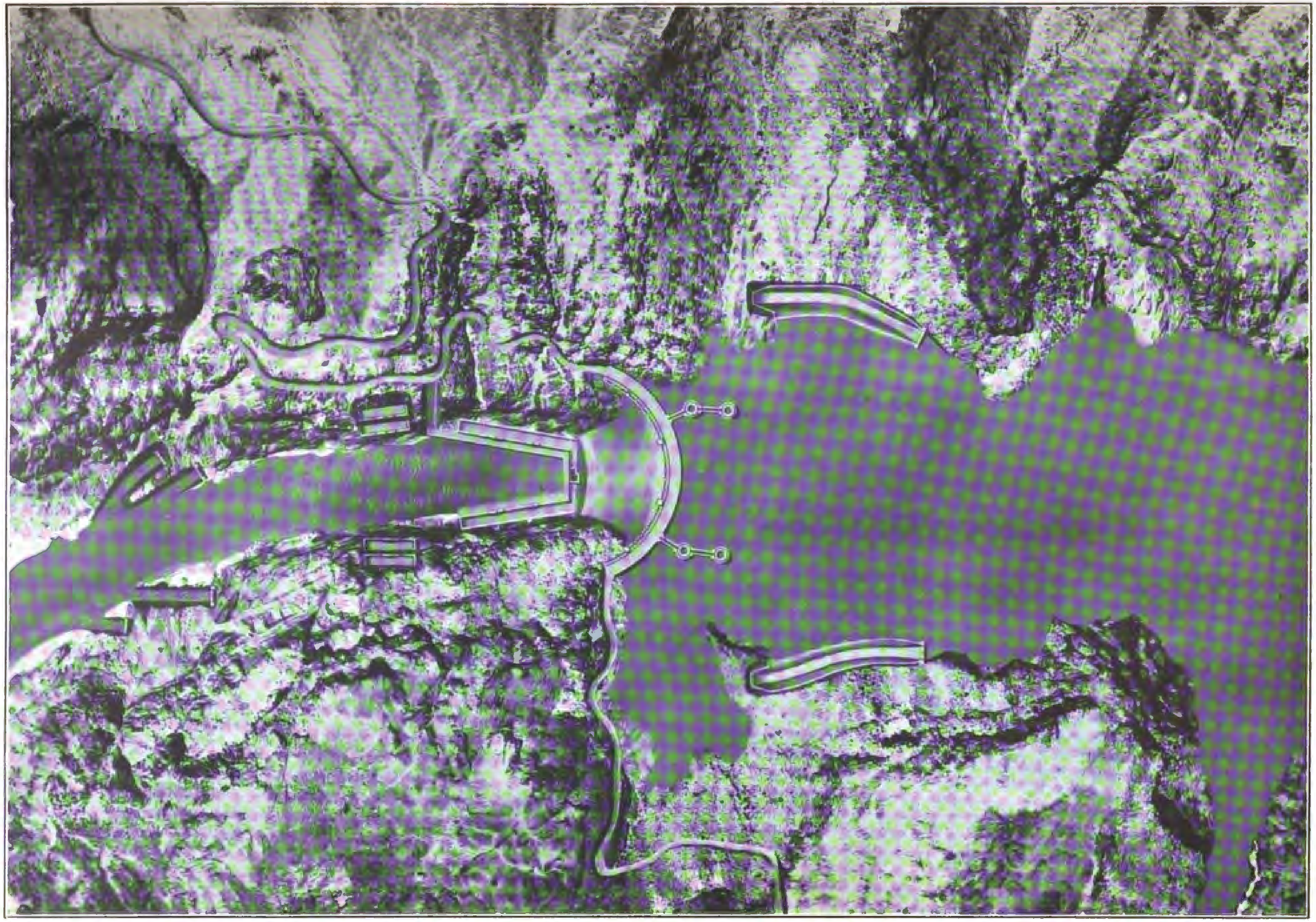


PLATE I



CONTENTS

HOOVER DAM, POWER PLANT, AND APPURTENANT WORKS, BOULDER CANYON PROJECT, ARIZONA-CALIFORNIA-NEVADA

Bids will be considered on the following schedule, but no bid will be considered for only a part of the schedule

SCHEDULE

Construction of Dam, Power Plant, and Appurtenant Works

Item No.	Work or material	Quantity and price	Amount
1	Excavation: All classes, stripping canyon walls of loose rock.	150,000 cu. yds., at ________ (Words) ________ ($________) per cu. yd______	$________
2	Excavation: Common, in open cut for diversion tunnels.	59,000 cu. yds., at ________ (Words) ________ ($________) per cu. yd______	________
3	Excavation: Rock, in open cut for diversion tunnels.	344,000 u. yds., at ________ (Words) ________ ($________) per cu. yd______	________
4	Excavation: All classes, in diversion tunnels.	1,563,000 cu. yds., at ________ (Words) ________ ($________) per cu. yd______	________
5	Excavation: Common, in open trench for concrete cut-off in upstream cofferdam.	1,000 cu. yds., at ________ (Words) ________ ($________) per cu. yd______	________
6	Excavation: Rock, in open trench for concrete cut-off in upstream cofferdam.	500 cu. yds., at ________ (Words) ________ ($________) per cu. yd______	________
7	Excavation: Removal of earth fill in downstream cofferdam.	230,000 cu. yds., at ________ (Words) ________ ($________) per cu. yd______	________
8	Excavation: Removal of rock fill in downstream cofferdam and rock barrier.	191,000 cu. yds., at ________ (Words) ________ ($________) per cu. yd______	________
9	Excavation: Common, for foundation of dam, power house, and cofferdams.	857,000 cu. yds., at ________ (Words) ________ ($________) per cu. yd______	________
10	Excavation: Rock, for foundation of dam.	400,000 cu. yds., at ________ (Words) ________ ($________) per cu. yd______	________
11	Excavation: All classes, for upstream cut-off trench in foundation of dam.	35,000 cu. yds., at ________ (Words) ________ ($________) per cu. yd______	________

SCHEDULE—Continued

Construction of Dam, Power Plant, and Appurtenant Works—Continued

Item No.	Work or material	Quantity and price	Amount
12	Excavation: All classes, for spillways, in open cut.	1,012,000 cu. yds., at ____ (Words) ____ ($____) per cu. yd.____	$____
13	Excavation: All classes, in inclined spillway tunnels.	144,000 cu. yds., at ____ (Words) ____ ($____) per cu. yd.____	____
14	Excavation: All classes, for canyon wall valve houses.	255,000 cu. yds., at ____ (Words) ____ ($____) per cu. yd.____	____
15	Excavation: All classes for intake towers.	300,000 cu. yds., at ____ (Words) ____ ($____) per cu. yd.____	____
16	Excavation: All classes, in shafts for outlet works and connecting galleries.	29,000 cu. yds., at ____ (Words) ____ ($____) per cu. yd.____	____
17	Excavation: All classes, in penstock tunnels, outlet tunnels and power penstocks.	176,000 cu. yds., at ____ (Words) ____ ($____) per cu. yd.____	____
18	Excavation: Rock, for power house.	122,000 cu. yds., at ____ (Words) ____ ($____) per cu. yd.____	____
19	Excavation: All classes, for switching station.	16,500 cu. yds., at ____ (Words) ____ ($____) per cu. yd.____	____
20	Excavation: All classes, for inclined freight elevator structures.	40,000 cu. yds., at ____ (Words) ____ ($____) per cu. yd.____	____
21	Excavation: Common, for highway.	3,700 cu. yds., at ____ (Words) ____ ($____) per cu. yd.____	____
22	Excavation: Rock, for highway	109,000 cu. yds., at ____ (Words) ____ ($____) per cu. yd.____	____
23	Excavation: All classes, for highway structures.	1,000 cu. yds., at ____ (Words) ____ ($____) per cu. yd.____	____
24	Back fill for power house	1,300 cu. yds., at ____ (Words) ____ ($____) per cu. yd.____	____

SCHEDULE—Continued

Construction of Dam, Power Plant, and Appurtenant Works—Continued

Item No.	Work or material	Quantity and price	Amount
25	Back fill for switching station	4,400 cu. yds., at ______ (Words) ______ ($______) per cu. yd	$______
26	Back fill on roofs	35,000 cu. yds., at ______ (Words) ______ ($______) per cu. yd	______
27	Rock fill in upstream cofferdam	151,000 cu. yds., at ______ (Words) ______ ($______) per cu. yd	______
28	Rock fill in downstream cofferdam.	63,000 cu. yds., at ______ (Words) ______ ($______) per cu. yd	______
29	Rock protection in river channel and elsewhere.	84,000 cu. yds., at ______ (Words) ______ ($______) per cu. yd	______
30	Rock blanket on upstream cofferdam.	13,000 cu. yds., at ______ (Words) ______ ($______) per cu. yd	______
31	Rock barrier below downstream cofferdam.	127,000 cu. yds., at ______ (Words) ______ ($______) per cu. yd	______
32	Earth fill in upstream cofferdam	568,000 cu. yds., at ______ (Words) ______ ($______) per cu. yd	______
33	Earth fill in downstream cofferdam.	230,000 cu. yds., at ______ (Words) ______ ($______) per cu. yd	______
34	Rubble masonry walls	7,500 cu. yds., at ______ (Words) ______ ($______) per cu. yd	______
35	Drilling grout holes in tunnels, adits, and shafts.	232,000 lin. ft., at ______ (Words) ______ ($______) per lin. ft	______
36	Drilling grout holes in foundations for dam and spillway crests, not more than 50 feet deep.	6,500 lin. ft., at ______ (Words) ______ ($______) per lin. ft	______
37	Drilling grout holes in foundations for dam and spillway crests more than 50 feet and not more than 100 feet deep.	25,000 lin. ft., at ______ (Words) ______ ($______) per lin. ft	______

SCHEDULE—Continued

Construction of Dam, Power Plant, and Appurtenant Works—Continued

Item No.	Work or material	Quantity and price	Amount
38	Drilling grout holes in foundations for dam and spillway crests, more than 100 feet and not more than 150 feet deep.	17,000 lin. ft., at ________ (Words) ________ ($________) per lin. ft________	$________
39	Drilling holes for anchor bars and grouting bars in place.	23,500 lin. ft., at ________ (Words) ________ ($________) per lin. ft________	________
40	Drilling drainage holes in foundation for dam, not more than 50 feet deep.	5,600 lin. ft., at ________ (Words) ________ ($________) per lin. ft________	________
41	Drilling drainage holes in foundation for dam, more than 50 feet and not more than 100 feet.	28,000 lin. ft., at ________ (Words) ________ ($________) per lin. ft________	________
42	Drilling drainage holes in foundation for dam, more than 100 feet and not more than 150 feet deep.	500 lin. ft., at________ (Words) ________ ($________) per lin. ft________	________
43	Pressure grouting in tunnels, adits and shafts.	376,000 cu. ft., at________ (Words) ________ ($________) per cu. ft________	________
44	Pressure grouting in foundations for dam and spillway crests.	12,000 cu. ft., at________ (Words) ________ ($________) per cu. ft________	________
45	Pressure grouting contraction joints in dam.	34,000 cu. ft., at________ (Words) ________ ($________) per cu. ft________	________
46	Manufacturing and placing porous concrete draintile in dam.	38,400 lin. ft., at________ (Words) ________ ($________) per lin. ft________	________
47	Placing tile roofs________	10,000 sq. ft., at________ (Words) ________ ($________) per sq. ft________	________
48	Placing asphalt saturated felt roofing, complete with flashing.	120,000 sq. ft., at________ (Words) ________ ($________) per sq. ft________	________
49	Concrete in inlet structures for inner diversion tunnels.	5,600 cu. yds., at________ (Words) ________ ($________) per cu. yd________	________
50	Concrete in inlet structures for outer diversion tunnels and bulkhead gates.	13,400 cu. yds., at________ (Words) ________ ($________) per cu. yd________	________

SCHEDULE—Continued

Construction of Dam, Power Plant, and Appurtenant Works—Continued

Item No.	Work or material	Quantity and price	Amount
51	Concrete in outlet structures for diversion tunnels.	5,800 cu. yds., at ______ (Words) ______ ($______) per cu. yd______	$______
52	Concrete in linings of diversion tunnels.	312,000 cu. yds., at ______ (Words) ______ ($______) per cu. yd______	______
53	Concrete in paving for upstream cofferdam.	3,500 cu. yds., at ______ (Words) ______ ($______) per cu. yd______	______
54	Concrete in dam______	3,400,000 cu. yds., at ______ (Words) ______ ($______) per cu. yd______	______
55	Concrete in parapets______	6,600 cu. yds., at ______ (Words) ______ ($______) per cu. yd______	______
56	Concrete in spillway structures__	51,000 cu. yds., at ______ (Words) ______ ($______) per cu. yd______	______
57	Concrete in linings of inclined spillway tunnels.	29,000 cu. yds., at ______ (Words) ______ ($______) per cu. yd______	______
58	Concrete in diversion tunnel plugs_	121,000 cu. yds., at ______ (Words) ______ ($______) per cu. yd______	______
59	Concrete in linings of outlet and penstock tunnels.	26,000 cu. yds., at ______ (Words) ______ ($______) per cu. yd______	______
60	Concrete in linings of shafts for outlet works and connecting galleries.	10,200 cu. yds., at ______ (Words) ______ ($______) per cu. yd______	______
61	Concrete in canyon wall outlet works.	51,000 cu. yds., at ______ (Words) ______ ($______) per cu. yd______	______
62	Concrete in intake towers, foundations, and superstructures.	108,000 cu. yds., at ______ (Words) ______ ($______) per cu. yd______	______
63	Concrete in bridges to intake towers.	1,000 cu. yds., at ______ (Words) ______ ($______) per cu. yd______	______

SCHEDULE—Continued

Construction of Dam, Power Plant, and Appurtenant Works—Continued

Item No.	Work or material	Quantity and price	Amount
64	Concrete in power house above generator floor.	28,000 cu. yds., at ________ (Words) ________ ($________) per cu. yd	$________
65	Concrete in power house below generator floor and in penstock .	115,000 cu. yds., at ________ (Words) ________ ($________) per cu. yd	________
66	Concrete in switching station and steel tower footings.	600 cu. yds., at ________ (Words) ________ ($________) per cu. yd	________
67	Concrete in inclined freight elevator structures.	4,800 cu. yds., at ________ (Words) ________ ($________) per cu. yd	________
68	Concrete in highway structures	900 cu. yds., at ________ (Words) ________ ($________) per cu. yd	________
69	Gunite surfacing on concrete, 1 inch thick.	50,000 sq. yds., at ________ (Words) ________ ($________) per sq. yd	________
70	Special finishing of walls in power house, parapets, and other concrete surfaces.	250,000 sq. ft., at ________ (Words) ________ ($________) per sq. ft	________
71	Placing ¾-inch finish on concrete floors.	50,000 sq. yds., at ________ (Words) ________ ($________) per sq. yd	________
72	Thin walls of metal lath and plaster.	4, 000 sq. yds., at ________ (Words) ________ ($________) per sq. yd	________
73	Placing reinforcement bars and rails.	35,000,000 pounds, at ________ (Words) ________ ($________) per pound	________
74	Placing anchor bars in rock	168,000 pounds, at ________ (Words) ________ ($________) per pound	________
75	Installing standard steel and cast-iron pipe, fittings, and valves.	6,600,000 pounds, at ________ (Words) ________ ($________) per pound	________
76	Installing control piping for high-pressure gates.	51,700 pounds, at ________ (Words) ________ ($________) per pound	________

SCHEDULE—Continued

Construction of Dam, Power Plant, and Appurtenant Works—Continued

Item No.	Work or material	Quantity and price	Amount
77	Laying metal pipe for highway drains and culverts.	10,000 pounds, at ________ (Words) ________ ($________) per pound______	$________
78	Installing conduit lining castings_	9,570,000 pounds, at ________ (Words) ________ ($________) per pound______	________
79	Installing plate-steel conduit linings for outlet works.	6,435,000 pounds, at ________ (Words) ________ ($________) per pound______	________
80	Installing plate-steel conduit linings for power penstocks.	13,915,000 pounds, at ________ (Words) ________ ($________) per pound______	________
81	Installing structural steel, except bridges to intake towers.	17,875,000 pounds, at ________ (Words) ________ ($________) per pound______	________
82	Installing structural steel in bridges to intake towers.	577,500 pounds, at ________ (Words) ________ ($________) per pound______	________
83	Installing trash rack metal work_	2,340,800 pounds, at ________ (Words) ________ ($________) per pound______	________
84	Driving steel sheet piling for upstream cofferdam.	704,000 pounds, at ________ (Words) ________ ($________) per pound______	________
85	Installing track rails__________	413,000 pounds, at ________ (Words) ________ ($________) per pound______	________
86	Installing metal work in inclined freight elevator guide structure.	330,000 pounds, at ________ (Words) ________ ($________)[per pound)______	________
87	Installing metal floor plates_____	132,000 pounds, at ________ (Words) ________ ($________) per pound______	________
88	Installing metal stairways_______	303,000 pounds, at ________ (Words) ________ ($________) per pound ______	________
89	Furnishing and erecting steel ribs, steel liner plates, and arch ring segmental bars in tunnels, adits, and shafts.	3,170,000 pounds, at ________ (Words) ________ ($________) per pound ______	________

SCHEDULE—Continued

Construction of Dam, Power Plant, and Appurtenant Works—Continued

Item No.	Work or material	Quantity and price	Amount
90	Installing 50-foot by 50-foot Stoney gates and hoists.	2,600,000 pounds, at ______ (Words) ______ ($______) per pound ______	$______
91	Installing high-pressure hydraulically operated gates.	10, 340,000 pounds, at ______ (Words) ______ ($______) per pound ______	______
92	Installing cylinder gates and hoists in intake towers.	4,620,000 pounds, at ______ (Words) ______ ($______) per pound ______	______
93	Installing needle valves______	4,070,000 pounds, at ______ (Words) ______ ($______) per pound ______	______
94	Installing traveling cranes______	295,000 pounds, at ______ (Words) ______ ($______) per pound ______	______
95	Furnishing, installing, and operating cooling plant.	Complete, for the lump sum of ______ ______ (Words) dollars__	______
96	Installing electrical cable for resistance thermometers embedded in concrete.	20,000 lin. ft., at ______ (Words) ______ ($______) per lin. ft______	______
97	Installing electrical metal conduit not larger than 1-inch diameter.	75,000 lin. ft., at______ (Words) ______ ($______) per lin. ft______	______
98	Installing electrical metal conduit larger than 1-inch diameter and not larger than 2½-inch diameter.	60,000 lin. ft., at______ (Words) ______ ($______) per lin. ft______	______
99	Installing electrical metal conduit larger than 2½-inch diameter and not larger than 4-inch diameter.	2,000 lin. ft., at ______ (Words) ______ ($______) per lin. ft______	______
100	Installing electrical metal conduit larger than 4-inch diameter and not larger than 6-inch diameter.	500 lin. ft., at ______ (Words) ______ ($______) per lin. ft______	______

SCHEDULE—Continued

Construction of Dam, Power Plant, and Appurtenant Works—Continued

Item No.	Work or material	Quantity and price	Amount
101	Installing fiber conduit	2,000 lin. ft., at ________ (Words) ________ ($________) per lin. ft.	$________
102	Installing metal sash windows and partitions.	75,000 sq. ft., at ________ (Words) ________ ($________) per sq. ft.	________
103	Installing metal sash window operators.	120,000 pounds, at ________ (Words) ________ ($________) per pound	________
104	Installing metal swing doors	3,200 sq. ft., at ________ (Words) ________ ($________) per sq. ft.	________
105	Installing metal rolling doors	500 sq. ft., at ________ (Words) ________ ($________) per sq. ft.	________
106	Installing wooden doors	800 sq. ft., at ________ (Words) ________ ($________) per sq. ft.	________
107	Placing hollow clay tile walls and ceilings.	2,000 sq. yds., at ________ (Words) ________ ($________) per sq. yd	________
108	Placing ceramic tile walls and floors.	250 sq. yds., at ________ (Words) ________ ($________) per sq. yd	________
109	Installing plumbing fixtures and hardware accessories.	10,000 pounds, at ________ (Words) ________ ($________) per pound	________
110	Installing steel partitions	10,000 pounds, at ________ (Words) ________ ($________) per pound	________
111	Installing sheet-metal work	33,000 pounds, at ________ (Words) ________ ($________) per pound	________
112	Placing copper expansion strips in contraction joints.	150,000 lin. ft., at ________ (Words) ________ ($________) per lin. ft.	________
113	Installing miscellaneous items of metal work.	231,000 pounds, at ________ (Words) ________ ($________) per pound	________

SCHEDULE—Continued

Construction of Dam, Power Plant, and Appurtenant Works—Continued

Item No.	Work or material	Quantity and price	Amount
114	Transporting freight of all kinds on the construction railroad for the Government or its agents, other than the contractor, in less than car lots between delivery yard and end of construction railroad.	60,000 cwt., at ______ (Words) ______ ($______) per cwt______	$______
115	Transporting freight of all kinds on the construction railroad for the Government or its agents, other than the contractor, in car lots, between delivery yard and end of construction railroad.	1,000 cars, at ______ (Words) ______ ($______) per car______	______
116	Unloading freight of all kinds for the Government or its agents, other than the contractor, at the end of the construction railroad and placing in Government warehouse.	60,000 cwt., at ______ (Words) ______ ($______) per cwt______	______
117	Transporting freight of all kinds for the Government or its agents, other than the contractor, between end of construction railroad, in less than car lots, or between Government warehouse, in any amount, and power house.	60,000 cwt., at ______ (Words) ______ ($______) per cwt______	______
118	Transporting freight of all kinds for the Government or its agents, other than the contractor, between end of construction railroad and power house, in car lots.	600 cars, at ______ (Words) ______ ($______) per car______	______
119	Excavation: All classes, stripping Arizona gravel deposits	[illegible]50,000 cu. yds. at ______ (Words) ______ ($______) per cu. yd.______	______
	Total for Schedule______	______	______

STATEMENT OF EQUIPMENT

Each bidder shall fill in the following blanks stating the equipment with which it is proposed to do the work:

Excavating equipment:

Mucking machines--

Power shovels--

Dragline excavators--

Transporting equipment:

Cableways--

Tramways--

Locomotives--

Cars--

Trucks--

Air compressors--

Concrete mixers--

Concrete placing equipment, including guns--

Pumps--

Blowers--

Drilling equipment--

Other equipment--

STATEMENT OF ELECTRIC POWER REQUIREMENTS

Each bidder shall fill in the following blanks, stating the maximum amount of electric power, in horsepower, which it is estimated will be required for his operations during each year of the construction period:

Year	*Horsepower*
1931------------------------	------------------------
1932------------------------	------------------------
1933------------------------	------------------------
1934------------------------	------------------------
1935------------------------	------------------------
1936------------------------	------------------------
1937------------------------	------------------------
1938------------------------	------------------------

SPECIFICATIONS

GENERAL CONDITIONS

1. **Performance bond.**—Unless another sum is specified in the invitation for bids, the contractor shall furnish bond in an amount not less than 20 per cent of the estimated aggregate payments to be made under the contract. Bonds in amounts of $1,000 or less will be made in multiples of $100; in amounts exceeding $1,000 but not exceeding $5,000, in multiples of $500; in amounts exceeding $5,000, in multiples of $1,000: *Provided*, That the amount of the bond shall be fixed by the contracting officer at the lowest sum that fulfills all conditions of the contract.

2. **Mongolian labor prohibited.**—Pursuant to section 4 of the act of June 17, 1902 (32 Stat. 388, 389), no Mongolian labor shall be employed under this contract.

3. **Climatic conditions.**—The contracting officer may order the contractor to suspend any work that may be subject to damage by climatic conditions.

4. **Rights of way.**—The site for the installation of machinery or the right of way for the works to be constructed under this contract and for necessary borrow pits, channels, spoil banks, ditches, roads, etc., will be provided by the Government.

5. **Quantities and unit prices.**—The quantities noted in the schedules are approximations for comparing bids, and no claim shall be made against the Government for excess or deficiency therein, actual or relative. Payment at the prices agreed upon will be in full for the completed work and will cover materials, supplies, labor, tools, machinery, and all other expenditures incident to satisfactory compliance with the contract, unless otherwise specifically provided.

6. **Staking out work.**—The work to be done will be staked out for the contractor who shall, without cost to the Government, provide such material and give such assistance as may be required by the contracting officer.

7. **Bench marks and survey stakes.**—Bench marks and survey stakes shall be preserved by the contractor, and in case of their destruction or removal by him or by his employees, they will be replaced by the contracting officer at the contractor's expense, and his sureties shall be liable therefor.

8. **Data to be furnished by contractor.**—The contractor shall furnish the contracting officer reasonable facilities for obtaining such information as he may desire respecting the character of the materials and the progress and manner of the work, including all information necessary to determine its cost, such as the number of men employed, their pay, the time during which they worked on the various classes of construction, etc. The contractor shall also furnish the contracting officer copies of freight bills on all machinery, materials, and supplies shipped to or from the project in connection with the work under the contract.

9. **Sanitation.**—The contracting officer may establish sanitary and police rules and regulations for all forces employed under this contract, and if the contractor fails to enforce these rules the contracting officer may enforce them at the expense of the contractor.

10. **Extras.**—The contractor shall, when ordered in writing by the contracting officer, perform extra work and furnish extra material, not covered by the specifications or included in the schedules, but forming an inseparable part of the work contracted for. Extra work and material will ordinarily be paid for at a lump-sum or unit price agreed upon by the contractor and the contracting officer and stated in the order. Whenever in the judgment of the contracting

officer it is impracticable because of the nature of the work or for any other reason to fix the price in the order, the extra work and material shall be paid for at actual necessary cost as determined by the contracting officer, plus 15 per cent for superintendence, general expense, and profit. The actual necessary cost will include all expenditures for material, labor, and supplies furnished by the contractor, and a reasonable allowance for the use of his plant and equipment, where required, to be agreed upon in writing before the work is begun, but will in no case include any allowance for office expenses, general superintendence, or other general expenses.

11. **Cleaning up.**—Upon completion of the work the contractor shall remove from the vicinity of the work all plant, buildings, rubbish, unused materials, concrete forms, and other like material, belonging to him or used under his direction during construction, and in the event of his failure to do so the same may be removed by the Government at the expense of the contractor, and his surety or sureties shall be liable therefor.

12. **Failure of Congress to appropriate funds.**—If the operations of this contract extend beyond the current fiscal year, it is understood that the contract is made contingent upon Congress making the necessary appropriation for expenditures thereunder after such current year has expired. In case such appropriation as may be necessary to carry out this contract is not made, the contractor hereby releases the Government from all liability due to the failure of Congress to make such appropriation.

13. **Patents.**—The contractor shall hold and save the Government, its offices, agents, servants, and employees, harmless from liability of any nature or kind for or on account of the use of any patented or unpatented invention, article, or appliance furnished or used in the performance of this contract, excepting patented articles required by the Government in its specifications, the use of which the contractor does not control.

SPECIAL CONDITIONS

14. **The requirement.**—It is required that there be constructed and completed, in accordance with these specifications and the drawings listed in paragraph 22 hereof, the Hoover Dam, power plant, and appurtenant structures. The work is located on the Colorado River at the Black Canyon dam site approximately 30 miles southeast of Las Vegas, Nevada, as shown on the location map.

15. **Description of diversion works.**—The diversion works, as shown on the drawings, will consist of an upstream cofferdam, a downstream cofferdam, rock protection of part of the river channel above the upstream cofferdam, a rock barrier below the downstream cofferdam, and four diversion tunnels in the canyon walls through the abutment rock. The upstream cofferdam will be of the earth and rock-fill type, the upstream earth-fill slope being protected by a rock blanket covered with reinforced concrete paving. Steel sheet piling will be driven in a trench at the upstream toe to form a water-tight cut-off wall in the river bed and the top of this piling will be incased in the concrete wall at the toe of the concrete paving. The downstream cofferdam will also be of the earth and rock-fill type, the downstream earth-fill slope being protected from eddy action by a rock barrier. The rock barrier will be placed downstream from the downstream cofferdam and will consist of a massive embankment of dumped rock. The four diversion tunnels will be circular in cross-section, lined with concrete and 50 feet in diameter inside of the lining. Two tunnels will be placed on each side of the river and all four tunnels will be in approximately the same horizontal plane. The two tunnels nearest the river on each side of the river are referred to in these specifications as the "inner" diversion tunnels and the other two tunnels as the "outer" diversion tunnels.

16. Description of dam.—The dam will be of the massive concrete arch-gravity type. It will be about 1,180 feet long on the crest and about 730 feet in height above the lowest point of foundation bedrock. The radius of curvature of the axis will be about 500 feet. A cut-off trench will be excavated in the foundation rock along the upstream toe. The foundation and abutment rock will be drilled and pressure grouted, the holes being located at 5-foot intervals in one line in the trench. The grout holes will vary in depth up to a maximum of about 150 feet, with alternate holes about two-thirds the depth of adjacent holes. The main drainage gallery will be parallel to the axis of the dam, with the upstream wall of the gallery at a horizontal distance of 6 feet downstream from the axis of the dam. In elevation the gallery will generally follow the cross section of the canyon, rising by steps with the abutments of the dam. Spiral stairways will be provided in the vertical sections of the gallery. Drainage holes varying in depth from about 15 feet near the crest of the dam, to a maximum of about 100 feet at the lowest points, will be drilled into the abutments and foundation from the main drainage gallery. These holes will be located in a single line, and will be spaced at 5-foot intervals. The main drainage gallery will connect with radial drainage conduits discharging at the downstream toe of the dam. To provide for expansion and contraction the concrete will be built up in sections or columns. The upstream and downstream vertical faces of these columns will be curved on a 500-foot radius. The other faces from the bottom of the dam to elevation 800 will be approximately parallel to the river channel; from elevation 1100 to the top of the dam they will be radial, or normal to the axis of the dam; and the faces at intervening elevations will be warped between those below and above. The joints thus formed between adjacent columns will be equipped with pipe and fittings, installed in systems 100 feet in height, by which, after the concrete embedding each system is placed and after the setting heat has been dissipated, the joints will be filled with grout under pressure. The setting heat will be reduced by means of a refrigeration plant supplying and forcing cooled water through 2-inch pipes embedded in the concrete of the dam. In addition to the drainage galleries there will be a number of inspection galleries. Two elevator shafts with adits at the elevation of the generator floor of the power house will connect the two wings of the power house with the top of the dam. The top of the dam will be provided with concrete parapets, and other architectural features.

17. Description of spillways.—Two spillways will be constructed, one on each side of the river. Each of these will consist, in downstream order, of a 50-foot by 50-foot Stoney gate, a concrete ogee overflow crest about 700 feet long, a reinforced concrete-lined open channel, and a 50-foot diameter concrete-lined inclined tunnel through which the water will pass into the outer diversion tunnel, which tunnel, after having served its purpose as a diversion tunnel, will be plugged with concrete immediately upstream from its junction with the inclined spillway tunnel and the downstream portion will become a part of the spillway system. In order to unwater the outer diversion tunnel so that the concrete plug may be constructed, a large concrete bulkhead will be constructed directly in front of and above the upstream portal of the tunnel. This concrete bulkhead will rest on three supporting columns of concrete at each side of the portal opening. The bases of the columns will rest on sand placed in concrete-lined wells, the sand being sealed in the wells by the concrete bases of the columns and by copper sealing strips embedded in the bases of the columns and in the walls of the wells. The bulkheads will be lowered into place by jetting the sand from the wells through pipes placed in the columns.

18. Description of outlet works.—Outlet works similar in design will be constructed on both sides of the river, the capacity on each side being the same. The outlet works on each side of the river will consist of two separate systems, each being regulated by a cylinder gate in the bottom of an intake tower, the two towers being about 165 feet apart in a direction parallel with the river. The system regulated from the upstream intake tower will consist, in downstream order, of the tower with a cylinder gate 31 feet in diameter discharging into a 30-foot diameter inclined tunnel connecting with the inner diversion tunnel, the upstream tunnel plug in the diversion tunnel with temporary slide gates installed therein, the inner diversion tunnel below the upstream tunnel plug, the downstream lower and upper canyon wall outlet gates and needle valves, the downstream tunnel plug with outlet gates and needle valves installed therein, and the 50-foot by 50-foot Stoney gate at the outlet end of the inner diversion tunnel. An adit will connect an inspection gallery in the dam with the operating chamber for the gates in the upstream tunnel plug and another adit will be constructed from the power house to the downstream tunnel plug, with elevator shafts to the upper and lower canyon wall valve houses. The system regulated from the downstream intake tower will consist of the tower with a cylinder gate 31 feet in diameter discharging into a 30-foot diameter horizontal penstock tunnel leading to the upstream lower and upper canyon wall outlet gates and needle valves. Power penstocks which divert from each system are described in paragraph 19. The lower and upper canyon wall outlet gates and needle valves on each side of the river are housed in separate buildings, known as the lower canyon wall valve house and the upper canyon wall valve house, respectively.

19 ~~14.~~ **Description of power plant.**—The power house will be located immediately downstream from the dam. It will be a U-shaped structure of concrete and structural steel with one wing of the U on each side of the river and with the connecting portion constructed across the downstream toe of the dam. Each wing of the building will be constructed sufficiently large to accommodate at least 6 and possibly 8 main power-generating units together with transformers, switching, and control equipment, and auxiliary apparatus. The length of the front or river face of each wing will be about 500 feet, the depth from this face to the excavated canyon wall will be about 66 feet, and the height from the generator floor to the top of the roof will be about 85 feet. Where the power house roof is extended beyond the back wall of the power house to connect the roof with the canyon wall, extension roof trusses will be used, with one end notched into and supported by the rock in the canyon wall. The construction of the power house is covered by these specifications. The hydraulic and electrical machinery, equipment, and wiring will be installed by the Government. The contractor will be required to place all concrete around such machinery as is installed prior to completion of the dam. Half of the power penstocks on each side of the river will divert from the 30-foot diameter horizontal penstock tunnel, and the other half will divert from the inner diversion tunnel. The power penstocks will be lined with plate-steel conduit lining, having a thickness varying from 1½ to 2 inches, and the space between the steel lining and the rock will be filled with concrete.

20. **Description of inclined freight elevator.**—The inclined freight elevator guide structure will be located on the slope of the canyon wall immediately downstream from the power house on the Nevada side of the river. The top of the structure will connect with the highway at about elevation 1261 and the bottom elevation will be at about 667. It will consist of a channel excavated in the rock wall and lined with concrete, in which track rails, structural guides, and other metal work will be installed to guide the elevator car. This guide structure will be connected to the power house by a spur track constructed in a concrete foundation. The hoisting equipment, hoist structure, and transfer or elevator car with the necessary control and operating mechanisms will be furnished and installed by the Government. The concrete guide structure for the elevator and the spur track to the power house shall be constructed by the contractor. The inclined freight elevator and spur track will be used by the Government for general operation and maintenance purposes after the construction of the dam, power plant, and appurtenant works is completed.

21. **Description of highway.**—A highway will connect with the end of the construction highway being constructed under a separate contract and will descend by light grades to the crest of the dam on the Nevada side of the river, passing the top of the inclined freight elevator. After crossing over the canyon to the Arizona side on the roadway along the crest of the dam, the highway grade will rise to a terminus above the canyon rim, where it will connect with a State highway which, it is contemplated, will be constructed at a later date. It is contemplated that the length of the highway on the Nevada side of the river will be about 4,000 feet, with a maximum grade of 6 per cent, and the length on the Arizona side of the river will be about 1,400 feet, with a maximum grade of 8 per cent.

22. **List of drawings.**—The following drawings are made a part of these specifications:

1. (*24101*) 45–D–901—Colorado River basin—General map.
2. (*24102*) 45–D–902—Dam and appurtenant works—Location map.
3. (*24103*) 45–D–903—Hydrograph of Colorado River—Lees Ferry.
4. (*24104*) 45–D–904—Hydrograph of Colorado River—Bright Angel.
5. (*24105*) 45–D–905—Hydrograph of Colorado River—Topock.
6. (*24106*) 45–D–906—Gage heights of Colorado River—Yuma (1878–1915).
7. (*24107*) 45–D–907—Hydrograph of Colorado River—Yuma (1902–1930).
8. (*24108*) 45–D–908—Black Canyon gaging station—Discharge curves.
9. (*24109*) 45–D–909—Profile and log of drill holes—Centerline of river.
10. (*24110*) 45–D–910—Profile and log of drill holes—Line "U" 940.
11. (*24111*) 45–D–911—Profile and log of drill holes—Line "U" 200.
12. (*24112*) 45–D–912—Profile and log of drill holes—Line "D."
13. (*24113*) 45–D–913—Profile and log of drill holes—Line "D" 200.
14. (*24114*) 45–D–914—Profile and log of drill holes—Line "D" 400.
15. (*24115*) 45–D–915—Profile and log of drill holes—Line "D" 600.
16. (*24116*) 45–D–916—Profile and log of drill holes—Line "D" 1000.
17. (*24117*) 45–D–917—Area and capacity curves—Black Canyon dam site.
18. (*24118*) 45–D–918—Government space reservation.
19. (*24119*) 45–D–919—Mass concrete yardage.
20. (*24120*) 45–D–920—Construction progress chart—By features.
21. (*24121*) 45–D–921—Construction progress diagram—Pictorial.
22. (*24122*) 45–D–922—Dam and appurtenant works—General layout.
23. (*24123*) 45–D–923—Dam and appurtenant works—Sectional elevation.
24. (*24124*) 45–D–924—Maximum section of dam—Grout and drainage system.
25. (*24125*) 45–D–925—Contraction joint layout—Plan and sections.
26. (*24126*) 45–D–926—Contraction joint layout—Detail perspective.
27. (*24127*) 45–D–927—Grouting system layout.
28. (*24128*) 45–D–928—Cooling system layout.
29. (*24129*) 45–D–929—Shafts and galleries.
30. (*24130*) 45–D–930—Parapet and roadway.
31. (*24131*) 45–D–931—Tunnel alignment layout.
32. (*24132*) 45–D–932—Upper and lower tunnel plug adits.
33. (*24133*) 45–D–933—Profiles and sections—Spillway tunnels.
34. (*24134*) 45–D–934—Profiles and sections—50-foot penstock tunnels.
35. (*24135*) 45–D–935—Profiles and sections—30-foot penstock tunnels.
36. (*24136*) 45–D–936—Outer diversion tunnel portal—Inlet structure.
37. (*24137*) 45–D–937—Outer diversion tunnel portal—Concrete bulkhead.

38. (*24138*) 45-D-938—Inner diversion tunnel portal—Trash rack structure.
39. (*24139*) 45-D-939—General plan and sections—Arizona spillway.
40. (*24140*) 45-D-940—General plan and sections—Nevada spillway.
41. (*24141*) 45-D-941—Spillway tunnel plug—Typical design.
42. (*24142*) 45-D-942—Spillway tunnel portal—Outlet structure.
43. (*24143*) 45-D-943—Upstream plug outlet works—Nevada side.
44. (*24144*) 45-D-944—Upstream plug outlet works—Arizona side.
45. (*24145*) 45-D-945—Upstream plug outlet works—Reinforcing details.
46. (*24146*) 45-D-946—Upstream plug outlet works—Gate installation.
47. (*24147*) 45-D-947—High pressure emergency gates—General assembly.
48. (*24148*) 45-D-948—Canyon wall outlet works—Typical design.
49. (*24149*) 45-D-949—Canyon wall outlet works—Sections—Arizona side.
50. (*24150*) 45-D-950—Canyon wall outlet works—Sections—Nevada side.
51. (*24151*) 45-D-951—Canyon wall outlet works—Reinforcing details—Elevation 945.
52. (*24152*) 45-D-952—Canyon wall outlet works—Reinforcing details—Elevation 820.
53. (*24153*) 45-D-953—Canyon wall outlet works—Gate and valve assembly.
54. (*24154*) 45-D-954—Downstream plug outlet works—Typical design.
55. (*24155*) 45-D-955—Downstream plug outlet works—Gate and valve assembly.
56. (*24156*) 45-D-956—50 foot by 50 foot Stoney gate—Typical design.
57. (*24157*) 45-D-957—50 foot by 50 foot Stoney gate—Leaf assembly.
58. (*24158*) 45-D-958—50 foot by 50 foot Stoney gate—Hoist assembly.
59. (*24159*) 45-D-959—50 foot by 50 foot Stoney gate—Counterweight assembly.
60. (*24160*) 45-D-960—Cylinder gate intake towers—Typical design.
61. (*24161*) 45-D-961—Cylinder gate intake towers—Concrete bridge.
62. (*24162*) 45-D-962—Cylinder gate intake towers—Cylinder gate assembly.
63. (*24163*) 45-D-963—Cylinder gate intake towers—Gate-hoist assembly.
64. (*24164*) 45-D-964—Hoover power plant—Elevations.
65. (*24165*) 45-D-965—Hoover power plant—General plan.
66. (*24166*) 45-D-966—Hoover power plant—Typical wing sections.
67. (*24167*) 45-D-967—Hoover power plant—Partial wing plans.
68. (*24168*) 45-D-968—Hoover power plant—Central section.
69. (*24169*) 45-D-969—Hoover power plant—Central portion floor plans—Above elevation 710.
70. (*24170*) 45-D-970—Hoover power plant—Central portion floor plans—Below elevation 710.
71. (*24171*) 45-D-971—Hoover power plant—Structural steel details.
72. (*24172*) 45-D-972—Hoover power plant—Section through penstock tunnels.
73. (*24173*) 45-D-973—Inclined freight elevator.
74. (*24174*) 45-D-974—Passenger elevator layout.
75. (*24175*) 45-D-975—Black Canyon highway.
76. (*24176*) 45-D-976—Canyon cross sections.

The drawings show the general arrangement of all features. Where required, as determined necessary by the contracting officer, additional drawings showing details of the work will be furnished to the contractor during the progress of the work. The contractor will be furnished such additional copies of the specifications and drawings as may be required for carrying out the work.

Contact prints of the original drawings from which the attached reductions were made will be furnished to the contractor for construction purposes upon request. Two reproductions from photographs (Plates 1 and 2) are included in these specifications. The reproductions show the topography and general nature of the site of the work. Prior to the reproduction of the photographs, the dam and other features were sketched thereon as they may appear after completion.

23. Preference rights of ex-service men and citizens of the United States.—The contractor and/or his subcontractor or subcontractors shall, so far as practicable, give preference at the time of employment, first, to qualified persons who have served in the United States Army, Navy, or Marine Corps during the War with Germany, the War with Spain, or in the suppression of the insurrection in the Philippines, and who have been honorably separated or discharged therefrom or placed in the Regular Army or Navy Reserve, and second, to qualified citizens of the United States.

24. Commencement, prosecution, and completion of work.—The contractor shall begin work within thirty (30) calendar days after date of receipt of notice to proceed. Each part of the work shall be completed within the number of calendar days after the date of receipt of notice to proceed as follows:

(*a*) All that portion of the two wings of the power house sufficient to permit installation of the 6 upstream power units on each side of the river; ~~the portion of the building connecting the two wings~~; the substructure of the power house, for installation of two additional power units on each side of the river immediately downstream from the other power units, up to elevation 660; and all other portions of the power plant and other works which must be completed before the necessary power machinery and other equipment to be installed by the Government for the operation of power units N1, N3, N5, A1, A3, and A5 can be placed, within one thousand six hundred (1,600) calendar days.

(*b*) All other portions of the dam, power plant, and appurtenant works which will permit, without damage to any part of the required works, the permanent storage of water up to a maximum elevation of 935 and the operation of power units N1, N3, N5, A1, A3, and A5, within one thousand nine hundred and sixty-five (1,965) calendar days.

(*c*) All of the remainder of the work under the schedule, including the completion of the power house and power plant for 6 power units on each side of the river, within two thousand five hundred and sixty-five (2,565) calendar days: *Provided*, That if the Government gives the contractor written notice within one thousand six hundred (1,600) calendar days, after date of receipt of the original notice to proceed, that a total of 7 or 8 power units will be required on each side of the river, instead of 6, then the work required for the additional units shall be completed within the same period, i. e., within two thousand five hundred and sixty-five (2,565) calendar days. The contractor shall at all times during the continuance of the contract prosecute the work with such forces and equipment as, in the judgment of the contracting officer, are sufficient to complete it within the specified periods of time.

25. Liquidated damages.—The damages that may result from any delay in completion of any part of the work by the time agreed upon will be difficult, if not impossible, of ascertainment. If any part of the work is not completed on or before the date fixed for its completion by the terms of the contract, the contractor shall pay to the Government as fixed, agreed, and liquidated damages the sum of three thousand dollars ($3,000) per day for each part of the work, as subdivided in paragraph 24 for each calendar day's delay until it is satisfactorily completed or until such time as the Government may reasonably procure the completion of the work by another contractor or complete the work itself. Whatever sums may be due as liquidated damages for delay may be deducted from payments due to the contractor or may be collected from the contractor or the contractor's surety or sureties. The provision for liquidated damages shall not prevent the Government from terminating the right of the contractor to proceed in case of default, as provided in article 9 of the contract.

26. Construction program.—The construction program shall be at all times subject to the approval of the contracting officer. The capacity of the construction plant, sequence of operations, and methods of operation shall be such as to insure the completion of the work within the periods of time of completion specified. The construction program shall meet all the requirements of these specifications in connection with the stripping of the canyon walls of loose rock; the construction of the diversion tunnels, cofferdams, and other diversion works; excavations for foundation; sequence in placing concrete; installation of gates and the control of river flow; grouting of contraction joints; and other parts of the work. A tentative construction program has been outlined by the Government, which, if followed, would permit all parts and features to be completed as specified in paragraph 24, and is shown on the drawings. This program assumes that the date of receipt by the contractor of notice to proceed will be April 15, 1931. It calls for completion of the diversion tunnels by October 1, 1933; the cofferdams by May 1, 1934; and the placing of the first mass concrete in the dam not later than December 1, 1934. It contemplates that the construction of all necessary features for the beginning of storage of water by June 15, 1936, and of all other necessary features for the generation of power, as provided in paragraph 24, by September 1, 1936, with the storage of water to elevation 935, will be completed by the required dates. The necessary features include installing the Stoney gates in the outlets of the inner diversion tunnels; placing the upstream tunnel plugs, with high-pressure slide gates for temporary use, in the inner diversion tunnels during the fall of 1935; constructing the bulkheads for the inlets of the outer diversion tunnels, lowering the bulkheads into position by June 15, 1936, and constructing the solid tunnel plugs in the outer diversion tunnels immediately thereafter; completing portions of the power house and other work as specified in paragraph 24 (*a*), by September 1, 1935; completing the intake towers and appurtenant parts, except the bridges, by July 1, 1936; and completing the entire canyon-wall outlet works connected with the downstream intake towers by September 1, 1936. Although the tentative construction program calls for completion of the spillways by November 1, 1933, this date could be postponed a year or more, but the spillways and the concrete in the dam, except the parapets, should be completed by such dates as will permit ample time for building up the storage to the spillway crests; the construction of the downstream plugs, including the installation of the needle valves therein and the construction of the canyon-wall outlet works connected with the upstream intake towers; and other work required before the date of completion of the contract, the construction of which is dependent on the prior completion of the spillways. It is contemplated that, if required, the completed upstream intake towers and the tunnel plug and downstream canyon-wall outlet works will serve as spillways in passing the flood water of 1937, and possibly a portion of the flood water of 1936. The construction program shown on the drawings is tentative only and the Government assumes no responsibility for any use that bidders or the contractor may make of this program or for any deductions or conclusions that may be made by them from the study thereof. It is included in the specifications solely to assist bidders and the contractor in preparing their own construction programs, and takes into consideration work which has been, or will be performed, under other contracts or by the Government. None of the statements in this paragraph, nor anything on the tentative construction program, shall relieve the contractor from the obligation to commence, prosecute, and complete the work as provided in paragraph 24.

27. Materials furnished by the Government.—The Government will furnish cement for use in concrete, grout, gunite, and mortar; reinforcement bars, rails, and fabric; anchor bars, rods, and bolts; metal pipe and fittings; conduit lining castings and plate-steel conduit linings for power penstocks and outlet works; copper sheets and rivets for contraction joints and other seals; gates and hoists; needle valves; traveling cranes; operating machinery; structural steel for trash racks, bridges, and other structures; sheet piling; rails and structural-steel guides for the inclined freight elevator; pipe for hand railings; all necessary doors, windows, and hardware except as otherwise provided; metal floor plates and stairways; steel partitions; fabricated parts for sheet metal work; metal lath, hair or fiber, and hydrated lime for lath and plaster wall; paint materials; plumbing and hardware; hollow tile, lime putty or plastic fire clay, and white Portland cement for hollow-tile walls; ceramic tile for walls and floors; roofing materials except back fill; corrugated metal pipe and coupling bands for highway drains and culverts; resistance thermometers; electrical conduits; forms for concrete relief work as provided in paragraph 122; well casing and steel pipe forms for concrete bulkhead gate supports as provided in paragraph 116; and all other materials not specifically mentioned in this paragraph or in paragraph 28 that will become a part of the completed construction work. All materials furnished by the Government will be delivered to the contractor f. o. b. cars at the delivery yard near Boulder City as shown on the location map and further described in paragraph 40 for construction railroad. The contractor shall haul all such materials from the point of delivery to the work, shall provide suitable warehouses or other means of protection satisfactory to the contracting officer for such of the materials as, in the opinion of the contracting officer, require storage or protection, and will be charged for any materials lost or damaged after delivery, except as otherwise specifically provided, the same amounts that the materials cost the Government at the point of delivery to the contractor. The contractor shall be responsible for the prompt unloading of material delivered and the proper care of the materials, and will be held liable for any demurrage charges incurred due to failure to unload cars promptly, and for any rental or other charges incurred on rolling stock while in the possession or under the control of the contractor. The contractor shall report to the contracting officer in writing, within 24 hours after unloading, any shortage or damage to materials when delivered. The cost of unloading, hauling, storing, and caring for all materials furnished by the Government for use or installation by the contractor shall be included in the prices bid for the work in which the materials are to be used. The cost of handling and installing minor miscellaneous items of timber or other work, except metal work, for which specific unit prices are not provided in the schedule shall be included in the unit prices bid for the work to which they are appurtenant. The contractor shall return to the Government at the delivery yard, at the dam site, or at any point on the construction railroad, as directed by the contracting officer, all unused materials, and will be charged for any materials not used and not returned the same amounts that the materials cost the Government at the point of delivery to the contractor.

28. **Materials to be furnished by the contractor.**—The contractor will be required to furnish all sand, broken rock or gravel, and cobbles for concrete; sand for grout, sand blasting, gunite, and mortar; stones for rubble-masonry walls; all form materials, including oil for oiling forms, except as otherwise provided in paragraph 122; all lumber for temporary timbering in tunnels, shafts, and adits, if required, and for stop planks for inlet of inner diversion tunnel; steel liner plates, steel ribs, and arch ring segmental bars or I-beams for tunnels, if required; all spikes and nails for forms and other uses; all wire, wire ties, or other appliances used for holding forms and for securing reinforcement steel; all embankment and back-fill materials; all water used for mixing, cleaning, and curing concrete, for grouting, for cooling plant and accessories, and for drinking purposes at the site of the work; joint compound for joints in gate control piping and cooling pipes; pipe and fittings not required for the permanent installations; oakum or other suitable

materials for calking grout pipes; brazing and soldering materials for copper expansion and sealing strips; muriatic acid for use in the construction of hollow-tile walls; and also all other required materials not specifically mentioned in this paragraph or in paragraph 27, that will not become a part of the completed construction work. The contractor shall haul all these materials as well as all materials delivered to the contractor by the Government from the point of delivery to the site of the work. The cost of hauling, storing, and handling all the materials described above and of furnishing all the materials required to be furnished by the contractor shall be included in the unit prices bid for the work for which the materials are required.

29. Preference for domestic articles or materials.—Preference will be given to articles or materials of domestic production, conditions of quality and price, including duty, being equal. Unless otherwise stated in the bid, it will be understood that domestic articles or materials only will be used, and the use of foreign articles or materials will not be permitted unless (1) they are of better quality, or (2) being equal in quality, will be furnished at lower cost to the Government, or (3) domestic articles or materials are not available. The term "domestic articles or materials" in this connection means articles or materials manufactured or assembled in the United States or its possessions.

30. Foundation and other test drilling records.—The drawings included in these specifications show the available records of test drilling done at the dam site during 1922 and 1923. The Government does not guarantee any interpretation of these records. Additional drilling is in progress at the date of the issuance of these specifications and available information, including logs of holes and drill cores, for all of the drilling done, will be available for the information of bidders and the contractor at the office of the Bureau of Reclamation at Las Vegas, Nev. The contractor must assume all responsibility for deductions and conclusions as to the nature of the rock or other materials to be excavated, for the difficulties of making and maintaining the required excavations and doing other work affected by the geology at the site of the work, and for the final preparation of the foundations for the dam, power plant, and other structures.

31. Report on geology.—A report on the geology of the Boulder Canyon and Black Canyon dam sites and reservoir sites on the Colorado River was prepared in 1923 by Geologist F. L. Ransome, then with the United States Geological Survey. A copy of this report is available at the office of the Bureau of Reclamation at Denver, Colo., and another copy at the office of the Bureau of Reclamation at Las Vegas, Nev., where prospective bidders and the contractor may consult it, but permission will not be given to remove the copies from the respective offices. The Government assumes no responsibility for the interpretation of this report and the prospective bidders and the contractor must assume all responsibility for deductions and conclusions as to geologic formations and conditions which might affect the required operations under these specifications.

32. River discharge records.—Hydrographs of the Colorado River at different points are shown on the drawings. Except for hydrographs after October 1, 1929, the data used in preparing the hydrographs were taken from water supply papers published by the United States Geological Survey. Estimated discharge curves for the Colorado River at Black Canyon dam site above and below the dam have also been prepared and are included with the drawings. The hydrographs and the discharge curves are included in the drawings for the convenience of bidders and the contractor, but the Government does not guarantee their reliability or the accuracy of any of the figures on these drawings.

33. Approval of plans by Colorado River Board.—Public Resolution No. 65 adopted by the Seventieth Congress and approved by the President on May 29, 1928 (45 Stat. 1011), authorized and directed the Secretary of the Interior to appoint a board of engineers and geologists, designated the Colorado River Board, to examine the proposed site of the dam and to review and approve the plans therefor. The drawings included with these specifications are those which have been submitted to the Colorado River Board for approval. Final approval has been given to the designs for the diversion works and other features which must be completed during the early stages of construction. Final approval of plans for the section of the dam and for the spillways is deferred awaiting the results of further analysis and of tests on models of these features. These tests are being conducted at the time of issuing these specifications and the final design drawings, for these features, as approved by the Colorado River Board, will be made available to the contractor early in the construction period and in advance of the requirements therefor. Construction of the dam and spillways shall not be commenced until these final approved drawings are furnished to the contractor. Required changes in all features will be handled under the provisions of articles 3 and 4 of the contract. The contractor's plant shall be laid out and his operations shall be conducted in a manner to accommodate any reasonable change in the location and design of the dam, power plant, and appurtenant works, or any part thereof, without additional cost to the Government.

34. Use of Boulder City as camp site.—Owing to the inaccessibility of the work, the magnitude of the operations, and the severe weather conditions during a large part of the year on account of extreme heat, and having in mind the health, comfort, and general welfare of those engaged on the work, it has been decided to establish the Government town of Boulder City, Nev., located approximately 23 miles southeast of Las Vegas, Nev., as shown on the drawings. A general plan of the town has been made, including provision for water supply and sewerage disposal and a layout of streets, sidewalks, city lighting, and other municipal improvements. Construction of these improvements will be in progress at the time award is made for the work under these specifications and it is expected that the water supply and sewerage systems for the town will be completed ready for use within six months thereafter. The town will be for the joint use of the Government, the contractor, and the employees of both, and for others who may be permitted, through leases or otherwise, to engage in business therein or to follow their trades or practice their professions. Certain areas as determined by the contracting officer will be set aside in Boulder City for the use of the contractor as sites for office and headquarters buildings, warehouses, garages, commissary, hospital, dormitories, boarding houses, homes for the contractor's employees, and other incidental purposes. The plans and type of construction of the buildings to be erected by the contractor and his employees in Boulder City shall be subject to the approval of the contracting officer and all such buildings shall be connected with the water supply and sewerage systems of the town. Expensive or permanent types of construction will not be required, but the buildings erected by the contractor or his employees shall have a reasonably attractive appearance and no unpainted shanties or tar paper shacks will be permitted. When the water supply system is completed and in operation, the contractor and his employees may obtain water from it for domestic and other purposes, as required for use in those portions of Boulder City set aside for the use of the contractor and his employees. The contractor shall furnish and install at his own expense all necessary piping for obtaining the water from the city mains, such installations to be in accordance with plans and specifications approved by the contracting officer. For the use of the land set aside for the contractor and for the municipal services and facilities made available for the benefit of the contractor and his employees, the contractor will be charged at the rate of five thousand dollars

($5,000) per month for and during the entire period from the date when the water system for the town is first put in operation to the date of final acceptance of the work under these specifications by the Government, such charge to also cover the contractor's proportionate part of the cost and expense of operation and administration of the town. In addition to such charge the contractor will be charged monthly for all water used at the rates to be established for water service, not to exceed fifty cents ($0.50) per thousand gallons. Electricity for domestic purposes will be made available to the contractor upon request, from the electrical distribution system to be provided by the Government in Boulder City, for which the contractor will be charged at the rates to be established. The contractor will be permitted to sublease to his employees for home sites any part of the land set aside for his use, but such land shall not be used or subleased for business or professional enterprises or concessions, except commissary, hospital, dormitories, boarding houses, and clubhouses equipped with barber shops and other facilities for the use of the contractor's employees. After the date of final acceptance of the work the contractor shall have the right to lease the land at the regular established rates and to pay for water and electricity or other conveniences at the regular established rates: *Provided*, That should the contractor not elect to exercise the right to lease the land, the improvements placed thereon shall be removed by the contractor within six months from the date of final acceptance of the work, subject to the supervision and approval of the contracting officer: *And provided further*, That if such improvements are not so removed by the contractor they shall become the property of the Government. It is contemplated that Boulder City will be under the exclusive administration and control of the Government through the instrumentality of a commission to be appointed by the Secretary of the Interior. The contractor will be afforded the privilege of nominating one member of such commission. Nothing contained in this paragraph shall be construed as in any wise obligating the Government to continue to operate the town of Boulder City beyond such date as may be determined by the Secretary of the Interior, or to preclude the Secretary of the Interior from transferring the control and operation of such town to any instrumentality other than the Government after the date of final acceptance of the work under these specifications. The main camp of the contractor and homes for not less than eighty (80) per cent of the contractor's employees shall be established and maintained in Boulder City, and except as may be permitted in writing by the contracting officer for small isolated camps, such as at the Arizona gravel deposits, and for necessary boarding and lodging facilities at the dam site, the contractor and those operating or associated with the contractor will not be permitted during the period of the contract to establish camps at other sites. The contractor may, with the consent of the contracting officer, use for plant, storage, and incidental purposes any land which is the property of the Government in the vicinity of the work but outside the area to be flooded by the reservoir, except such reservations as are made by the Government for its use or the use of other contractors: *Provided*, That if private land is so used by the contractor, the contractor shall make all necessary arrangements with the owner and pay all rentals or other costs connected therewith: *Provided further*, That such use shall not interfere with any part of the work or with the work of other contractors or the Government: *And provided further*, That the Government will assume no responsibility for damage to or interference with the contractor's use of such land due to any operations under the contract or to floods due to construction of the dam or otherwise.

35. Drinking water at site of works.—During the construction period the contractor shall provide an adequate supply of pure cool water for drinking purposes at the site of all works. This water shall meet all local or State requirements for domestic water, and the quality and adequacy of the supply of water shall be subject to the approval of the contracting officer. The entire cost of furnishing drinking water as required by the provisions of this paragraph shall be included in the unit prices bid for the various items of work in the schedule. The contractor shall furnish water for use by the Government in the testing laboratory and for other purposes at the site of the work and payment therefor will be made at the price per thousand gallons established for use of water by the contractor in Boulder City.

36. Electric power for construction purposes.—A contract has been entered into with the Southern Sierras Power Co. and the Nevada-California Power Co. to furnish power for construction purposes. This power will be delivered at 2,300 volts, 3-phase, 60 cycles, at a substation near the dam site in such amounts as desired up to a maximum of 15,000 kilowatts. The power will be transmitted from San Bernardino or Victorville, Calif., over a single transmission line about 240 miles in length and the power service will be subject to such interruptions as may be expected in the normal operation of a line of this length. The contractor shall provide, at his own expense, whatever amount of stand-by power he may consider necessary to supplement the delivery of power over a single transmission line, to insure continuity of operation of the essential part of his construction plant. The contract with the Southern Sierras Power Co. and the Nevada-California Power Co. requires that power shall be available for use not later than June 25, 1931, and the power may be available thirty days or more previous to that date, but the Government does not guarantee that power will be available for use by the contractor by June 25, 1931. Beginning with the date when power is first used, but in no event later than June 25, 1931, unless power is not available on that date, in which event beginning on the date when power is available, the contractor will be charged monthly for such power as is used by the contractor at the following rates:

(*a*) *Power furnished by power companies.*—A readiness to serve charge of seventeen thousand one hundred six dollars ($17,106) per month plus an energy charge of six mills ($0.006) per kilowatt-hour. For fractional months at the beginning or end of the period, the readiness to serve charge shall be computed in accordance with the actual number of days that power is so obtained. Should suspensions occur in the delivery of power exceeding twenty-four (24) hours in duration, the total elapsed time during which the delivery of power is suspended in any calendar month in excess of twenty-four (24) hours will be ascertained and a deduction of twenty-five dollars ($25) will be made from the monthly bill to the contractor for each one quarter (¼) hour of such suspension in excess of twenty-four (24) hours. Suspensions of less than twenty-four (24) hours or prearranged suspensions of longer duration which are approved in writing in advance by the contractor will not be considered in determining the total elapsed time during which delivery is suspended in any one calendar month.

(*b*) *Power furnished from Hoover power plant.*—When power becomes available from the power plant at the Hoover Dam the Government will terminate the contract with the Southern Sierras Power Co. and the Nevada-California Power Co. and will thereafter serve power to the contractor from the Hoover power plant. The contractor will be charged monthly for such energy as is received from the Hoover power plant at the rate of six mills ($0.006) per kilowatt-hour and no readiness-to-serve charge will be required. After termination by the Government of the contract with the Southern Sierras Power Co. and the Nevada-California Power Co., no deductions will be made for suspensions in the delivery of power. The contractor shall furnish, construct, and maintain at his own expense the necessary circuits, equipment, and material for distributing the power from the substation and from the Hoover power plant, and all equipment, material, and work in connection with the contractor's electrical installation shall conform to specifications and plans acceptable to the contracting officer and shall be maintained in a safe and satisfactory operating condition. On each circuit leaving the substation or the

Hoover power plant, the contractor shall furnish and install an automatic oil circuit breaker, having an interrupting capacity of not less than 26,000 amperes at 2,500 volts, so that troubles on one circuit will not interfere with the operation of other parts of the distribution system, and a watt-hour meter for measuring the energy used on the circuit. Meters shall be subject to test by the Government at any reasonable time at the option of the Government and will also be tested upon the request of the contractor. If test discloses that the error of a meter exceeds two per cent (2%) it shall be adjusted so that the error shall not exceed one per cent (1%) and proper correction shall be made in the amount of energy recorded by said meter as used in the thirty (30) day period immediately preceding the test and such correction shall constitute full adjustment of any claims arising out of such inaccuracy. The energy delivered will be determined from the readings of these meters: *Provided*, That should the meters fail to register, the energy delivered will be estimated from the best information available. Power furnished to the contractor at the substation near the dam site and from the Hoover power plant is for use in the contractor's operations in that vicinity only and power will be made available from the Boulder City electric distribution system for the contractor's camp and other requirements in Boulder City at rates to be established for the sale of power in Boulder City.

37. **Sand and gravel deposits.**—Sand, gravel, and cobbles for concrete and sand for mortar, grout, and gunite shall be obtained by the contractor from natural deposits on the Arizona side of the Colorado River about 8 miles upstream from the dam site. These deposits will be referred to in these specifications as the Arizona gravel deposits and are so designated on the drawings which show their approximate location. The deposits are the property of the Government and will be turned over to the contractor at the time the contractor commences operations, for the purpose of furnishing the aggregates required by these specifications. No charge will be made to the contractor for sand, gravel, and cobbles taken from these deposits. The fact that the Government is hereby designating the deposits from which the aggregates are to be obtained shall not be construed as constituting the approval of all materials taken from the deposits and the contractor will be held responsible for the specified quality of all such materials used in the work. The contractor shall carefully clear the site of the deposits, or so much thereof as is required, of top soil, vegetation, roots, brush, sod, loam, unsuitable sand, gravel and cobbles, and other objectionable matter and shall develop and maintain the deposits in a suitable condition for the excavation and removal of the required material in a manner satisfactory to the contracting officer and so as to utilize at all times in the most economical and practicable manner the entire yield of suitable materials in the portion of the deposits being worked. Combustible materials taken from the deposits shall be burned and other rejected materials shall be disposed of by the contractor in a manner satisfactory to the contracting officer. Since the provisions of these specifications, as stated in other paragraphs, require that water be stored in the reservoir prior to the completion of the work and as such storage will flood the gravel deposits, it will be necessary for the contractor to remove and store sufficient material from these deposits to complete the work after the deposits have been flooded. The storage of this material may be above the water surface of the required storage at any location which may be selected by the contractor and approved by the contracting officer. The contractor shall assume all risk of damage to his plant and equipment at the gravel deposits, by reason of seasonal floods in the river adjacent to the gravel deposits which possibly may, after construction of the cofferdams, reach an elevation of 720 or higher. The cost of all work required by this paragraph shall be included in the unit prices bid in the schedule for the items of work in which the materials obtained are used, which unit prices shall also include all expenses of the contractor in screening, washing, furnishing, hauling, storing, mixing, and other operations necessary on the aggregates.

SUPERSEDED
See Page 26-a

(Revision of February 17, 1931, to be inserted at page 26 of Specifications No. 519 and substituted for original paragraph 37)

37. Sand and gravel deposits.—Sand, gravel, and cobbles for concrete and sand for mortar, grout, and gunite shall be obtained by the contractor from natural deposits on the Arizona side of the Colorado River about 8 miles upstream from the dam site. These deposits will be referred to in these specifications as the Arizona gravel deposits and are so designated on the drawings which show their approximate location. The deposits are the property of the Government and will be turned over to the contractor at the time the contractor commences operations for the purpose of furnishing the aggregates required by these specifications. No charge will be made to the contractor for sand, gravel, and cobbles taken from these deposits. The fact that the Government is hereby designating the deposits from which the aggregates are to be obtained shall not be construed as constituting the approval of all materials taken from the deposits, and the contractor will be held responsible for the specified quality of all such materials used in the work. The contractor shall carefully strip the site of the deposits or so much thereof as is required, of topsoil, vegetation, roots, brush, sod, loam, unsuitable sand, gravel, and cobbles, and other objectionable matter. Disposal of all materials wasted by stripping shall be as approved by the contracting officer. Measurement for payment for stripping the gravel deposits will be made in excavation and will include only the stripping in locations and to the depths as directed by the contracting officer. Payment for stripping and disposal of materials wasted by stripping as described in this paragraph will be made at the unit price per cubic yard bid under item No. 119 of the schedule. No payment will be made for any other material wasted from the gravel deposits, including excess material of any of the sizes into which the aggregates are required to be separated by the contractor, or materials which have been discarded by reason of being below the minimum or above the maximum sizes specified for use. The contractor shall develop and maintain the deposits in a suitable condition for the excavation and removal of the required material in a manner satisfactory to the contracting officer and so as to utilize at all times the greatest practicable yield of suitable materials in the portion of the deposits being worked. It is specified in paragraphs 98, 99, and 100 of these specifications that if washing of the aggregates is required it shall be done at the gravel deposits. Water used for washing aggregates shall meet the requirements for water for mixing as covered by paragraph 102. Since the provisions of these specifications, as stated in other paragraphs, require that water be stored in the reservoir prior to the completion of the work and as such storage will flood the gravel deposits, it will be necessary for the contractor to remove and store sufficient material from these deposits to complete the work after the deposits have been flooded. The storage of this material may be above the water surface of the required storage at any location which may be selected by the contractor and approved by the contracting officer. The contractor shall assume all risk of damage to his plant and equipment at the gravel deposits, by reason of seasonal floods in the river adjacent to the gravel deposits. The cost of all work required by this paragraph, except as provided for stripping under item No. 119, shall be included in the unit prices bid in the schedule for the items of work in which the materials obtained are used, which unit prices shall also include all expenses of the contractor in screening, washing, furnishing, hauling, storing, mixing, and other operations necessary on the aggregates.

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38. Roads and highways, general.—The approximate locations of existing roads in the vicinity of the dam site and also of the construction highway described in paragraph 39, are shown on the drawings. The Government assumes no responsibility for the condition or maintenance of any road or highway or structure thereon that may be used by the contractor in performing the work under these specifications, or in traveling to and from the site of the work. No payment will be made to the contractor by the Government for any work done in improving, repairing, or maintaining any road, highway, including the construction highway, or structures thereon for use in the performance of the work under these specifications.

39. Construction highway.—A highway between Boulder City and the rim of the canyon above the dam site on the Nevada side of the river, terminating about 1,500 feet west of the dam near the end of the construction railroad, will be constructed by the Government as shown on the location map. This highway will have an oiled gravel surface, and it is planned to construct it so that the maximum grade toward the dam will be 4 per cent and from the dam 6.7 per cent. It is contemplated that the highway will be completed and ready for travel by July 1, 1931, but the Government does not guarantee that it will be completed by that date. The construction of additional highway, as described in paragraph 21, is covered by these specifications. The term construction highway shall include the portion of the highway to be constructed under a separate contract as above described, and the highway to be constructed under these specifications, shown on the drawings as the Black Canyon Highway. The construction highway is to be constructed by the Government for the use of its employees, the contractor for the dam, other contractors, and the public in general. The contractor will not be required to maintain and repair the oiled surface portion of the construction highway, but should the contractor desire to do so, all such maintenance and repair work shall be subject to the approval of the contracting officer. The contractor shall at all times maintain the portion of the construction highway to be constructed under these specifications in a condition suitable to provide access to the work, and upon the completion of the work covered by this contract shall leave the highway in a finished condition as described in paragraph 70, and if necessary, as determined by the contracting officer, to accomplish this purpose, shall scarify, blade, and roll the subgrade as described in said paragraph 70. The cost of the work required by this paragraph shall be included in the unit prices bid in the schedule for the items covering the construction of the highway and transporting freight. The contractor shall not use the construction highway for any vehicle, machinery, or other use that, in the opinion of the contracting officer, would unduly injure the road surface or subgrade, and shall obey all rules set up by the contracting officer for the use of the highway.

40. Construction railroad.—A railroad for use in transporting construction materials to the vicinity of the dam site will be constructed by the Government. This railroad will run from its junction with the branch line of the Los Angeles & Salt Lake Railroad, of the Union Pacific System, at the railway delivery yard near Boulder City to a point about 1,500 feet west of the dam on the Nevada side of the river, a distance of about 10¼ miles, as shown on the location map. There will be no up grades toward the dam and the maximum grade from the dam will be about 3 per cent. The railroad will be standard gauge, of substantial construction, and will consist of a single track, with no siding, passing, or spur tracks, except side tracks to Government warehouses and storage yards. It is contemplated that the railroad will be completed and ready for operation by September 1, 1931, but the Government does not guarantee that it will be completed and turned over to the contractor for the dam by that date. Upon completion, the railroad will be turned over to the contractor for the dam, by a written order from the contracting officer. Upon the receipt of this written order, the contractor shall immediately accept the railroad and assume its operation and maintenance. The contractor shall construct at his own expense all siding, passing, spur and switching tracks, and wyes required for his operations and shall furnish all necessary rolling stock and other equipment required for the operation and maintenance of the railroad. The contractor shall operate and maintain the railroad and haul and handle all materials delivered to the contractor by the Government as provided in paragraph 27 for use in constructing the dam and related works, and the entire cost thereof shall be included in the unit prices bid in the schedule for the items of work in the performance of which the railroad is used. The engines used by the contractor shall not be heavier than 150 tons and carloads shall not be heavier than 100,000 pounds: *Provided*, That for infrequent loads, carloads heavier than 100,000 pounds may be transported subject to the specific approval of the contracting officer: *And provided further*, That all materials delivered in carload lots to the contractor by the Government may, at the option of the contractor, be hauled unchanged over the railroad. In addition to the materials to be transported over the railroad as specified above, the contractor shall also transport from the delivery yard to the end of the construction railroad or from the end of the construction railroad to the delivery yard, materials of every kind and nature required to be transported for the Government or for other contractors or agents of the Government engaged on work on any part of the Boulder Canyon project. Such additional transportation service shall be promptly and efficiently handled to the satisfaction of the contracting officer and the contractor shall be liable for any damage to material while it is in the care of the contractor during loading, transporting, and unloading. The rules and regulations under which such additional transportation service shall be furnished shall be subject to the approval of the contracting officer. Payment for such additional transportation service will be made to the contractor at the unit prices bid under items 114 and 115 of the schedule. All portions of the materials or freight which have been transported for the Government under items 114 and 115 and which are designated by the contracting officer for temporary storage in the warehouse shall be unloaded at the end of the construction railroad and placed in the Government warehouse which will be located at the end of the construction railroad. Payment for unloading and placing such materials will be made to the contractor at the unit price bid under item 116 of the schedule. The unit of measurement for payment under item 114 will be one hundred pounds, and under item 115 will be a car. In making payment to the contractor for any shipment in one car the rate will be used which will result in the lower cost to the Government. The unit prices bid under items 114 and 115 shall apply to transportation of freight in either direction between the points stated. The contractor will not be paid under items 114 to 118 inclusive for any materials and equipment which are furnished to the contractor by the Government for installation or use in the work to be done by the contractor under these specifications. All transportation and unloading service to be paid for under items 114 to 118, inclusive, of the schedule will be ordered in writing by the contracting officer, and the unit prices bid shall include the cost of all rental of or demurrage or other charges for railroad equipment while in the contractor's possession and the cost of returning the empty cars to the railroad company at the interchange yard. In the event of any dispute or doubt as to the payment to be made for any transportation or unloading service specified herein or as to the rules or regulations applicable thereto, the matter shall be submitted to the contracting officer, whose decision shall be final. In so far as practicable and applicable, as determined by the contracting officer, the practices, rules, and regulations current with the Union Pacific System will be used as a guide by the contracting officer in approving practices, rules, and regulations and deciding questions regarding them or their application. The contractor shall install all crossing and warning signs and will be held responsible for the safe and proper operation of the railroad. The joint section of the railroad, being that portion between

Mile Post 22.39 and Mile Post 22.71 of the railroad now being constructed by the Los Angeles & Salt Lake Railroad Co., including the delivery yard near Boulder City, will be used in common by the Government, the railroad company, and the contractor for delivering cars and equipment from one party to the other, but the operation of the joint section will be under the direction and control of the railroad company, and before making use of the joint section the contractor shall agree, in writing, with the Government and the railroad company to observe, so far as applicable to the contractor, the terms and conditions of the agreement between the United States of America and the Los Angeles & Salt Lake Railroad Co. dated August 1, 1930, copy of which may be examined in the office of the Bureau of Reclamation at Washington, D. C., Denver, Colo., or Las Vegas, Nev. All operations of the contractor in connection with the railroad shall be subject to the approval of the contracting officer. The contractor shall maintain the railroad in good operating condition for the entire period during which the construction railroad is being operated by the contractor. If, in the opinion of the contracting officer, the contractor does not at any time properly maintain the railroad or any part thereof, the Government reserves the right to do any work which, in the opinion of the contracting officer, is necessary for its proper repair, maintenance, or operation, and to charge the cost thereof to the contractor. Within ninety (90) days after the date on which the railroad is turned over to the contractor, the contractor shall inaugurate regular train service at least twice each week until the railroad is returned to the Government. If, in the opinion of the contracting officer, the contractor fails at any time to provide proper transportation service as required, the Government reserves the right to assume complete control of the railroad, to take over any or all of the contractor's railroad equipment in use on the railroad and to operate the railroad for the purposes required by the contract, at the expense of the contractor. The Government reserves the right to operate its own trains or motor cars of any nature desired for any period of time over the railroad: *Provided*, That such operation of trains or motor cars will be arranged to interfere as little as practicable, as determined by the contracting officer, with the necessary work of the contractor, and the trains shall be dispatched by the contractor. Except as otherwise provided in this paragraph, the cost of all work described in this paragraph shall be included in the unit prices bid for the various items of work in the schedule in the performance of which the railroad is used.

41. Transporting Government freight from construction railroad to power house.—As stated elsewhere in these specifications, the Government contemplates doing certain work at the dam site during the period of the contract for the work under these specifications, and it is possible that work other than that now contemplated will be done by the Government during the contract period. It is expected, however, that the major feature of work by the Government will be the installation of the hydraulic and electrical power machinery. As provided in paragraph 40, the contractor will be paid for transporting freight of all kinds on the construction railroad for the Government, or its agents other than the contractor, to the end of the construction railroad and for unloading some of this freight and placing it in the Government warehouse. Items have been provided in the schedule to cover the transportation of such freight from the end of the construction railroad, and from the Government warehouse, to the generator floor in the power house or, as directed by the contracting officer, at intervening points which are on the contractor's line of travel for such freight. The contractor shall unload and haul, or otherwise transport, all such freight from the end of the railroad, from the Government warehouse, or from a point on the construction highway at the end of the railroad, whether delivered on trucks traveling on the highway or delivered on cars on the railroad, to the generator floor or intervening points, regardless of size, shape, or kind of material or equipment. The contractor will be charged for any such freight lost or damaged after delivery to him at the end of the construction railroad or at the Government warehouse and prior to the time it is delivered in proper condition at the required destination, the same amount that the freight cost the Government at the end of the construction railroad. The contractor shall be responsible for the prompt unloading of freight delivered and will be held liable for any demurrage charges incurred due to failure to unload cars promptly, and for any rental or other charges incurred on rolling stock while in the possession or under the control of the contractor. The contractor shall report to the contracting officer in writing, within 24 hours after unloading, any shortage or damage to materials when delivered. In the transportation of the Government freight as described in this paragraph the contractor may use the inclined freight elevator after its completion as provided in paragraph 42. Payment for unloading, hauling, or otherwise transporting and caring for the Government freight described in this paragraph during the time of transportation will be made at the unit prices bid in the schedule for transporting Government freight from the Government warehouse to the power house or from the end of the construction railroad to the power house, the division for payment between the two items for hauling from the end of the construction railroad being determined on the same basis as the division between items 114 and 115 as provided in paragraph 40. The unit prices bid under items 117 and 118 shall apply to transportation of freight in either direction between the points stated.

42. Use of inclined freight elevator by contractor.—It is contemplated that the inclined freight elevator to be furnished and installed by the Government as provided in paragraph 20 will be designed for the following conditions:

Weight of transfer car, estimated	100,000 pounds.
Load:	
Special car	100,000 pounds.
Live load	150,000 pounds.
Distance between upper and lower landings	594 feet.
Speed of car	60 feet per minute.
Size of car platform	12 feet by 50 feet.

The hoisting equipment will have the necessary electrical control apparatus, brakes, take-up adjustment, indicator, safety devices, and other necessary appurtenances to insure reliability and safety of operation. Should the contractor desire to use the inclined freight elevator for transporting labor, equipment, materials, and supplies for work under these specifications the Government will, upon request, immediately proceed with the purchase and installation of the elevator equipment which will then be turned over the the contractor: *Provided,* That the contractor shall maintain and operate it at no expense to the Government, and shall, after completion of the contract, return the freight elevator to the Government in as good condition as when received, reasonable wear and tear excepted. It is contemplated that the purchase and installation of the freight elevator can be accomplished within 300 calendar days after receipt of request from the contractor for its installation.

43. Acceptance of cofferdams by Government.—After the upstream cofferdam, rock blanket in the river channel, the downstream cofferdam and rock barrier, and the rock protection on the two excavated slopes to bedrock have all been completed in accordance with these specifications and as directed by the contracting officer, they will be accepted by the Government in writing: *Provided,* That the four diversion tunnels have been completed and the river satisfactorily diverted through them. After the date of this written acceptance the Government will assume liability for any damage to the accepted works, and damage resulting thereby to other features of required construction due to flood or other causes not the fault of the contractor, but the Government will not assume any liability for damage to the contractor's plant and equipment nor for any incidental damages not specifically provided for in this paragraph: *Provided further,* That after the date of acceptance the contractor shall enlarge, repair, and maintain the accepted works as directed by the contracting officer, and payment, for any enlargement repairs, or replacements will be made to the contractor at the appropriate prices bid in the items of the schedule for such work as determined by the contracting officer, and if such items are not included in the schedule, payment therefor will be made as extra work under the provisions of article 5 of the contract and paragraph 10 of these specifications: *And provided further*, That if the contractor shall fail to use due diligence in the enlargement, repair, and maintenance of the accepted works as directed by the contracting officer, the contractor shall assume liability for all damage to the accepted works or other features due to his failure to diligently perform such enlargement, repair, and maintenance. Prior to the date of the written acceptance of the cofferdams, the contractor shall assume all liability for any damage to the cofferdams and other parts of the diversion works, and damage resulting thereby to other features of required construction work and to the contractor's plant and equipment, by flood or any other causes.

44. Development of power prior to completion of dam.—The Government reserves the right to commence the generation of power from the Hoover power plant at any time after water has been stored to elevation 900. It is expected that four units will be placed in operation about one year and eight months previous to the completion of the dam, and that about one year later two additional units will be placed in operation, all of these units being operated by water from the downstream intake towers. The completion of all of the power house substructure work below water level and the removal of the downstream cofferdam and rock barrier shall be arranged and timed, subject to the approval of the contracting officer, to permit such generation of power. No operation of the contractor shall interfere with or prevent this generation of power unless specifically approved in writing by the contracting officer. No payment for any part of the work, in addition to that provided at the unit prices bid in the schedule for the various items of work, will be made to the contractor on account of the generation of power as provided for in this paragraph, or elsewhere in these specifications.

EARTHWORK

45. Stripping canyon walls of loose rock.—Early in the construction program and before any extensive construction operations are carried on in the river bed either in the construction of the diversion works or in excavating for the base of the dam or otherwise, the canyon walls, outside of the area to be excavated for the construction of the dam, spillway, power plant, outlet works, and other features to be located on the canyon walls shall be stripped of loose rock or semidetached masses of rock that, in the opinion of the contracting officer, are liable to fall or are otherwise in a condition dangerous to the safety of workmen when performing the other construction operations. The areas over which these stripping operations shall extend and the depth thereof shall be as directed by the contracting officer. All loose material that is liable to be dislodged by any construction operation and thus become a menace to the safety of workmen or the work shall be effectively removed in a manner satisfactory to the contracting officer. The methods used shall be such as not to shatter or render unstable and unsafe any rock that was originally sound and safe. The material removed shall be disposed of in cofferdams, waste banks, or otherwise in a manner satisfactory to the contracting officer and in accordance with these specifications. Nothing contained in this paragraph shall be construed as relieving the contractor of full responsibility for the safety of persons or damage to property in any operations under this contract. Nothing in this paragraph shall prevent the contractor from taking any suitable steps to protect life or property or from removing material in addition to that ordered by the contracting officer: *Provided*, That such operations shall not be permitted to cause detriment to the work or to the site of future work or to increase the net cost of the work to the Government: *And provided further*, That no work will be paid for except that ordered by the contracting officer. No additional payment will be made for the removal of any of the material required to be removed by this paragraph on account of the nature, condition, or position of the material nor on account of the number of times the material is handled. Any material which, in the opinion of the contracting officer, was originally sufficiently sound and stable to not require removal as contemplated by this paragraph but which is loosened or otherwise rendered unstable by any unnecessary or careless operation of the contractor so that, in the opinion of the contracting officer, it is a menace to the safety of workmen or the work, shall be removed by the contractor in a manner satisfactory to the contracting officer and at the contractor's expense. Measurement for payment of the material moved in stripping will be based on its original volume in place, and the manner and method of making this measurement will be determined by the contracting officer. The entire cost to the Government of all work required by this paragraph shall be included in the unit price bid in the schedule for "Excavation: All classes, stripping canyon walls of loose rock."

46. Classification of excavation.—Except as otherwise provided in these specifications, materials moved in excavation will be measured in excavation only and will be classified for payment as follows:

Rock excavation.—All solid rock in place which can not be removed until loosened by barring, wedging, or blasting, and all bowlders or detached pieces of solid rock more than one cubic yard in volume. Solid rock under this class, as distinguished from soft or disintegrated rock under common excavation, is defined as sound rock of such hardness and texture that it can not be effectively loosened or broken down by hand drifting picks.

Common excavation.—All material required to be excavated except solid rock, including earth, gravel, and also indurated material of all kinds such as hardpan, cemented gravel, and soft or disintegrated rock, which may require blasting before removal by team-drawn scrapers or excavating machinery; also all bowlders or pieces of rock not exceeding one cubic yard in volume that are detached or are embedded in common excavation material.

No additional allowance above the prices bid in the schedule for the excavation of materials will be made on account of any of the materials being wet or frozen. It is desired that the contractor or the contractor's representative be present during measurement of materials excavated. On written request of the contractor, made within ten (10) days after the receipt of any monthly estimate, a statement of the quantities and classifications between successive stations, or in otherwise designated locations, included in said estimate will be furnished the contractor within ten (10) days after the receipt of such request. This statement will be considered as satisfactory to the contractor unless specific written objections thereto with reasons therefor are filed with the contracting officer within ten (10) days after receipt of said statement by the contractor or the contractor's representative on the work. Failure to file such written objections with reasons therefor within said ten (10) days shall be considered a waiver of all claims based on alleged erroneous estimates of quantities or incorrect classification of materials for the work covered by such statement.

47. Lines and grades.—The contractor shall provide such drill holes, forms, ladders, spikes, nails, troughs for plumb-bob lines, light, and such assistance as may be required by the contracting officer in giving lines and grades. The contracting officer's marks shall be carefully preserved by the contractor until they have served their purpose. Work in the shafts, tunnels, and open excavations or elsewhere shall be suspended for such reasonable time as the contracting officer may require to transfer lines and to mark points for line and grade. No additional compensation will be paid to the contractor for required assistance in setting lines and grades nor for loss of time on account of such necessary suspension of work or otherwise on account of the requirements of this paragraph.

48. Blasting.—Blasting will be permitted only when proper precautions are taken for the protection of persons, the work, or private property, and any damage done to the work or private property by blasting shall be repaired by the contractor at the contractor's expense. Caps or other exploders or fuzes shall in no case be stored, transported, or kept in the same place in which dynamite or other explosives are stored, transported, or kept. The location and design of powder magazines, methods of transporting explosives, and in general the precautions taken to prevent accidents shall be subject to the approval of the contracting officer, but the contractor shall be liable for all injuries to or deaths of persons or damage to property caused by blasts or explosives.

49. Open-cut excavation, general.—Except as otherwise provided for definite features of open-cut excavation in these specifications or shown on the drawings, open-cut excavation, including excavation for structures, will be measured for payment to slopes of 1 to 1 for common excavation and ¼ to 1 for rock excavation, and in the case of excavation for structures to lateral dimensions 1 foot outside of the foundations of the structure: *Provided*, That where the character of the material cut into is such that it can be trimmed to the required lines of the concrete structure and the concrete placed against the sides of the excavation, without the use of intervening forms, measurement for payment will be made only for the excavation within the neat lines of the structure: *And provided further*, That for any structure or open cut where, in the opinion of the contracting officer, the conditions warrant, the excavation will be measured for payment to the most practicable dimensions and lines as staked out or otherwise established by the contracting officer. Where the concrete in walls, slabs, and floors of the power house, outlet valve houses, hoist house for the inclined elevator, inlet and outlet structures for the diversion tunnels and highway structures is to be placed upon or against rock, and for the spillway crests and channels, the excavation shall be sufficient to provide for the minimum thicknesses of concrete at all points and the average thicknesses shall be exceeded as little as possible. Measurement of such excavation for payment will be limited to the excavation required for the prescribed average thicknesses of the concrete for which measurement for payment is made as provided elsewhere in these specifications. Any and all excess or over-excavation performed by the contractor for any purpose or reason, except as may be ordered in writing by the contracting officer, and whether or not due to the fault of the contractor, shall be at the expense of the contractor. No blasting that might injure the work will be permitted, and any damage done to the work by blasting, including the shattering of the material beyond the required excavation lines, shall be repaired by the contractor at his expense and in a manner satisfactory to the contracting officer. Except as otherwise provided for payment for the construction of the upstream and downstream cofferdams, the rock barrier, and the rock blanket in the river, the unit prices bid in the schedule for excavation in open cut and for the various structures shall include the cost of all labor and materials for temporary construction and of all pumping, bailing, draining, and all other work necessary to maintain the excavation in good order during construction.

50. Preparation of rock foundations for the dam and other structures.—The surface of the rock foundations for all structures in which the concrete of the structure is to be placed directly upon or against rock in open cut without the use of intervening forms shall be left rough so as to bond well with the concrete. Care shall be taken not to shatter or disturb the rock foundations unnecessarily. All dirt and other objectionable materials must be removed from the rock surfaces. Immediately before placing concrete upon or against any rock surface, the surface shall be thoroughly cleaned by the use of stiff brooms, hammers, picks, streams of water and air, separately or in combination, steam, sandblasting, or other effective means satisfactory to the contracting officer. After clearing and before concrete is placed, all water shall be removed from depressions so as to permit thorough inspection and proper bond of concrete with the foundation rock. In the preparation of rock foundations for the dam and spillway crests, the contractor shall take particular care to remove from the foundation surface all loose rock fragments, spalls, dirt, gravel, or other objectionable material. Where necessary, as determined by the contracting officer, the surface of the excavation for the dam and spillway crests shall be cut to rough benches or steps to secure the required roughness. If flowing springs are encountered in the foundations for any structure, the springs shall be closed by pressure grouting, for which payment will be made at the price bid in the schedule for pressure grouting for foundation of dam and spillway crests. The cost of all work described in this paragraph, except as otherwise provided for pressure grouting, shall be included in the unit prices per cubic yard bid for excavation.

51. Tunnel, adit, and shaft excavation, general.—The tunnels, adits, and shafts shall be excavated to the lines and grades shown on the drawings or as directed by the contracting officer. Permanent timbering will not be permitted. The contractor shall use every precaution to avoid excavating beyond the outside lines of steel ribs and steel tunnel liner plates and beyond the specified outside neat concrete lines where no steel ribs or liner plates are required. The required minimum thicknesses of concrete lining shall be provided for at all points and the average thicknesses shall be exceeded as little as possible. No points of unexcavated material will be allowed within the minimum prescribed distance from the finished inside surface of the concrete lining. Measurement of tunnel, adit, and shaft excavation for payment will be limited to the specified sectional dimensions and, except as otherwise provided in these specifications, will be made along the located center lines of the tunnels, adits, and shafts only for reaches of the tunnels, adits, and shafts that are excavated by tunneling methods. Where steel ribs and steel liner plates are not required, measurement of excavation for payment will be limited to the excavation required for the prescribed average thicknesses of concrete lining for which measurement for payment is made as provided in paragraphs 113, 118, 125, and 127. Where steel ribs without liner plates are required, measurement of excavation for payment will be made to lines formed by the outer perimeter of the steel ribs, as used in sets of which the design and locations are approved by the contracting officer in advance of installation. Where steel ribs and steel liner plates are required, measurement of excavation for payment will be limited to the area of a circle of which the radius is 6 inches greater than the outside radius of the steel lining, the outside radii to be as directed by the contracting officer. Any and all excess or over-excavation performed by the contractor to provide space for any purpose, except as may be ordered in writing by the contracting officer, and whether or not due to the fault of the contractor, shall be at the expense of the contractor. No additional allowance above the unit prices bid in the schedule for excavation of tunnels, adits, and shafts will be made on acccount of the class, nature, or condition of any of the materials encountered. No blasting that might injure the work will be permitted, and any damage done to the work by blasting, including the shattering of the material beyond the required excavation lines, shall be repaired by the contractor at his expense and in a manner satisfactory to the contracting officer. Except as otherwise provided in paragraph 53 for steel ribs and liner plates, the cost of all work or materials required for or incidental to the excavation of the tunnels, adits, and shafts, and including, but not restricted to, all draining, pumping, ventilating, lighting, and temporary timbering or other temporary supports shall be included in the unit prices bid in the schedule for the various items of tunnel, adit, and shaft excavation.

52. Temporary timbering in tunnels.—Suitable temporary timbering, including lagging, may be used to support the roofs and sides of tunnels and adits and the sides of all shafts until the concrete lining is placed at any points where temporary timbering is necessary. Lumber for timbering, if required, shall be furnished by the contractor, as provided in paragraph 28. The cost of furnishing and erecting temporary timbering shall be included in the unit prices bid for excavation of tunnels, adits, and shafts. Nothing contained in this paragraph shall prevent the contractor, at his own expense, from erecting such amounts of temporary timbering as he may consider necessary, nor shall it be construed to relieve the contractor from sole responsibility for the safety of the tunnels and for liability for injuries to or deaths of persons or damage to property.

53. Steel ribs and steel liner plates in tunnels, adits, and shafts.—Where approved or ordered in writing by the contracting officer, steel ribs or steel liner plates and arch ring segmental bars shall be installed in the tunnels, adits, and shafts as shown on the drawings or as directed by the contracting officer. The steel ribs, steel liner plates, and arch ring segmental bars or I-beams for this purpose, complete with all required bolts and accessories, shall be furnished by the contractor as provided in paragraph 28. They shall be installed by the contractor in a workmanlike manner, true to line and grade as established by the contracting officer, and shall be maintained by the contractor in proper condition and alignment until the concrete lining is completed against them. All excavated space behind the steel liner plates shall be solidly packed with clean washed gravel or spalls in a manner satisfactory to the contracting officer. The design, material, and installation of the steel ribs and liner plates and arch ring segmental bars shall be subject to the approval of the contracting officer. For all steel ribs, liner plates, and arch ring segmental bars ordered in writing by the contracting officer and which are installed under the foregoing provisions, payment will be made at the unit price per pound bid in the schedule for furnishing and erecting steel ribs, steel liner plates, and arch ring segmental bars in tunnels, adits, and shafts, which unit price shall include the cost of furnishing, hauling, handling, storing, placing, maintaining the installed liner plates until completion of the concrete lining, and packing the space back of the plates as described in this paragraph. The amount of steel ribs, steel liner plates, and arch ring segmental bars required is uncertain and the contractor shall be entitled to no additional allowance above the unit prices bid in the schedule by reason of none or any amount of steel ribs, liner plates, and arch ring segmental bars being required, although changes in the schedule quantities will be covered in the estimates. Nothing in this paragraph shall prevent the contractor from using at his own expense any amount of suitable temporary supports for the roof and sides of the tunnels, nor shall it be construed to relieve the contractor from sole responsibility for the safety of the tunnels during construction and for liability for injuries to or deaths of persons or damage to property.

54. Open-cut excavation for diversion tunnels.—Open-cut excavation for diversion tunnels consists of all required open-cut excavation, as shown on the drawings or directed by the contracting officer, at the inlet and outlet ends of the diversion tunnels, both for channels leading to the inlets and away from the outlets and for all inlet and outlet structures with their appurtenant parts, and includes the open-cut excavation that may be required for portals and portal structures above portions of the tunnels. Berms shall be provided where and as directed by the contracting officer. It may be desirable during the progress of the work to vary the slopes and dimensions of the excavation from those indicated on the drawings. The contractor shall be entitled to no additional allowance above the unit prices bid in the schedule for excavation in open cut for diversion tunnels by reason of the lines, grades, berms, and slopes required by the contracting officer, although changes in the estimated quantities will be covered in the estimates. In the channels leading from the outlets, rock bottoms and banks, within the maximum probable wetted perimeter at any section, as estimated by the contracting officer, must show no points of rock projecting more than 1 foot into the prescribed sections of the channels. Above the maximum high-water line the rock will be allowed to stand at its steepest safe angle, and no finishing will be required other than the removal of rock masses that are loose and liable to fall. Payment for the excavation described in this paragraph will be made at the unit prices per cubic yard bid in the schedule for excavation in open cut for diversion tunnels.

55. Excavation of diversion tunnels.—The excavation of the 50-foot diameter diversion tunnels shall be in accordance with the provisions of paragraph 51. Only excavation that is actually performed by tunneling methods will be measured for payment for excavation of diversion tunnels, and the item of the schedule covering the excavation of diversion tunnels will be further limited, in the vicinity of the connecting inclined spillway tunnel in each outer diversion tunnel, by a horizontal plane at an elevation 64 feet above the center line of the outer diversion tunnel; in the vicinity of the connecting inclined tunnel from the upstream intake tower in each inner diversion tunnel, by a horizontal plane at an elevation 64 feet above the center line of the inner diversion tunnel; and in the vicinity of each power penstock and the riser shaft to the canyon wall outlet works, in each inner diversion tunnel, by the theoretical excavation surfaces in the inner diversion tunnel as determined by the specified average thickness of concrete. The item for excavation of diversion tunnels will include all excavation outside of the regular section of the diversion tunnels required, as shown on the drawings or determined by the contracting officer, for the construction of the tunnel plugs and installation of the gates and needle valves, and includes the excavation of each gallery or adit from the upstream plugs in the inner diversion tunnels to their connection with the inspection galleries in the dam at the surface of the excavation for the foundation for the dam. In the excavation of the diversion tunnels the contractor will be permitted to make one additional adit to each inner tunnel, and one adit from each inner diversion tunnel to the adjacent outer tunnel or to enlarge required adits: *Provided*, That the location of the additional adits and the amount of enlargement of required adits shall be subject to the approval of the contracting officer: *And provided further*, That the additional adits shall be solidly backfilled with concrete for such lengths as directed by the contracting officer and that the entire enlargements of required adits shall be solidly filled with concrete: *And provided further*, That the entire expense of excavating for additional adits and for enlargements of required adits and the filling of both with concrete as required, after they have served their purpose, including the cost of the cement required for concrete, shall be borne by the contractor.

56. Care of river and unwatering foundations.—As provided elsewhere in these specifications the contractor shall construct the diversion tunnels, with plugs, gates, and other appurtenant parts, the upper and lower cofferdams, rock protection in the river channel above the upper cofferdam, rock protection of part of the excavated slopes to the foundation of the dam, and the rock barrier, for which payment will be made at the unit prices bid in the schedule. Except as otherwise provided for paying the contractor for construction of the above-mentioned diversion works, the contractor shall, at the contractor's entire expense, construct and maintain all necessary temporary cofferdams, flumes, or other protective works, shall furnish all material required, and shall install, maintain, and operate all necessary pumping and other equipment for unwatering the site of the work, including the sites of the cofferdams, and for maintaining the foundations of the dam and cofferdams, cut-off trenches, and other parts of the work free from water as required for constructing each part of the work, including constructing the diversion tunnels, cofferdams, and other parts of the diversion works. The contractor shall be responsible for and shall repair at the contractor's expense any damage to the foundations of the cofferdams or other parts of the diversion works caused by floods or failure of any part of the protective works constructed by the contractor incidental to constructing the required work under the contract. The contractor shall pump all water from the site of the dam and power house and shall maintain the foundations for these structures dry while excavating, preparing the foundations, and placing concrete, and, except as otherwise provided in paragraph 43, shall be entitled to no claim for damages or additional compensation by reason of any amount of water that may result from leakage through the cofferdams or from other works which have been constructed by the contractor. After having served their purpose, the downstream cofferdam and rock barrier or so much thereof as directed by the contracting officer shall be removed to give a sightly appearance and so as not to interfere in any way with the operation or usefulness of the reservoir and power plant. Payment will be made to the contractor for this work as provided in paragraph 57. The contractor will not be required to remove the upstream permanent cofferdam or any temporary cofferdams constructed above the dam: *Provided*, That such temporary cofferdams do not interfere with the satisfactory use, as determined by the contracting officer, of the diversion tunnels. In the event that such temporary cofferdams interfere with the satisfactory operation of the diversion tunnels, they shall be removed by the contractor to the extent necessary to avoid interference with the satisfactory operation of the diversion tunnels as determined by the contracting officer and at no cost to the Government. The contractor shall not interrupt the natural or required flow of water for irrigation or other purposes past the dam without the approval of the contracting officer. The cost of all work required by this paragraph for which items of payment have not been provided in the schedule, shall be included in the unit prices bid in the schedule for the construction of cofferdams and for excavation for foundation of dam and power house.

57. **Removal of downstream cofferdam and rock barrier.**—After the downstream cofferdam and the rock barrier have served their purpose they, or such portions of them as directed by the contracting officer, shall be removed from the river channel. Disposal of the excavated materials shall be in accordance with the provisions of paragraph 83. The contractor shall use such excavating equipment, methods, and care in the removal of the materials from the river as may be required to insure a minimum amount of loss of materials down the river. Any such loss of materials due to carelessness on the part of the contractor or due to the use of equipment and methods which are not approved by the contracting officer will be subtracted from the quantities of excavation measured for payment. Measurement for payment will be made of the materials in excavation in the cofferdam and rock barrier. Payment for the excavation and removal of materials as described in this paragraph will be made at the unit price per cubic yard bid in the schedule for removal of rock fill in downstream cofferdam and rock barrier.

58. **Common excavation for foundations of dam, power house, and cofferdams.**—Common excavation for the dam and power house shall extend to rock. Excavation for the foundations of the cofferdams shall extend through the silt and into the coarser strata below only to the extent and as directed by the contracting officer. Measurement for payment for common excavation for the foundations of the dam, power house, and cofferdams will be made on the basis of slopes and berms at the toes of slopes as established by the contracting officer. Payment for common excavation for foundations of dam, power house, and cofferdams will be made at the unit price bid therefor in the schedule. The contractor shall excavate the cut-off trench at the upstream toe of the upstream cofferdam to the lines and grades established by the contracting officer. Measurement for payment of material excavated in the cut-off trench will be made after the general excavation for the foundation of the cofferdam has been made. Payment for excavation in open trench for concrete cut-off in upstream cofferdam will be made at the unit prices per cubic yard bid therefor in the schedule.

59. Rock excavation for foundation of dam.—The excavation for the dam and its abutments shall be made to sufficient depth to secure foundation on sound ledge rock, free from open seams or other objectionable defects as determined by the contracting officer. All necessary precautions shall be taken to preserve the rock below and beyond the lines of excavation in the soundest possible condition. Blasting may be done only to the extent approved by the contracting officer, with explosives of such quantity and moderate power and in such locations as will neither crack nor damage the rock outside of the prescribed limits of excavation. The depth of blasting holes, the size of the charges, and the number of charges fired at one time shall be subject to the approval of the contracting officer. Whenever, in the opinion of the contracting officer, further blasting is liable to injure the rock upon or against which concrete is to be placed, the use of explosives shall be discontinued and the excavation completed by wedging and barring, or other suitable methods. The excavation for the base of the dam at all elevations shall be so shaped and roughly stepped where necessary, as determined by the contracting officer, to produce surfaces of contact between the concrete of the dam and the foundation rock which are as nearly normal to the stresses in the dam as is practicable without excessive excavation. Rock shall be excavated as closely as practicable to the neat lines of the structure, as shown on the drawings or as established by the contracting officer, and payment will be made only for the volume actually required by the contracting officer to be excavated. Measurement for payment of rock excavation for the foundation of the dam will be limited at the downstream face of the dam, where the dam and power house are in contact, to the volume of rock excavated within the neat lines of the dam as shown on the drawings or as actually constructed. Payment for rock excavation for the foundation of the dam will be made at the unit prices per cubic yard bid therefor in the schedule, which price shall include the cost of all labor and materials, shoring, pumping, draining, and all work necessary to maintain the excavation in good order during construction. All cavities in any part of the foundation caused by careless excavation or by the removal, as directed by the contracting officer, of rock needlessly damaged by blasting or other careless operations of the contractor, shall be solidly filled with concrete, at the entire expense of the contractor.

60. Excavation for upstream cut-off trench in foundation of dam.—A cut-off trench shall be excavated under the upstream toe of the dam, as shown on the drawings or as directed by the contracting officer. In performing this excavation, all provisions of paragraph 59 relating to care in excavation shall apply. The cut-off trench excavation will be measured for payment to the actual excavated lines as approved by the contracting officer below the general level of the adjacent excavated dam foundation and payment will be made therefor at the unit price bid in the schedule for "Excavation: All classes, for upstream cut-off trench in foundation of dam," which unit price shall include the cost of all labor and materials, shoring, pumping, draining, and all other work necessary to maintain the excavation in good order during construction.

61. Excavation for spillways, in open cut.—The item of the schedule covering excavation for spillways in open cut covers all excavation upstream from the faces of the required excavation for the portals of the inclined spillway tunnels and includes the open-cut excavation that will be required for the Stoney gate structures, channels thereto, spillway crests, spillway channels, and portal walls above the upper portions of the inclined spillway tunnels. The excavation for the spillway crests shall be performed in accordance with the provisions of paragraph 59 for rock excavation for foundation of dam, and the excavation for the spillway channels shall be performed in accordance with the provisions of paragraph 49 for open-cut excavation, where the provisions of these paragraphs are applicable as determined by the contracting officer.

62. Excavation of inclined spillway tunnels.—Excavation of the 50-foot diameter inclined spillway tunnels shall be made in accordance with the provisions of paragraph 51. The item of the schedule covering this excavation will be limited for each inclined spillway tunnel by the face of the required excavation for the upstream portal wall and by a horizontal plane through the inclined spillway tunnel at an elevation 64 feet above the center line of the outer diversion tunnel into which it discharges.

63. Excavation for canyon-wall valve houses.—The item in the schedule covering excavation for canyon-wall valve houses includes all required excavation, for both upper and lower canyon-wall valve houses on both sides of the canyon. The excavation for these structures shall be made to the lines and grades established by the contracting officer, and in accordance with the provisions of paragraph 49 where applicable as determined by the contracting officer. As shown on the drawings the concrete in the canyon-wall sides of the valve houses is to be placed directly against undisturbed rock without the use of intervening forms.

64. Excavation for intake towers.—The item in the schedule covering excavation for intake towers includes the required excavation for all intake towers, terminating at the base of the concrete foundation for the superstructures of the intake towers, as shown on the drawings or directed by the contracting officer. The excavation around the intake towers shall be sufficient to provide a 10-foot berm, and the rock cut above the berm shall be excavated to ¼ to 1 slopes or to slopes as established by the contracting officer. These slopes must show no points of rocks projecting more than 2 feet into the prescribed lines of the slopes.

65. Excavation of shafts for outlet works and connecting galleries.—The item of the schedule covering excavation of shafts for outlet works and connecting galleries includes all lengths and sections of the 24-foot 3-inch diameter and 15-foot 9-inch riser shafts for the outlet works which are adjacent to concrete linings in shafts for outlet works as described in paragraph 128. It also includes all excavation of the elevator shafts for the canyon wall outlet works, and the adits leading to these elevators from the lower canyon wall outlet works and from the power house, as limited by the concrete in the walls of the upper canyon-wall valve houses, the excavation for the power house, or the face of the canyon walls. It also includes excavation of the adits, from the excavated surface of the entrance to the valve chamber in the downstream inner diversion tunnel plugs to the elevators for the canyon-wall outlet works. The excavation described in this paragraph shall be in accordance with the provisions of paragraph 51, where applicable, as determined by the contracting officer.

66. Excavation of penstock tunnels, outlet tunnels, and power penstocks.—Excavation of the penstock tunnels, outlet tunnels, and power penstocks shall be in accordance with the provisions of paragraph 51. Only excavation that is actually performed by tunneling methods will be measured for payment for excavation of penstock tunnels, outlet tunnels, and power penstocks. The item of the schedule covering this excavation includes the excavation of 30-foot diameter inclined tunnels from the upstream intake towers to the inner diversion tunnels, as limited by the description of other items of excavation in paragraphs 55 and 64; the 30-foot diameter penstock tunnels from the downstream intake towers with all diverting power penstocks to the prescribed outside neat lines of the power-house structure, and all diverting tunnels to the prescribed outside neat lines of the canyon-wall valve houses, but not the shafts for the outlet works as described in paragraph 65; the other power penstocks between the prescribed outside neat lines of the power-house structure and the limits of the excavation of the inner diversion tunnels as described in paragraph 54; and all outlet tunnels from the 24-foot 3-inch riser shafts to the prescribed outside neat lines of the canyon-wall valve houses, but not the shafts for the outlet works as described in paragraph 65.

67. Rock excavation for power house.—The item in the schedule covering rock excavation for power house includes all required solid rock excavation for the power house downstream from the theoretical downstream face of the dam and within the prescribed outside neat lines of the power-house structure, down to the surfaces of the required excavation for power-house and turbine foundations, and includes notching out the canyon walls for the roof truss supports. The excavation described in this paragraph shall be performed in accordance with the provisions of paragraphs 49 and 50, where applicable, as determined by the contracting officer.

68. Excavation for switching station.—The item of the schedule covering excavation for switching station includes all required excavation for footings of structural-steel switch structures, bases for oil circuit breakers and other apparatus required for the switching station. It also includes the excavation for footings for the transmission line towers, which shall be constructed at locations designated by the contracting officer. The excavations shall be made to the lines and grades established by the contracting officer, and in accordance with the provisions of paragraph 49.

69. Excavation for inclined freight-elevator structures.—The excavation for the inclined freight-elevator structures, including hoist house, guide structure, loading and unloading platforms, and spur track foundation, shall be made to the lines and grades shown on the drawings or established by the contracting officer. The excavation for these structures and the measurement for payment for excavation shall conform to the requirements of paragraph 49 for open-cut excavation. Payment for excavation for inclined freight-elevator structures will be made at the unit price bid therefor in the schedule.

70. Excavation for highway.—The term "subgrade" refers to the top of fills or the bottom of excavations. The roadbed for the highway shall be constructed to the full dimensions shown on the drawings or established by the contracting officer and shall be finished to the prescribed lines and grades in a workmanlike manner. It shall be widened near the top of the inclined freight elevator, as shown on the drawings or as directed by the contracting officer, to provide ample space for turning around and for temporary storage for loaded vehicles. In rock excavation the bottom shall, in all cases, be taken out to six (6) inches below subgrade, and all loose rock or bowlders and all ridge rock encountered in common excavation shall be removed or excavated to a depth of not less than six (6) inches below the surface of the subgrade. Payment for such excavation will be made at the unit prices bid in the schedule for excavation for highway. Rock excavations and all holes or depressions resulting from removal of rock or bowlders from common excavation below subgrade elevation shall be back filled to subgrade with material, satisfactory to the contracting officer, obtained from excavation for the roadbed or from borrow pits designated by the contracting officer. Where fills are to be built on sloping ground, the surface of the ground shall be deeply plowed or stepped as directed by the contracting officer, or, in the case of steep rock slopes, benches shall be blasted in the rock surface, as directed by the contracting officer. The cost of this work shall be included in the unit prices bid for excavation: *Provided,* That if the material in benches blasted in rock slopes is required to be excavated, payment therefor will be made at the unit prices bid for excavation for highway. Fills shall be built of material satisfactory to the contracting officer and in accordance with his instructions, either by dumping from grade or in layers of such thickness as he may direct. Where fills are formed of rock, the material shall be carefully placed so that the large rock will be well distributed and the interstices shall be completely filled with smaller rock and earth so as to form a dense, solid fill. Except as otherwise specified, all suitable material excavated in the construction of the roadbed shall be used in the construction of fills and refills to subgrade. Should any material for fills or refills to subgrade, in addition to the material obtained from required excavation for roadbed, be required, it shall be furnished by the contractor from borrow pits and shall be hauled and placed by the contractor. Payment for borrowed material, regardless of length of haul, will be made at the price bid in the schedule for excavation for highway. The necessary material will be measured in excavation at the borrow pits. Wherever the construction of drains or dikes on the uphill side of the roadbed is not ordered by the contracting officer, and where the slope on the uphill side of the roadbed consists of material subject to erosion, the contractor shall plow a furrow to keep surface water away from such slopes. After all drains have been built and the road has been constructed to subgrade, it shall be shaped by means of a blade grader, and scarifying, if required, to a uniform cross-section and at such height above subgrade elevation that when compacted it will conform accurately to the established subgrade elevation and cross-section. It shall then be brought to a firm, unyielding surface by rolling the entire area with a roller having a weight of at least 400 pounds per linear inch of tire width. Measurement for payment, and payment for excavation for highway will be made in accordance with the provisions of paragraph 49 for open-cut excavation. Except as otherwise provided, the price bid in the schedule for excavation for highway shall include the cost of all labor, materials, and plant required in carrying out the provisions of this paragraph, including excavating, constructing fills and refills, plowing furrows, and compacting and finishing of subgrade.

71. **Excavation for highway structures.**—Excavation for corrugated metal pipe culverts and drains, rubble masonry walls, a concrete arch culvert if required, and other highway structures shall be made in accordance with the provisions of paragraph 49. Suitable materials for excavation refill and for back fill after completion of the structure, shall be furnished, placed, and compacted by the contractor, as directed by the contracting officer. The compacting shall be equivalent to that obtained by the tramping of well-distributed scraper teams, depositing the material in layers not over eight (8) inches in thickness when compacted. Excavation for highway structures, or the portion of such excavation not included in the highway prism, will be measured for payment in accordance with the provisions of paragraph 49, and payment therefor will be made at the unit price per cubic yard bid in the schedule, which unit price shall include the cost of all work and materials required in excavating for highway structures, and in back filling such structures in accordance with the provisions of this paragraph.

72. **Back fill for power house.**—Depressions between the back walls of the power house and the cliffs shall, if required by the contracting officer, be back filled with materials from spoil piles or elsewhere to give a neat and finished appearance to the structure. No special compacting of back fill is contemplated and any special compacting required by the contracting officer will be ordered in writing and paid for as extra work under the provisions of article 5 of the contract and paragraph 10 of these specifications. Back fill for power house will be measured for payment in place and will be paid for at the unit price per cubic yard bid therefor in the schedule: *Provided*, That payment will not be made for any material used in such back fill which may be moved directly from required excavation into place in the fill. Any excavation outside of the limits prescribed for excavation which is required to be back filled shall be back filled by and at the expense of the contractor.

73. **Back fill for switching station.**—Depressions in the natural ground surface at the switching station shall, if required by the contracting officer, be back filled with materials from spoil piles or elsewhere to give a neat and finished appearance to the structures. No special compacting of back fill is contemplated and any special compacting required by the contracting officer will be ordered in writing and paid for as extra work under the provisions of article 5 of the contract and paragraph 10 of these specifications. Back fill for switching station will be

measured for payment in place and paid for at the unit price per cubic yard bid therefor in the schedule: *Provided*, That payment will not be made for any material used in such back fill which may be moved directly from required excavation into place in the fill. Any excavation outside of the limits prescribed for excavation for the switching station which is required to be back filled shall be back filled by and at the expense of the contractor.

74. Back fill on roofs.—In order to provide a cushion for protection against falling rocks a back fill composed of a layer of pea gravel, a layer of broken rock or gravel, and a layer of rock will be required on the roofs of the power house, the canyon-wall valve houses, and other buildings if directed by the contracting officer. The layer of pea gravel shall be not less than six (6) inches in depth, the broken rock or gravel not less than twelve (12) inches, and the rock no l than four and one-half (4½) feet. The pea gravel, broken rock or gravel, and rock shall furnished by the contractor as provided in paragraph 28. The pea gravel shall meet the requirements of the smallest size gravel for concrete as provided in paragraph 99 of these specifications. The gravel or broken rock shall meet the requirements of paragraph 99 of these specifications and shall not exceed in size the maximum specified therein. The rock must be hard, dense, durable rock fragments not exceeding one (1) cubic foot in volume and which will be retained on a screen having 8-inch square or 9-inch round openings. The fills shall be carefully placed, as directed by the contracting officer, to the grades established by the contracting officer. Back fill on roofs will be measured for payment in place, and payment will be made at the unit price per cubic yard bid therefor in the schedule, which unit price shall include the cost of furnishing, hauling, and placing the pea gravel, broken rock or gravel, and rock as provided in this paragraph.

75. Embankment construction, general.—For the purpose of these specifications, the term "embankments" includes the rock-fill portions and the earth-fill portions of the upstream and downstream cofferdams, the rock blanket on the upstream face of the upstream cofferdam, the rock protection in the river bed above the upstream cofferdam, the rock protection of the excavated slopes to the foundation of the dam, and the rock barrier below the downstream cofferdam, and does not include any works constructed by the contractor for his use in performance of the contract or fills constructed for the highway and for the elevator spur track. Embankments shall be constructed to the lines and grades shown on the drawings or established by the contracting officer. Embankments shall be built to the heights designated by the contracting officer to allow for settlement. No brush, roots, sod, or other perishable or unsuitable material, as determined by the contracting officer, shall be placed in embankments. The suitability of all materials for construction of embankments shall be subject to the approval of the contracting officer. No material shall be placed in embankments when either the material or the foundation or embankment on which it is to be placed is frozen. The contractor shall care for and maintain all embankments in a manner satisfactory to the contracting officer until the completion and acceptance of the feature of work of which they are a part. Any approved material placed in embankments that is lost before the date of the written acceptance described in paragraph 43, by floods or other action of the river, by weathering, by any operation of the contractor, or by other causes, shall be replaced by the contractor in a manner satisfactory to the contracting officer and without cost to the Government. Each portion of the embankments shall be constructed in accordance with the specifications therefor, including the provisions of this paragraph. All portions of required embankments, whether constructed of materials excavated for other required parts of the work, from borrow pits, or from quarries, will be measured and paid for in embankment, and where the materials are excavated for other required parts of the work payment for placing the materials in embankments will be in addition to the payment made for the required excavation. It should be feasible to transport a large portion of the materials, which are excavated for other required parts of the work and which are suitable for embankment construction, direct to the embankments at the time of making the excavations. The contractor, however, shall be entitled to no additional compensation above the prices bid for excavation and embankments by reason of it being necessary or required, for any reason, that such excavated materials be deposited in spoil banks prior to being placed in the embankments.

76. Borrow pits and quarries.—Where the amount of required excavation does not furnish sufficient suitable material for embankments the contractor shall obtain the necessary material from borrow pits or quarries in the vicinity of the work. The location of all borrow pits and quarries and the suitability of the material for the purpose for which it is required shall be subject to the approval of the contracting officer. Where borrow pits and quarries are located outside of the area to be flooded by the reservoir and where they are exposed to view from the dam and the highway from Boulder City the excavated surfaces shall be left in a reasonably smooth and even condition as approved by the contracting officer. Drainage ditches shall be constructed by the contractor from borrow pits and quarries to the nearest natural outlets to avoid the formation of pools. The cost of all work prescribed in this paragraph shall be included in the unit prices bid for the various items of embankment construction.

77. Rock fill in diversion cofferdams.—The rock fill portions of the upstream and downstream cofferdams shall consist of a freely draining mixture of durable gravel and cobble or rock fragments from natural deposits, from borrow pits, or quarries in the vicinity of the work, or from the excavations required for other parts of the work. The largest rock permissible in the rock fills shall be not more than one (1) cubic yard in volume and the materials in the fills shall be equal in grading to quarry-run material for rock in that vicinity. The inclusion of fine muck, spalls, or gravel in the mass in an amount not in excess of that required to fill the voids in the coarser material, as determined by the contracting officer, will be permissible: *Provided,* That the contractor shall not sluice silt from the river into the rock fills. It is contemplated that material direct from any of the required rock excavation will be suitable. The rock in the rock embankments need not be especially compacted but shall be built up by dumping and roughly leveling off the dumped piles in a manner satisfactory to the contracting officer, and such as to insure that the completed fill will be stable, without tendency to slide, and that there will be no unfilled spaces within the fill. Measurement, for payment, of the materials placed in the rock-fill portions of the cofferdams will be made in the embankments, and payment therefor will be made at the unit prices per cubic yard bid in the schedule for rock fill in cofferdams, which unit prices shall include the entire cost of all excavation in the borrow pits, if necessary to get material from such pits, loading, hauling, dumping, and other operations required in placing the materials in the finished embankments as described in these specifications.

78. Rock protection.—The upstream and downstream slopes of the common excavation for the foundation for the dam, and the river channel immediately upstream from the toe of the paving on the upstream cofferdam, the latter for such distance upstream as shown on the drawings or as directed by the contracting officer, shall be protected by loose dumped rock. The thicknesses of the rock protection shall be as shown on the drawings or as otherwise specified by the contracting officer. The largest rock permissible in the rock protection shall not exceed two (2) cubic yards in volume, and quarry-run material below this maximum size will be acceptable. The inclusion of muck, spalls, or gravel in the mass in an amount not in excess of that required to fill the voids in the material will be permissible. The rock in rock protection shall be so dumped and roughly leveled off in the fill as to insure that the completed fill is stable, without tendency to slide, and so that there shall be no unreasonably large unfilled spaces within the fill. Measurement of rock protection will be made in place on the basis of the actual thicknesses placed up to the specified thicknesses. Payment for placing rock protection in the locations described in this paragraph, as shown on the drawings and elsewhere on the work, as directed by the contracting officer, will be made at the unit price per cubic yard bid in the schedule for rock protection in river channel and elsewhere, which unit price shall include the entire cost of procuring the rock, hauling, handling, and placing the material in the fills.

79. Rock blanket on upstream cofferdam.—The upstream slope of the upstream cofferdam shall be covered with a 3-foot layer of rock as shown on the drawings, or as directed by the contracting officer. This rock blanket shall consist of sound, durable rock fragments or bowlders the maximum dimensions of which shall be not less than 4 inches nor more than 30 inches. The rock for this blanket may, at the option of the contractor, be obtained from stripping of the canyon walls or foundation, from excavation for tunnels, from other required excavation, or from borrow pits approved by the contracting officer, and shall be dumped loose on the upstream slope of the cofferdam. The rock shall be evenly distributed or leveled to a roughly uniform layer of the required thickness, on which the concrete paving is to be placed. The placing of the rock blanket may proceed in lifts as the earth fill of the cofferdam is built up, or the materials for the blanket may be dumped in place after the placing of the earth fill is completed. The method used in placing the rock blanket shall be at the option of the contractor: *Provided*, That the method used shall, in the opinion of the contracting officer, secure the required compactness necessary as a foundation for the concrete paving. In preparing the face of the rock blanket for the 6-inch layer of concrete paving, the contractor shall furnish and place, as directed by the contracting officer, any gravel or small rock fragments, which, in the opinion of the contracting officer, are necessary to fill the voids in the upper surface of the rock blanket and furnish a suitable surface on which to lay the concrete paving. Measurement, for payment, of the materials used in the rock blanket and for preparing the surface of the rock blanket for paving will be made in place on the basis of the actual thickness, but not to exceed three (3) feet, and payment therefor will be made at the unit price bid in the schedule for rock blanket on upstream slope of upstream cofferdam, which unit price shall include the entire cost of procuring, hauling, handling, and placing the material, including gravel in the blanket, and of preparing the face of the rock blanket as a suitable foundation for the concrete paving.

80. Rock barrier below downstream cofferdam.—The rock barrier below the downstream cofferdam shall consist of hard, dense, and durable rock, equivalent in this respect, in the opinion of the contracting officer, to the best rock for resisting wear or erosion that exists in the vicinity of the work and that may be readily obtained from near-by borrow pits, quarries, or, at the option of the contractor, from required excavation. There will be no limit to the size of rock permitted in the rock barrier. The inclusion of muck, spalls, or gravel in the mass in an amount not in excess of that required to fill the voids in the material as specified above will be permissible. The rock may be loosely dumped but in such order and in such a manner as will, in the opinion of the contracting officer, insure that the completed fill is stable, without tendency to slide, and so that there shall be no unreasonably large unfilled spaces within the fill. Measurement, for payment, of materials in the rock barrier will be made in place, and payment therefor will be made at the unit price per cubic yard bid in the schedule for rock barrier below downstream cofferdam, which unit price shall include the entire cost of procuring the rock and hauling, handling, and dumping it in the fill.

81. Earth fill in cofferdams.—The earth fill portions of the cofferdams shall consist of a mixture similar to the natural mixture of silt, sand, and gravel in Hemenway Wash and may be obtained from borrow pits in Hemenway Wash or other places in the vicinity of the work or from required common excavation in the river channel: *Provided,* That only the gravelly material from the river channel excavation, which will form a stable and compact embankment when placed and rolled in 12-inch layers as provided elsewhere in this paragraph, will be acceptable, as determined by the contracting officer after actual excavation is in progress. No separation, sorting, blending or segragation of the materials will be required: *Provided further,* That material from different parts of the borrow pits or required excavation shall be placed on certain parts of the embankments as designated by the contracting officer: *And provided further,* That no stones having maximum dimensions of more than nine (9) inches shall be placed in the earth-fill embankments. Should stones of such size be found in the otherwise approved embankment materials, they shall be removed by the contractor either at the site of the excavation or after transporting to the embankments but prior to rolling and compacting the materials in the embankment. Such stones may be used in the rock-fill portions of the embankments or in the rock blankets on and above the upstream cofferdam if their maximum dimensions are not in excess of the requirements for these features. The mixture of silt, sand, and gravel shall be placed in the embankment in approximately horizontal layers not more than twelve (12) inches in thickness after rolling. All materials shall be uniformly moistened by sprinkling on the embankment. The full thickness of each 12-inch layer shall be moistened to such degree that, in the opinion of the contracting officer, the maximum compactness of embankment will be assured after rolling as specified. The roller used for compacting the embankment shall be of the "Rohl" type, having cast-iron ball feet equally spaced over its cylindrical surface and its weight shall be not less than 1,000 pounds per linear foot of width of tread. The entire surface of each layer of embankment rolled shall have the roller pass over it at least three times. If, in the opinion of the contracting officer, the rolled surface of any layer of material is too smooth to bond properly with the succeeding layer it shall be roughened or loosened by harrowing or otherwise to the satisfaction of the contracting officer before the succeeding layer is placed thereon. Measurement, for payment, of the materials placed in the earth-fill portions of the cofferdams will be made in embankment after compacting by moistening and rolling as specified, and payment will be made at the unit prices per cubic yard bid in the schedule for earth fill in cofferdams, which unit prices shall include the cost of clearing, grubbing, and stripping the approved borrow pits, if required, and the entire cost of all excavating in the borrow pits, loading, hauling, spreading, moistening, harrowing, and other operations required in placing the materials, as described in these specifications, in the finished embankments.

82. Rubble masonry walls.—The contractor shall construct rubble masonry walls along the canyon rim above the power plant and intake towers and below the highway on both sides of the canyon, as directed by the contracting officer, wherever necessary for protection of the permanent works from injury by falling rocks, as determined by the contracting officer. Rubble masonry parapets and retaining walls, where and if required as determined by the contracting officer, shall also be constructed by the contractor, as shown on the drawings or as directed by the contracting officer. The rock used for the rubble masonry shall be clean, hard, dense, and durable. Either bowlders or broken rock from excavation may be used if fulfilling the requirements as to quality and dimensions. If broken rock is used, excessive projections and acute angles shall be removed, and the stones used as headers shall have a roughly squared and reasonably flat exposed face. At least one-fourth of the total volume of masonry shall consist of headers of a length equal to the thickness of the wall for walls less than 18 inches in thickness, and headers at least 18 inches in length for walls over 18 inches in thickness. The headers shall be distributed uniformly throughout the wall. The stones in the wall shall be placed as closely as practicable to the lines and grades established by the contracting officer. The largest stones shall be used in the foundation and lower part of the wall, and all stones shall be laid upon their broadest face. Cement mortar of a mix and consistency approved by the contracting officer shall be used for filling the joints between stones. The surfaces of all stones used in the wall shall be thoroughly cleaned and wetted before being firmly embedded in the layer of mortar previously spread over the preceding layer of stones. The contractor shall not use mortar that has taken an initial set before being placed in the wall, and shall place all stones before the mortar in which they are embedded has taken an initial set. The headers and other large masses of stone shall be brought to an even bearing on the layer immediately below, and the interstices between the larger masses of stone shall be filled by thrusting rock fragments or spalls into the mortar. No unfilled spaces will be permitted in the wall. In order to provide sufficient lateral bond in the wall, the stones in any layer shall break joints with the stones of the preceding layer. Transverse bond shall be provided by the use of headers. If it is necessary to move a stone after it has been placed upon the mortar bed, it shall be lifted clear without sliding and reset, so that no injury will result to the mortar bond of stones already laid. After the stone has been laid as above specified, the joints of all exposed faces shall be thoroughly cleaned and pointed in a workmanlike manner satisfactory to the contracting officer. Measurement for payment for constructing rubble masonry walls will be made in place on the basis of the sectional area specified by the contracting officer. Payment for rubble masonry walls will be made at the unit price per cubic yard bid therefor in the schedule, which unit price shall include the cost of procuring, handling, hauling, and placing the broken rock or bowlders, and materials, except cement, required for constructing the rubble masonry walls.

83. **Disposal of excavated materials.**—As provided elsewhere in these specifications, portions of the excavated materials may be used in required embankments, but the remainder of the excavated materials must be wasted. The disposal of all excavated materials that are wasted shall be subject to the approval of the contracting officer. All spoil banks or waste piles shall be located where, in the opinion of the contracting officer, they will not harmfully interfere with the natural flow of the river, with the operation of the future power plant, or with the discharge of water through the diversion tunnels and the outlet works. No materials shall be wasted in the river channel, either above or below the dam site, below the maximum high-water surface except by written permission of the contracting officer. Spoil banks shall be located where they will not detract from the appearance of the completed structure, or interfere with the accessibility of the structure for operation. Where required by the contracting officer, spoil banks which are visible from the dam or highway shall be roughly leveled and trimmed to reasonably regular lines, and the contractor shall not be entitled to any additional compensation on account of such work. The cost of disposal of all excavated materials that are wasted shall be included in the unit prices bid in the schedule for excavation. Materials excavated from the dam and power house foundations and from other required work may be used in the construction of cofferdams and other embankments: *Provided*, That such materials shall fulfill the requirements for these structures, as specified in paragraphs 77 to 81, inclusive. As provided elsewhere in these specifications payment for placing materials from required excavation, in embankments, except temporary embankments that are to be constructed at the expense of the contractor and except fills required in the construction of the highway and for the elevator spur track, will be made at the unit prices per cubic yard bid in the schedule for the items of embankment construction, which payment will be in addition to the payment for excavation of the material.

GROUT AND DRAINAGE SYSTEMS

84. Drilling grout holes in tunnels, adits, and shafts.—Except for considerable portions of the diversion tunnels upstream from the tunnel plugs in the outer diversion tunnels and upstream from the upstream plugs in the inner diversion tunnels, holes for high-pressure grouting shall be drilled through the concrete linings of the tunnels, adits, and shafts and into the surrounding rock as shown on the drawings or as directed by the contracting officer. At the option of the contractor, pipe connections for high-pressure grouting may be placed prior to placing concrete by attaching one end of the pipe to the forms and cutting the pipe so that the other end will be not less than 6 inches from the rock, or the pipe connections may be set after the holes have been drilled through the concrete. In the first case drilling will be through the portions of concrete lining only beyond the end of the pipes and into the rock, and in the second case will be continuous through the entire thickness of the lining and into the rock. The location, direction, order of drilling, and depth of each hole shall be as ordered by the contracting officer. The diameter of each hole at the bottom shall be not less than 1 inch. Each hole shall be protected from becoming clogged or obstructed by a grout connection grouted into the grout hole and suitably capped or otherwise protected until the hole is grouted, and any hole becoming obstructed before it is grouted shall be opened up to the satisfaction of the contracting officer by and at the expense of the contractor. Plate-steel liner plates furnished by the contractor shall be provided with properly located holes through which grout holes may be drilled, or, at the option of the contractor, holes may be drilled through the steel lining after it is placed. The grout holes will be measured for payment after the holes are drilled and only the length of holes actually drilled by direction of the contracting officer will be considered in making the measurements. Payment for drilling grout holes in tunnels, adits, and shafts will be made at the unit price per linear foot bid therefor in the schedule: *Provided*, That any hole required to be drilled to a greater depth than 25 feet will be ordered in writing and the drilling of the entire hole will be paid for as extra work under the provisions of article 5 of the contract and paragraph 10 of these specifications.

85. Drilling grout holes in foundations for dam and spillway crests.—Grout holes shall be drilled in the foundations of the dam, spillway crests, inlet structures for the outer diversion tunnels, and elsewhere if required, as shown on the drawings or directed by the contracting officer. It is intended that grout holes shall be drilled in the bottom of the upstream cut-off trench of the dam at about 5-foot intervals. It is expected that in general these grout holes will be required to be drilled to varying depths up to a maximum of 150 feet. The direction, order of drilling, and depth of each hole shall be as ordered by the contracting officer. The diameter of each hole at the bottom shall be not less than 1 inch. It may be found necessary to drill grout holes in other parts of the foundations than as shown on the drawings, or it may be found necessary, after all the holes in a given region have been drilled and grouted, to drill additional holes. No additional allowance over the unit prices bid in the schedule will be made to the contractor for drilling such holes nor for the expense of moving equipment or other operations incidental to returning to an old area or moving to a new area. Each hole shall be protected from becoming clogged or obstructed by being suitably capped or otherwise protected until it is grouted and any hole becoming obstructed before it is grouted shall be opened up to the satisfaction of the contracting officer by and at the expense of the contractor. The grout holes will be measured for payment after the holes are drilled and only the length of holes actually drilled by direction of the contracting officer will be considered in making the measurements. Payment for the drilling as described in this paragraph will be made at the unit prices per linear foot bid in the schedule for drilling grout holes in foundations for dam and spillway crests, which unit prices shall include the cost of all labor, materials, plant, and operations required in drilling the holes and maintaining them free from obstruction until grouted.

86. Drilling drainage holes in foundation for dam.—Drainage holes shall be drilled in the foundation for the dam, and elsewhere if required, as shown on the drawings or as directed by the contracting officer. In general, the elevation of the bottom of drainage holes shall be higher than the bottom of adjacent grout holes, and drainage holes will not be required to be drilled to a greater depth than 150 feet beyond the surface of contact between the concrete of the dam and the foundation rock. The depth of each hole shall be as ordered by the contracting officer. Drainage holes shall not be drilled until all adjacent grout holes within a minimum distance of 150 feet have been drilled and grouted. The diameter of each drainage hole at the bottom shall be not less than 2 inches. If after a given area is grouted and drilled for drainage it is found desirable to drill and grout additional grout holes, the contractor may be required to open up previously drilled drain holes by redrilling to secure perfect drainage. Such redrilling of old holes will be ordered by the contracting officer in writing and will be paid for as extra work under the provisions of article 5 of the contract and paragraph 10 of these specifications. Drainage holes will be measured for payment after the holes are drilled and only the length of holes actually drilled by direction of the contracting officer will be considered in making the measurements. Except as otherwise provided for redrilling, payment for the drilling as described in this paragraph will be made at the unit prices per linear foot bid in the schedule for drilling drainage holes in foundation for dam, which unit prices shall include the cost of all labor, materials, plant, and operations required in drilling the holes and maintaining them free from obstruction until the work is completed.

87. Pressure grouting, general.—Sand for pressure grouting shall be furnished by the contractor and shall be clean and of such fineness that 100 per cent will pass a No. 8 standard sieve, and 30 per cent will pass a No. 50 standard sieve. Cement for grouting will be furnished by the Government under the provisions of paragraph 27. When required by the contracting officer, the cement shall be screened before it is used in grout for pressure grouting. All high-pressure grouting shall be done with a neat cement mixture and by the pumping method. Before pressure grouting is begun, all holes and contraction joints shall be thoroughly washed out with water of a quality provided in paragraph 102, under continuous pressure, as required by the contracting officer, up to the required grouting pressure. Grouting shall not be stopped in any hole until the hole takes grout at the rate of not more than one cubic foot in ten minutes when the required grouting pressure is applied. After the grouting of the hole is finished, the pressure shall be maintained by means of a stop-cock or other suitable device until the grout has set sufficiently so that it will be retained in the hole. The apparatus for mixing and placing grout shall be of a type approved by the contracting officer and capable of effectively mixing and stirring the grout and forcing it into the holes at any desired pressure up to the maximum required. Measurement for payment for pressure grouting will be made on the basis of the number of sacks of cement and cubic feet of sand, counted separately, actually forced into the holes or grout connections at the direction of the contracting officer. In measuring the grout for payment the volume of one sack of cement will be considered as 1 cubic foot and the volume of the sand will be taken as that of the sand in its loose dry state. Pressure grouting will be paid for at the unit prices per cubic foot bid therefor in the schedule, which unit prices shall include the cost of all labor, materials except cement, plant, and operations required for the grouting. No payment will be made for grout lost due to improper anchorage of grout pipes, or for grout rejected by the contracting officer on account of improper mixing, and the contractor will be charged for cement used in such wasted or rejected grout the same amount that the cement cost the Government at the point of delivery to the contractor.

88. Pressure grouting in tunnels, adits, and shafts.—After the concrete lining in the tunnels, adits, and shafts and in the tunnel plugs is in place and the required holes have been drilled and grout connections, including vent pipes, provided for, the material surrounding the linings and tunnel plugs shall be pressure grouted as directed by the contracting officer. No grout hole or grout connection shall be grouted until the adjacent concrete is placed and has set a sufficient length of time up to a maximum of 60 days, as determined by the contracting officer. Each drilled grout hole, grout connection, and vent pipe where required shall have forced into it under a pressure of not less than 50 pounds and not more than 500 pounds per square inch, as directed by the contracting officer, a grout composed of cement and water, or cement, sand, and water in proportions to be determined by the contracting officer. In describing grouting operations in these specifications for tunnels, adits, and shafts, pressure grouting is referred to under two general divisions; viz, low-pressure grouting and high-pressure grouting. It is contemplated that the pressure ordinarily used in low-pressure grouting will vary from 50 to 100 pounds per square inch and in high-pressure grouting from 100 to 500 pounds per square inch. Low-pressure grouting shall usually precede high-pressure grouting, and will be used principally to fill the voids between the lining and the rock, particularly above the arches. If, during the grouting of any hole, grout be found to flow from adjacent grout connections in sufficient quantity to seriously interfere with the grouting operation, or to cause appreciable loss of grout, such connections may be temporarily capped. Where such capping is not essential, ungrouted holes shall be left open to facilitate the escape of air and water as the grout is pumped in. Where necessary, vent pipes shall be set, as shown on the drawings and provided in paragraph 145, to permit the excape of air and water from pockets in the material surrounding the concrete linings. Plate steel conduit linings for outlet works and power penstocks will be furnished with tapped holes for making grout connections. The contractor shall pressure grout around all metal conduits, gate frames, and transitions, where directed by the contracting officer, and payment for this work will be made at the unit price per cubic foot bid in the schedule for pressure grouting in tunnels, adits, and shafts.

89. Pressure grouting in foundations for dam and spillway crests.—Each drilled grout hole and grout connection for pressure grouting the foundations for the dam, spillway crests, and inlet structures for the outer diversion tunnels shall have forced into it under a pressure of not less than 100 pounds and not more than 300 pounds per square inch, as directed by the contracting officer, a grout composed of cement and water, or cement, sand, and water in proportions to be determined by the contracting officer. In general, the unit grout pressure required for all pressures above the minimum of 100 pounds per square inch will be determined by the contracting officer on the basis of the full reservoir hydrostatic head at the elevation of the grouting connection and an addition of 50 pounds per square inch. No grout hole or grout connection for grouting the foundations for the dam and spillway crests shall be grouted until all concrete required within a radius of 50 feet and to a thickness of 10 feet is placed and has set a sufficient length of time, as determined by the contracting officer. No grout hole or grout connection for grouting the foundations for the inlet structures of the outer diversion tunnels shall be grouted until all concrete within a radius of 50 feet is placed and has set a sufficient length of time, as determined by the contracting officer. If, during the grouting of any hole, grout be found to flow from adjacent grout connections in sufficient quantity to seriously interfere with the grouting operation or to cause appreciable loss of grout, such connections may be temporarily capped. Where such capping is not essential, ungrouted holes shall be left open to facilitate the escape of air and water as the grout is forced in. Measurement of and payment for pressure grouting as described in this paragraph will be made as provided in paragraph 87.

90. Contraction joints in dam.—Contraction joints in the concrete of the dam will be provided for convenience in construction and to provide for the expansion and contraction of the concrete in horizontal directions. The details of these joints are shown on the drawings and no contraction joints shall be made except in accordance with these details or as directed by the contracting officer. The contraction joints will divide the dam into sections. Horizontal keys shall be built into the circumferential joints and vertical keys into the other contraction joints as shown on the drawings. The entire face of each contraction joint in the dam including the copper expansion strips but not including the grouting units, shall be painted with one thin coat of water-gas tar paint, as directed by the contracting officer. The water-gas tar paint used for this purpose will be furnished by the Government under the provisions of paragraph 27. Copper expansion sealing strips consisting of 20-gauge soft copper sheets shall be placed across the radial contraction joints as shown on the drawings or as directed by the contracting officer. The copper sheets and rivets for connecting them will be furnished by the Government under the provisions of paragraph 27. The copper sheets will be furnished bent and punched in convenient lengths for riveting, and the contractor shall carefully join the sheets together, as shown on the drawings, in a workmanlike manner and so as to form complete continuous watertight diaphragms. The contractor shall take suitable precautions and means satisfactory to the contracting officer to support and protect the copper during the progress of the work and shall replace or repair at the contractor's expense any copper strip punctured or damaged before final acceptance of the work. Brazing and soldering materials for joining the copper sheets shall be furnished by the contractor and the contractor shall carefully rivet and solder these sheets as shown on the drawings and in a workmanlike manner to the satisfaction of the contracting officer. Copper expansion strips will be measured for payment in place and no allowance will be made for lap at joints. Payment for placing copper expansion strips in contraction joints will be made at the unit price per linear foot bid in the schedule. The cost of all work described in this paragraph, except as otherwise provided herein, shall be included in the unit price bid in the schedule for concrete in dam.

91. Pressure grouting contraction joints in dam.—The contraction joints in the dam shall be pressure grouted with cement grout pumped into the pipe grouting systems to be provided for this purpose, as shown on the drawings and specified in paragraph 147. The program of this grouting, the time when each joint or portion of joint shall be grouted, the grout mixture used, the pressure applied, and all details of the operation shall be in accordance with these specifications and as directed by the contracting officer. The grout shall be pumped into the bottom header of each grout system and forced to travel to all parts of the system in the shortest practicable time. In so far as practicable, as determined by the contracting officer, the outlet end of each pipe shall be left open until grout commences to flow from it, whereupon it shall be capped and every other practicable precaution shall be taken to insure that every part of the system and of the contraction joint in the concrete is filled with grout. The grout shall be pumped into each grouting system at a pressure to be determined by the contracting officer, but which will not exceed 500 pounds per square inch at the grout machine. The required pressure shall be maintained after the system ceases to take an appreciable amount of grout by means of a stop-cock in the header pipe or other suitable device approved by the contracting officer. The time consumed in grouting any individual grouting system shall be as short as practicable in order to insure that the grout does not set in any part of the system until after the complete system is grouted, and in no case shall the time consumed in filling any system with grout exceed one-half hour. The equipment used shall have ample capacity for this purpose, and the right is reserved to require the simultaneous application of grout at several points in any one system. The contractor shall not pump grout into any system until the concrete forming the joint or joints in which that system is located has sufficiently set and cooled as determined by the contracting officer.

92. Anchor bars in rock.—Wherever shown on the drawings or required by the contracting officer, holes shall be drilled into the rock to receive rods for anchoring the spillway channel lining and other structures or parts thereof to the rock. These holes shall be filled with cement grout or mortar of a mix and consistency specified by the contracting officer, and steel anchor rods shall be placed in the holes before the grout or mortar sets. Anchor bars shall not be disturbed until the grout has thoroughly set. The size, length, and spacing of the bars and the diameter and depth of the grout holes shall be as shown on the drawings or as specified by the contracting officer: *Provided*, That the diameter of holes shall be dependent on the size of bar used and that the diameter of the bottom of each hole shall be at least fifty per cent (50%) greater than the diameter or maximum dimension of the bar for that hole. Measurement for payment for drilling holes for anchor bars and grouting bars in place will be based upon the length of hole drilled beyond the face of the excavation or rock surface and payment will be made at the unit price per linear foot of hole bid therefor in the schedule, which unit price shall include the cost of furnishing all labor and materials, except cement and steel bars, used in the work. The cement and the steel bars will be furnished to the contractor by the Government under the provisions of paragraph 27. Measurement for payment for placing anchor bars in rock, which shall include cutting, bending, and placing the bars, will be based upon the total length of anchor bars as placed. Payment will be made at the unit price per pound bid therefor in the schedule, which payment will be in addition to the payment for drilling holes for anchor bars and grouting bars in place.

93. Porous concrete tile drains in dam.—Porous concrete tile drains shall be placed in the dam near its upstream face and shall be connected to the drainage gallery, all as shown on the drawings or as directed by the contracting officer. The tile shall be carefully placed, true to line and position, and shall be securely held in position during the placing of the concrete. The joints in the tile shall not be cemented. Special care shall be taken to avoid displacing or breaking the tile during the placing of concrete; and the contractor shall provide and use suitable means satisfactory to the contracting officer to prevent and insure against mortar or concrete entering the drains or the drains becoming clogged with mortar, concrete, or otherwise during the progress of the work. In case any such drain becomes partially stopped up or clogged during the progress of the work it shall be completely opened by and at the expense of the contractor and to the satisfaction of the contracting officer. The concrete tile used for this purpose shall be manufactured by the contractor. It shall have an internal diameter of not less than 20 inches, a wall thickness of not less than 4 inches, and shall be manufactured in units not less than 60 inches long. The end joints shall be suitably grooved or formed in a manner acceptable to the contracting officer so that the tile will fit together to hold the adjacent sections in alignment and prevent the infiltration of mortar from the concrete in the dam. Tongue and groove type, beveled type, or bell and spigot type joints will be acceptable if meeting all other requirements. The walls of the tile shall be uniformly porous so as to permit the passage of water freely through them. The tile shall be made of 1 part Portland cement and 4 parts total aggregate, the aggregates being so proportioned as to give a degree of porosity such that a 60-inch length of tile when set on end on a water-tight base shall discharge water poured into it at the rate of not less than 20 gallons per minute. Dry tile shall have a crushing strength, when tested by the 3-edge bearing method of making strength tests for draintile of the American Society for Testing Materials, of not less than 1,000 pounds per linear foot of tile. Cement for the tile will be furnished by the Government under the provisions of paragraph 27. Any tile manufactured that fails to meet the requirements specified or that is damaged in handling or otherwise, so that, in the opinion of the contracting officer, it is unfit for use, will be rejected and the cost of the cement used in its manufacture will be charged to the contractor. The parts of the tile forming the end joint grooves shall be made of well-graded sand that will pass a screen having ¼-inch round openings. Commercial porous concrete draintile may be furnished by the contractor in lieu of manufacturing the tile as specified above: *Provided*, That it meets the requirements, and in this event the contractor will be credited with the estimated cost of the cement, as determined by the contracting officer, that would have been furnished by the Government for manufacturing the tile. The tile drains will be measured for payment in place in the dam, and no allowance will be made for lap at joints. Placing and manufacturing or furnishing porous concrete draintile will be paid for at the unit price per linear foot bid in the schedule for manufacturing and placing porous concrete draintile in dam, which unit price shall include the cost of all work and materials described in this paragraph, except cement.

ROOFS

94. Tile roofs.—The contractor shall place tile roofs on any building, if directed by the contracting officer. Lumber, tile, roofing felt, and all other materials required for the construction of the roof systems will be furnished by the Government under the provisions of paragraph 27. The contractor shall place and attach all these materials in a workmanlike manner as shown on the drawings and satisfactory to the contracting officer. The contractor shall be responsible for all roofing materials delivered and shall use care in handling the roofing tile to avoid breakage. The contractor will be charged for all tile in excess of two per cent (2%) of the number of tile furnished that is damaged in handling to such an extent that, in the opinion of the contracting officer, it is unfit for use. Tile will be measured for payment in place and payment will be made at the unit price per square foot bid in the schedule for placing tile roofs, which unit price shall include the cost of unloading, hauling, handling, and placing all materials required for placing the tile roofs.

95. Asphalt saturated felt roofing.—Built-up asphalt-saturated felt roofing shall be placed between the two slabs of concrete on the roofs of the power house and on other buildings where directed by the contracting officer, in accordance with Federal specification, symbol SS–R–569, for the "Construction of built-up roofing, type 5 ACS," except that no slag or gravel is required. The roofing shall consist of 5 layers or plies of asphalt-saturated rag felt cemented together with asphalt. Flashings of the type shown on the drawings shall be installed where required. The concrete roof surfaces before applying the roof coverings shall be smooth, firm, dry, and free from high spots, depressions, and all loose and foreign material. The asphalt shall not be heated above 400° F. and shall be hot when the felts are laid. The layers of felt shall be laid so as to be free from wrinkles and buckles. The surfacing material shall always be dry when applied and in addition shall be heated in cold weather. The roofing material shall be applied in the following manner:

First.—Coat the roof surface uniformly with asphalt primer, using not less than one gallon per 100 square feet, and allow to dry.

Second.—On this coating of asphalt lay five layers of 32-inch asphalt-saturated felt over the entire roof surface, lapping each sheet 26 inches over the preceding sheet. Lap the ends of the sheets not less than 6 inches. When 36-inch felt is used, lap the sheets 29 inches. Mop each of these sheets the full width of the lap with hot asphalt, using not less than 20 pounds per 100 square feet in each mopping. Cut off these layers of felt at abutting vertical surfaces.

Third.—Over the entire surface apply a uniform coating of asphalt, using not less than 60 pounds per 100 square feet.

Fourth.—When the slab of concrete has been poured over the felt roofing, the slot around the edge of the slab, as shown on the drawings, shall be poured level full with hot asphalt. The roof will be measured for payment between the bounding lines of the main surface. Areas taken out of the roof surfaces by hatchways and other openings will be deducted from the measured surface. All materials required for the asphalt-saturated felt roofing will be furnished by the Government as provided in paragraph 27. Payment for placing asphalt-saturated felt roofing will be made at the unit price per square yard bid therefor in the schedule, which price shall include the cost of all work required in placing the roofing and flashing in accordance with the provisions of this paragraph.

CONCRETE

96. Composition.—Concrete shall be composed of cement, natural or crushed aggregates, and water well mixed and brought to a proper consistency. The exact proportions in which these materials are to be used for different parts of the work shall be as determined by the contracting officer from time to time during the progress of the work, and as analyses and tests are made of samples of the aggregates and the resulting concrete. In general, the proportions shall be determined by the contracting officer to produce concrete of maximum practical economy to the Government and having an ultimate compressive strength at the age of 28 days varying from not less than 2,500 pounds per square inch for the mass concrete of the dam to not less than 3,500 pounds per square inch for slabs, beams, and other thin reinforced members. The determination of compressive strength in pounds per square inch will be made by testing 6-inch by 12-inch or 8-inch by 16-inch cylinders, as determined by the contracting officer, made in accordance with the standard practice of the American Society for Testing Materials as outlined under serial designation C–39–27 in the latest yearbook of that society. Where the size of the cylinder mold or character of the concrete used in making the test cylinders is such that the cylinder strengths are not directly indicative of the compressive strength of the concrete entering the work, appropriate conversion or equalizing factors, determined by the contracting officer, will be applied to the cylinder strengths obtained. The mixes will be based upon securing concrete having suitable workability, density, and impermeability, and required strengths, without the use of an excessive amount of cement, and using, in so far as practicable, the entire yield of suitable materials from the natural deposits from which the concrete aggregates are obtained. If, in the opinion of the contracting officer, it is inpracticable to utilize in the concrete the entire pit-run yield of suitable material, the contractor shall not be entitled to additional compensation due to the necessity of wasting any of the excess material. The contractor shall provide such facilities and equipment as are required to accurately determine and control the relative amounts of the various materials, including water, cement, and each individual size of aggregate entering the concrete, and such facilities and equipment and their operation shall be subject to the approval of the contracting officer. The amount of cement and of each individual size of aggregate entering each batch of concrete shall be determined by direct weighing equipment approved by the contracting officer, and complying with the following requirements:

(*a*) The accuracy of the weighing equipment shall conform to the requirements of the United States Bureau of Standards.

(*b*) The equipment shall include a visible dial or equally suitable device which will accurately register the scale load at any stage of the weighing operation from zero to full capacity.

(*c*) The equipment shall include an accurate automatic recorder, capable of being locked, for visibly and graphically recording the time of weighing and the actual amount of each separate concrete ingredient weighed out.

(*d*) The equipment shall be capable of ready adjustment for compensating for the varying weight of moisture contained in the aggregates, or for changing the proportionate batch weights.

(*e*) The equipment shall be capable of controlling the delivery of material for weighing to within 1 per cent of the specified weight of cement and 2 per cent of the specified weight of each separate aggregate.

(*f*) The equipment shall be so arranged as to permit the convenient removal of overweight material in excess of the prescribed tolerances.

The amount of water used shall be changed as required to secure concrete of proper consistency and to adjust for any variation in the moisture content in the sand or other aggregates as they enter the mixer: *Provided,* That the inundation method of controlling the water content will not be required. The quantity of water entering the mixer shall be measured by weight, volume, or other suitable method. The measuring device shall be subject to the approval of the contracting officer and shall be capable of measuring the water in varying amounts within a tolerance of 1 per cent. The equipment shall include an accurate automatic recorder, capable of being locked, for visibly and graphically recording the time of measurement and the actual quantity of water used in each batch of concrete. The operating mechanism must be such that leakage will not occur when the valves are closed. The quantity of water entering any batch of concrete shall be just sufficient, with a normal mixing period, to produce concrete of the required consistency, as determined by the Government inspector. Excessive overmixing, requiring additions of water to preserve the required concrete consistency will not be permitted. Uniformity in concrete consistency from batch to batch will be required and the contractor shall equip each mixer with an efficient recording consistency gage and timer or provide equally suitable equipment or means, satisfactory to the contracting officer, for indicating and recording consistency. All graphic charts pertaining to equipment mentioned in this paragraph shall, after recordation, become the property of the Government. When directed, broken rock or gravel and cobbles shall be suitably moistened to prevent a variable quantity of water being introduced into the concrete. Tests and analyses of the aggregate and the resulting concrete will be made by the Government at frequent intervals and the mixes used shall be changed whenever necessary or desirable, in the opinion of the contracting officer, to secure the required economy, workability, density, impermeability, or strength, and the contractor shall be entitled to no additional compensation because of such changes. The contractor will be permitted, when approved by the contracting officer, to use proportions producing concrete of equal quality but with less economy than the proportions determined by the contracting officer: *Provided,* That any increase of cost as a result thereof shall be borne by the contractor. Only sufficient water shall be used to secure a plastic concrete of suitable workability, as determined by the contracting officer, and which, without segregation, will flow or can be worked properly into place with thorough spading or working. In general, a wetter consistency than that corresponding to a slump of 3 inches at point of placement, when tested in accordance with the "Tentative Specifications for Workability of Concrete for Concrete Pavements" of the American Society for Testing Materials, will not be permitted for the main portions of the concrete structures. A greater slump than 3 inches at point of placement, but not exceeding a maximum of 6 inches, will be permitted, where specifically authorized by the contracting officer, for concrete in positions difficult to place, such as thin reinforced walls or slabs, where it may be impracticable to properly place concrete having a slump of only 3 inches. The slumps stated herein are maximum slumps and the Government reserves the right to require a lower water-cement ratio in any or all mixes than required to produce these slumps whenever, in the opinion of the contracting officer, such lower water-cement ratios are practicable and will produce concrete of better quality.

97. Cement.—Portland cement for the concrete, grout, gunite, and mortar will be furnished to the contractor by the Government as provided in paragraph 27, and the cement will be delivered to the contractor in carload lots in bulk: *Provided*, That, at the request of the contractor, cement for grout, gunite, and isolated minor items of concrete work, as determined by the contracting officer, will be furnished in sacks. The contractor shall return to the delivery yard, as the contracting officer may direct, all empty sacks cleaned of cement in a manner satisfactory to the contracting officer, securely bound in bundles in such manner and of such size as the contracting officer may direct. For all sacks not returned in serviceable condition the contractor will be charged the same amount that the sacks cost the Government. In order that cement will not become unduly aged after delivery, the contractor shall not use cement in the work direct from his freighting or other hauling or transporting operations whenever any cement is available that has been stored more than sixty (60) days after delivery to the contractor. Any cement in excess of five hundred (500) barrels that is kept by the contractor in excess of two hundred (200) days before it is used in the work will be condemned and its entire cost to the Government at the point of delivery to the contractor will be charged to the contractor. Storage bins for cement shall be so constructed that there will be no dead storage. Cement will be tested at the mills to see that it conforms to the requirements of the Government. The contractor shall give the contracting officer not less than thirty (30) days' notice in writing of his cement requirements. The requirements shall be stated, in so far as practicable, in quantities of not less than carload lots. The contractor shall be responsible for the proper unloading of the bulk cement in such a manner that none of the cement will be damaged or wasted. Any cement damaged or wasted by the contractor due to carelessness in unloading and storing or otherwise will be charged to the contractor at its entire cost to the Government at the point of delivery to the contractor. It is now estimated that for all the items of concrete included in the schedule an average of between 1.1 and 1.2 barrels of cement per cubic yard of concrete will be used, this average including the cement used in grouting rock foundations and in horizontal construction joints. However, as provided in paragraph 96, the concrete mixtures shall be under the directional control of the contracting officer, and no adjustment in compensation to the contractor will be made on account of any variation in the amount of cement used in the concrete and grout, should the actual average amount of cement per cubic yard be greater or less than the estimated limits. The unit prices bid in the schedule for the various items of concrete, grouting, gunite, and other work shall include the cost of the required hauling, handling and storing of the cement that is used in the concrete, gunite, grout, and other work.

98. Sand.—Sand for concrete, gunite, grout, and mortar shall be obtained from natural deposits, under the provisions of paragraph 37. The sand particles shall be hard, dense, durable, uncoated, nonorganic rock fragments that will pass a 1/4-inch square or a 5/16-inch round opening. It must be free from injurious amounts of dust, lumps, soft or flaky particles, shale, alkali, organic matter, loam, mica, or other deleterious substances. The sand as it is used in the concrete must be so graded that concrete of the required workability, density, and strength can be made without the use of an excess of water or cement. The sand for concrete shall have a fineness modulus of not less than ~~2.50~~ 2.75 nor more than 3.25, unless approval is given by the contracting officer to use sand not meeting this requirement. The fineness modulus will be determined by dividing by 100 the sum of the percentages retained on Tyler standard sieves, numbers

4, 8, 14, 28, 48, and 100. The suitability of the sand will be determined by the contracting officer with the aid of tests made in accordance with the standard practice of the United States Bureau of Standards. The sand shall be washed unless specific written authority is given by the contracting officer to use unwashed sand. The contractor shall screen and, if required, wash all sand at the gravel deposits. The sand shall be such that tests of briquettes, made in proportion of three parts sand to one part cement, by weight, shall develop a tensile strength of not less than the strength developed by such tests with standard Ottawa sand. Any crushing, rolling, blending, screening, washing, or other operation on the sand required to meet these specifications shall be done by the contractor and the cost thereof shall be included in the unit prices bid in the schedule for the items of work in which the sand is used.

99. Broken rock or gravel.—The broken rock or gravel for concrete must be hard, dense, durable, uncoated rock fragments free from injurious amounts of soft, friable, thin elongated or laminated pieces, alkali, organic or other deleterious matter. It shall be so graded that concrete of the required workability, density, and strength can be made without the use of an excess of sand, water, or cement. The suitability of the broken rock or gravel will be determined by the contracting officer with the aid of tests made in accordance with the standard practices of the United States Bureau of Standards. Any crushing, blending, screening, washing, or other operation on the broken rock or gravel required to meet these specifications shall be done by the contractor and the cost thereof shall be included in the unit prices bid in the schedule for the items of work in which the broken rock or gravel is used. The broken rock or gravel shall be washed unless specific written authority is given by the contracting officer to use unwashed broken rock or gravel. The contractor shall screen and, if required, wash all gravel at the gravel deposits. The broken rock or gravel shall all pass through a screen having 2¼-inch square or 3-inch round openings and shall be retained on a screen having ¼-inch square or 5/16-inch round openings. It shall also be separated into three intermediate sizes by screens having ¾-inch square or ⅞-inch round openings, and 1½-inch square or 1¾-inch round openings. Screens having openings of other sizes or shapes may be used: *Provided*, That equivalent results, as determined by the contracting officer, are obtained. The relative amounts of each size of broken rock or gravel to be used in each mix of concrete and in all parts of the work will be determined by the contracting officer, and will be based on securing concrete having the required workability, density, impermeability, strength, and economy, without the use of an excess of sand, water, or cement and using in so far as practicable, the entire yield of suitable material from the natural deposits from which the broken rock or gravel is obtained. The contracting officer will determine the maximum size of broken rock or gravel to be used in each part of the work. For very thin or heavily reinforced parts, the maximum size will be that determined by the screen having ¾-inch square or ⅞-inch round openings; for somewhat heavier portions of the work the maximum size will be that determined by the screen having 1½-inch square or 1¾-inch round openings; and for the more massive portions the maximum size will be that determined by the screen having 2¼-inch square or 3-inch round openings.

100. Cobble rock.—Cobble rock shall in general be added to the mix. Such cobble rock shall be sound, clean gravel or broken rock of such size as will pass through a screen having 8-inch square or 9-inch round openings and be retained on a screen having 2¼-inch square or 3-inch round openings. The amount of such cobble rock to be used shall be as determined by the contracting officer, based on producing the most economical concrete of the required strength and in so far as practicable, utilizing the entire yeild of the natural deposit or quarry from which the broken rock or gravel is obtained. The contractor shall screen and, if required, wash all cobble rock at the gravel deposits. The use of cobble rock will not be required or permitted where the concrete is reinforced, or in any concrete structure the least dimension of which is less than 30 inches.

101. **Samples of concrete aggregates.**—Suitable samples of aggregates, as they are to be used in the concrete, gunite, grout, or mortar, shall be furnished and delivered to the contracting officer, either at the laboratory of the Bureau of Reclamation at Boulder City or at the laboratory at the dam site or at both, as required by the contracting officer, at least sixty (60) days in advance of the time when the pouring of the concrete is to begin, and at other times and in such amounts and manner as directed by the contracting officer. These samples shall be sufficient in quantity to permit the making of such test specimens as may be required for determining the suitability and proportions of the materials. The contractor shall give the contracting officer all necessary assistance in securing and handling the samples. The cost of all work required to carry out the provisions of this paragraph and the cost of hauling and handling cement used in testing concrete shall be included in the unit prices bid in the schedule for the items of work in which aggregates are used.

102. **Water for mixing.**—The water used in concrete, grout, gunite, and mortar must be reasonably clean and free from objectionable quantities of silt, organic matter, alkali, salts, and other impurities. It is contemplated that water equal in chemical analysis to the Colorado River water at the dam site prior to the beginning of construction work under these specifications will be satisfactory for mixing water. Water shall not be taken directly from the Colorado River and used in mixing but shall first be stored in settling basins so that the water used in mixing will be practically free from silt, or, at the option of the contractor, the silt may be removed by other methods as approved by the contracting officer. The entire cost of furnishing the mixing water of a quality as provided in this paragraph shall be included in the prices bid in the schedule for the items of work in which mixing water is used.

103. **Mixing.**—The cement, sand, broken rock or gravel, and cobbles shall be so mixed and the quantity of water added shall be such as to produce a homogenous mass of uniform consistency. Dirt and other undesirable substances shall be carefully excluded. All concrete shall be thoroughly mixed in a batch mixer of an approved type and size, and one so designed as to positively insure a uniform distribution of all the component materials throughout the mass during the mixing operation. Each mixer and its operation shall be subject to the approval of the contracting officer, and the use of any mixer that, in the opinion of the contracting officer, at any time produces unsatisfactory results shall be promptly discontinued until it is repaired or replaced. In general, only sufficient water shall be used in mixing to give a workable mix. The mixing of each batch shall continue not less than the number of minutes as stated in the tabulation at the end of this paragraph, after all materials, including water, are in the mixer, during which time the mixer shall rotate at the speed for which it has been designed or at such speed as will produce a mass of uniform consistency at the end of the mixing period. The drum of the mixer shall have a peripheral speed of about 200 feet per minute. Overloading of mixers will not be permitted. A mechanically operated timing device, satisfactory to the contracting officer, shall be installed by the contractor as provided in paragraph 96.

Capacity of mixer	*Time of mixing.*
2 yards and less	1½ minutes.
3 yards	2 minutes.
4 yards	2¼ minutes.
5 yards	2¾ minutes.
6 yards	3 minutes.

104. Temperature of concrete.—Concrete when deposited shall have a temperature of not less than 40° F. nor more than 100° F. In freezing weather suitable means shall be provided for maintaining the concrete at a temperature of at least 40° F. for not less than 72 hours after placing or until the concrete has thoroughly hardened. The methods of heating the materials, if required, and protecting the concrete shall be subject to the approval of the contracting officer.

105. Forms.—Forms to confine the concrete and shape it to the required lines shall be used wherever necessary. Where the character of the material cut into to receive a concrete structure is such that it can be trimmed to the prescribed lines, the use of forms will not be required. The forms shall be of sufficient strength and rigidity to hold the concrete and to withstand the necessary pressure and ramming without deflection from the prescribed lines. The surfaces of all forms in contact with the concrete must be rigid, tight, and smooth. In order to secure smooth surfaces on the main body of the dam and in the concrete linings in tunnels, adits, and shafts, the forms, if not entirely of metal construction, shall be faced with sheet steel or with other suitable metal material. The sheets shall be carefully selected and shall be placed and maintained on the forms without wrinkles, bumps, or other imperfections. When such metal-faced forms have been used repeatedly and are, in the opinion of the contracting officer, unfit for further use they shall be discarded by the contractor and new forms shall be provided by the contractor, and the contractor shall be entitled to no additional compensation by reason of the necessity for discarding any forms which are unsuitable for use, as determined by the contracting officer. Suitable devices shall be used to hold adjacent ends and edges of panels or other forms together and in accurate alignment. Metal surfaces will not be required on forms which are to be used only once: *Provided*, That the lagging of forms for concrete surfaces that will be exposed to view and for all other concrete surfaces that are to be finished smooth, shall be tight, smooth-surfaced, and bevel-edged or matched. Forms without metal facing may be used more than once on such portions of the work as may be determined by the contracting officer, if, in the opinion of the contracting officer, they are maintained in serviceable condition and thoroughly cleaned before being reused. Metal rods or other similar devices to hold the forms will be permitted in the structures if proper means are used to take out or omit a portion of each of the rods from the nearest surface of the concrete to a depth of at least 2 inches. All holes left after removal of the rods shall be immediately and completely filled with cement mortar and the surface left smooth and in good condition. Wire ties will be permitted only where approved by the contracting officer and if used they shall be cut off flush with the concrete surface after the forms are removed. Before placing concrete the surfaces of all wooden, metal, and metal-faced forms shall be oiled with a suitable nonstaining oil of a quality satisfactory to the contracting officer, and just before placing concrete precaution shall be taken to see that all form anchors and ties are thoroughly secure and tight. Where forms are placed in successive units for continuous surfaces, care shall be exercised to fit the forms tightly over the completed surface so as to prevent leakage of mortar from the concrete. Where the thickness of tunnel, adit, or shaft lining is not sufficient to permit men to work behind the forms, inspection openings shall be provided in the forms as directed by the contracting officer. Forms shall be left in place until their removal is authorized by the contracting officer, and shall then be removed by the contractor with care so as to avoid injury to the concrete. Except as otherwise provided in paragraph 122, the contractor shall furnish all equipment, labor, and materials for forms, including lumber, metal forms or metal facing, bolts, spikes, nails, metal rods or wire ties, and oil, and the cost thereof shall be included in the unit prices bid in the schedule for concrete.

106. Placing.—Concrete shall be placed in the work before the cement takes its initial set. The contractor will be charged for any cement wasted at its cost to the Government at the point of delivery to the contractor. All foundation surfaces upon or against which concrete is to be placed shall be free from mud and debris. After cleaning, and immediately before placing concrete, all approximately horizontal foundation surfaces for the dam and other parts of the work, as directed by the contracting officer, shall be covered with a layer of mortar 1 inch thick, consisting of the regular concrete mixture without the coarse aggregates, or as directed by the contracting officer. The concrete mortar shall be thoroughly worked with brooms or otherwise into all irregularities of the surface. Concrete shall then be placed immediately upon the fresh mortar. When the placing of concrete is to be interrupted long enough for the concrete to take its final set the working face shall be given a shape, as determined by the contracting officer, by the use of forms or other means, that will secure proper union with subsequent work. All concrete surfaces, such as the horizontal construction joints of the dam, upon or against which concrete is to be placed and to which the new concrete is to adhere, shall be roughened, and all laitance and loose or defective surface concrete shall be removed by thorough scrubbing, brushing, chipping, sand-blasting, washing, and blowing with compressed air. The cleaned surfaces shall be thoroughly moist when concrete or mortar is placed upon or against them, but shall be free from pools of water. The cleaning of concrete surfaces as described above shall be done while the concrete is still sufficiently soft to permit thorough cleaning. Any surface which is allowed to become thoroughly hardened before cleaning shall be completely chipped to a depth as directed by the contracting officer. All horizontal construction joints in the dam shall be provided with keys as shown on the drawings, or as directed by the contracting officer. All horizontal concrete surfaces for the dam, and other parts of the work as directed by the contracting officer, which have set for 48 hours or more, and upon which concrete is to be placed, and to which the new concrete is to adhere, shall be covered with a layer of mortar approximately ½ inch thick, consisting of the regular concrete mixture without the coarse aggregates, or in proportions determined by the contracting officer. Concrete shall then be placed immediately upon the fresh mortar. Methods of placing which will deliver concrete of the required consistency into the forms and into final position without segregation shall be used. Placing of concrete in the dam shall, in general, be done by means of bottom-dump buckets or other methods whereby each complete mixer batch or combination of mixer batches is conveyed in one mass to its location in the dam. Methods of conveying concrete to any of the structures, by which the mixed batch or combination of batches is progressively loaded into chutes, belts, conveyors, or other similar equipment and carried in a thin continuous flow to the forms, will not be permitted: *Provided*, That such methods of conveyance may be used, if approved in writing by the contracting officer, for very limited, isolated sections of the work. The continuous flow methods of conveyance are excluded under these specifications: First, because of the hazard to workmen from falling rock; and second, because of the difficulty of controlling the consistency of the concrete mix. Concrete shall be deposited in all cases as nearly as practicable directly in its final position and shall not be caused to flow in the mass in a manner to permit or cause segregation. Dropping the concrete vertically a distance of more than 5 feet or depositing a large quantity at any point and running or working it along the forms will not be permitted. Except as intercepted by contraction joints, all concrete shall be placed in continuous horizontal layers, the thickness of which generally shall not exceed 12 inches. All lifts in placing concrete shall be rammed, tamped, or worked with suitable appliances, tamping bars, shovels, or forked tools until it completely fills the forms, closes snugly against all surfaces, and is in perfect and complete contact with any steel used for reinforcement. Where smooth surfaces are required, and for all surfaces which will be permanently exposed to the weather, and for all surfaces next to metal conduits or other embedded metal around which it is desirable to prevent leakage, the adjacent concrete shall be worked, tamped, and stirred so that the coarser material is forced back and a mortar layer is brought next to the metal surface. No concrete shall be placed except in the presence of a duly authorized Government inspector. No concrete shall be placed in water except with the written permission of the contracting officer and under his supervision. If depositing in water is allowed, the concrete shall be carefully placed in the space in which it is to remain, in a compact mass by means of a tremie, bottom-dump bucket, or other method approved by the contracting officer, that will not permit the concrete to fall through the water without adequate protection. Concrete deposited under water shall not be disturbed after being deposited. No concrete shall be placed in running water. Concrete which is not placed in accordance with these specifications and is of inferior quality, as determined by the contracting officer, shall be removed and replaced by the contractor. The entire cost of removing and replacing such rejected concrete shall be borne by the contractor, including the cost of all materials required in the replacement.

107. Finishing.—The surface of concrete finished against forms must be smooth, free from projections, and thoroughly filled with mortar. Immediately upon the removal of forms all voids shall be neatly filled with cement mortar of the same proportions as the mortar in the concrete. All unsightly ridges or lips shall be rubbed down, and any local bulging on exposed surfaces shall be remedied by tooling and rubbing. All patching required shall be done as directed by the contracting officer and only by skilled workmen and in the presence of a Government inspector. The upstream face of the dam shall be surfaced with gunite as provided in paragraph 136. Exposed surfaces of concrete not finished against forms, such as horizontal or sloping surfaces, shall be brought to a uniform surface and worked with suitable tools to a smooth steel trowel finish, except as otherwise provided in paragraphs 123, 137, and 138. All sharp angles on surfaces which will be exposed to view and on other surfaces where required, including reentrant angles in contraction joints, shall be rounded, beveled, or filleted by the use of molding strips or suitable molding or finishing tools. Hand-rubbed finish may be required on portions of the power house and parapet walls and elsewhere as provided in paragraph 123. Special care shall be taken in the form work and finishing in all tunnels which will be subject to high velocities, and all projections or offsets in the surfaces shall be removed by rubbing or grinding with carborundum or by other methods satisfactory to the contracting officer.

108. Protection.—The contractor shall protect all concrete from injury until final acceptance by the Government. All horizontal construction joints in the dam and spillway crests shall be kept continuously moist, regardless of time, until they are covered with concrete. The upstream and downstream faces of the dam, the surfaces of all contraction joints in the dam and spillway crests, and the exposed surfaces of concrete in all other structures shall be kept continuously moist for at least 2 weeks after the concrete is placed. Horizontal, or approximately horizontal surfaces of concrete pavements shall be covered with sand or earth as soon as set and kept moist for at least 2 weeks after placing. The method of keeping concrete moist shall be by continuous sprinkling, spraying, or other methods approved by the contracting officer. Concrete placed or cured in freezing weather shall be protected from freezing by such means as are approved by the contracting officer. All water used in curing shall be free from excessive amounts of silt and other impurities and shall be equal in quality to that required for mixing water as provided in paragraph 102.

109. Damaged or defective concrete.—Concrete damaged by freezing, or from any other cause, or any concrete which shall be found defective in quality or workmanship at any time before the completion and acceptance of the work shall be removed and replaced with acceptable concrete by the contractor, as directed by the contracting officer, at no expense to the Government, and the contractor will be charged for the cement used in such concrete the same amount that the cement cost the Government at the point of delivery to the contractor.

110. Reinforcement bars and rails.—Steel bars and rails for reinforcement shall be placed in the concrete wherever shown on the drawings or prescribed by the contracting officer. Unless otherwise shown on the drawings or directed by the contracting officer, measurements made in placing the reinforcement shall be to the center line of the bar. The steel will be furnished to the contractor by the Government as provided in paragraph 27. The exact position, size, and shape of reinforcement bars and rails are not shown in all cases on the drawings, and where not shown they shall be in all respects as specified by the contracting officer, and where necessary, as determined by the contracting officer, the contractor will be furnished supplemental detailed drawings or lists which will give the information necessary for cutting, bending, and placing the bars and rails. The steel used for concrete reinforcement shall be so secured in position that it will not be displaced during the depositing of the concrete, and special care shall be exercised to prevent any disturbance of the steel in concrete that has already been placed. The contractor shall weld all hoop reinforcement around all outlet gates and conduit linings appurtenant thereto. The reinforcement bars shall be rolled to form hoops of the required diameter, and butt-welded by the arc-weld process. The weld shall develop the full strength of the metal in the bar. Each weld shall be tested in an approved type of testing machine furnished by the contractor in such a manner that the test load will develop 65 per cent of the yield point of the metal as determined by tensile tests of the bars made by the Government. In addition to this test the contractor shall furnish welded test specimens as required by the contracting officer. In case a test specimen breaks in the weld, two additional similar specimens may be broken, and if either of the two additional specimens breaks in the weld, the welding machine shall be adjusted to produce welds that develop the strength of the bar as required herein. The cost of furnishing and attaching wire ties, of unloading, hauling, storing, cutting, bending, placing, and securing in position reinforcement bars and rails for reinforcement, and welding reinforcement bars where required shall be included in the unit price bid in the schedule for placing reinforcement bars and rails.

111. Measurement of concrete.—Except as otherwise provided in paragraphs 113, 114, and elsewhere in these specifications, concrete will be measured for payment only to the neat lines shown on the drawings or prescribed by the contracting officer, and no payment will be made for concrete outside of the prescribed lines. In measuring concrete for payment, deductions will be made for the space occupied by all galleries, shafts, passageways, chambers, air ducts, waterways, drainage conduits, cavities, depressions, and all openings of every description, and for embedded pipes, tile, wood and metal work, except that the space occupied by reinforcement bars, rails, and anchors will not be deducted. In the event cavities resulting from careless excavation, as determined by the contracting officer, are required to be filled with concrete, the materials furnished by the Government and used for such refilling will be charged to the contractor at their cost to the Government at the point of delivery to the contractor.

112. Payment for concrete.—Payment for all required concrete will be made at the unit prices bid therefor in the schedule. Any required concrete for the dam or appurtenant works not definitely covered by an item of the schedule shall be included for payment under the item of the schedule which most nearly applies as determined by the contracting officer: *Provided*, That if it differs materially, as determined by the contracting officer, from all of the items listed in the schedule, its construction will be ordered in writing by the contracting officer, and payment will be made therefor as extra work under the provisions of article 5 of the contract and paragraph 10 of these specifications. The unit prices bid in the schedule shall include the cost of all work and materials required in the construction, except that cement will be furnished by the Government as provided in paragraph 27, and payment for placing reinforcement bars and rails will be made at the unit price bid therefor in the schedule. The cost of all labor and material used in forming the construction joints in the dam and in other concrete work, where and if required, shall also be included in the unit prices bid.

113. Concrete linings in tunnels, adits, and shafts.—Except as otherwise provided, the tunnels, adits, and shafts shall be lined throughout with concrete as nearly as practicable of the average thicknesses shown on the drawings or as directed by the contracting officer. Concrete shall conform to the requirements of paragraphs 96 to 112, inclusive, where applicable, as determined by the contracting officer. The spillway and pressure tunnels will be subject to very high velocities and every precaution shall be taken to secure concrete of the highest possible quality in the linings of these tunnels. The order of placing concrete in sections in a circumferential direction around the tunnels, adits, and shafts, the maximum length of linings to be placed each day, the design of joints between circumferential and transverse sections, and all other operations in placing the concrete linings shall be subject to the approval of the contracting officer. In all tunnels where the concrete lining is of sufficient thickness, as determined by the contracting officer, so that men can work behind the forms, the concrete shall be delivered into the forms at sufficiently close intervals to permit placing in horizontal layers. Methods of placing wherein the concrete within the forms is allowed to flow within the mass, or drops vertically more than 5 feet, will not be permitted: *Provided,* That in small tunnels, where the concrete lining is not thick enough to permit men to work behind the forms, methods of placing, wherein the concrete is delivered at the top of the tunnel sections and flows to place within the forms on a uniform grade, will be permitted, subject to the requirement that satisfactory settlement and compacting of the concrete is obtained as determined by the contracting officer. All concrete lining placed within steel tunnel liner plates shall have the full thicknesses shown on the drawings or as directed by the contracting officer. Minimum thicknesses, as shown on the drawings or as prescribed by the contracting officer, will be permitted only between the finished inside circumference of the lining and rock points. If, in the judgment of the contracting officer, a changed thickness is desirable at any point, it will be so ordered in writing and the contractor shall place the same at the unit price bid in the schedules for concrete lining in the particular tunnel, adit, or shaft involved. Where steel sets are used, they shall be set back a sufficient distance from the inside face of the lining to provide for a minimum covering of concrete over the steel sets of not less than the prescribed thicknesses. Where steel liner plates are used and left in place, measurement of concrete lining for payment will be made on the basis of the thickness to the inside surface of the liner plates of concrete actually placed up to and including the average thickness as specified or directed by the contracting officer. Where steel sets are erected and liner plates are not used, measurement of concrete lining for payment will be made on the basis of the average thickness of concrete actually placed at each measured section up to and including the average thickness shown on the drawings or prescribed by the contracting officer. The location of the sections to be measured and the distances between such measured sections will be determined by the contracting officer. In determining the average thicknesses at the measured sections, consideration will not be given to any thicknesses which are greater than 6 inches in excess of the prescribed average thicknesses. Where plate-steel tunnel lining is installed, measurement of concrete lining for payment will be made on the basis of the thickness of concrete actually placed up to and including the average thickness as specified or directed by the contracting officer. Payment for concrete in tunnel, adit, or shaft lining will be made at the applicable unit prices per cubic yard bid therefor in the schedule for

and also where neither steel sets nor liner plates are used each particular size tunnel, adit, or shaft. Except as otherwise provided in paragraph 53 for steel liner plates in tunnels, if the tunnels, adits, or shafts are excavated to greater dimensions than necessary for placing the prescribed average thicknesses of the concrete lining, the excess space shall be solidly filled with concrete. The entire expense of such filling shall be borne by the contractor, except that no charge will be made for cement, which will be furnished by the Government under the provisions of paragraph 27: *Provided*, That where such excess spaces are caused by careless excavation, as determined by the contracting officer, the contractor will be charged for such cement, as provided in paragraph 111.

114. Concrete linings, walls, and slabs against rock in open cut.—The concrete in all linings, walls, and slabs placed against rock in open cut without the use of intervening forms shall be as nearly as practicable of the average thicknesses shown on the drawings, or as directed by the contracting officer. Concrete for these structures or members of structures shall conform to the requirements of paragraphs 96 to 112 inclusive, as determined by the contracting officer. Minimum thicknesses, as shown on the drawings or as prescribed by the contracting officer, will be permitted only between rock points and the finished surface of the concrete. If, in the judgment of the contracting officer, a changed thickness is desirable at any point, it will be so ordered in writing and the contractor shall place concrete of the specified thickness at the unit price bid in the schedule for concrete in the particular structure involved. Measurement for payment for the concrete placed against rock in open cut without the use of intervening forms will be made on the basis of the average thickness of concrete actually placed at each measured section, up to and including the average thickness shown on the drawings or prescribed by the contracting officer. The location of the sections to be measured and the distances between such measured sections will be determined by the contracting officer. In determining the average thickness at each measured section, consideration will not be given to any thicknesses which are greater than 6 inches in excess of the prescribed average thickness. Payment for concrete placed directly against rock in open cut will be made at the unit price per cubic yard bid in the schedule for concrete in the particular structure involved. If the open-cut excavation against which concrete is to be placed is made to greater dimensions than necessary for placing the prescribed average thicknesses of concrete, the excess spaces shall be solidly filled with concrete. The entire expense of such filling shall be borne by the contractor, except that no charge will be made for cement, which will be furnished to the contractor by the Government under the provisions of paragraph 27: *Provided*, That where such excess spaces are caused by careless excavation, as determined by the contracting officer, the contractor will be charged for such cement, as provided in paragraph 111.

115. Concrete in inlet structures for inner diversion tunnels.—The item of the schedule, "Concrete in inlet structures for inner diversion tunnels," includes, for each inner diversion tunnel, the concrete in the trash rack and all concrete outside of the tunnel, as determined by the contracting officer. The contractor shall furnish and install the timber stop-planks for this structure, and the cost thereof shall be included in the unit price per cubic yard bid in the schedule for concrete in inlet structures for inner diversion tunnels.

116. Concrete in inlet structures for outer diversion tunnels and bulkhead gates.—The item of the schedule, "Concrete in inlet structures for outer diversion tunnels and bulkhead gates," includes, for each of these structures, all concrete upstream from the concrete face of the tunnel portal, which face corresponds with the concrete bulkhead gate seat or downstream face of the bulkhead gate, and includes the concrete in the bulkhead gates, supports therefor, sand wells, guides, and all other parts of these structures. After the wells have been constructed and the concrete has set for a sufficient length of time, as determined by the contracting officer, the contractor shall furnish fine sand and fill the wells therewith, after which he shall construct the concrete gate supports and gates, as shown on the drawings or as directed by the contracting officer. Great care shall be taken to construct all parts of the gate guides and gates to accurate lines, grades, and dimensions so that the gates will fit properly in the guides and there will be no danger of binding when the gates are lowered. The contractor shall install all piping for jetting the sand out of the wells and shall perform the operation of closing the gates in ample time so that other necessary operations may be performed and the reservoir will be filled to the height and within the time required by the provisions of paragraph 24. The contractor shall fabricate and install the copper seals, well casing, and pipes for jetting the sand with water, as shown on the drawings or as directed by the contracting officer. Copper sheets and rivets for connecting the well casing and jetting pipe, and also the permanent metal pipe forms fabricated in sections for the supporting columns will be furnished by the Government under the provisions of paragraph 27. Payment for installing the required well casing and jetting pipe will be made to the contractor at the unit price per pound bid in the schedule for installing standard steel and cast-iron pipe, fittings, and valves. The cost of furnishing and placing fine sand in the wells, of fabricating, connecting, and installing the copper seals, of installing the permanent sheet metal pipe forms, and the cost of the complete operation of lowering the concrete bulkhead gates by jetting the sand from under the supports shall be included in the unit price per cubic yard bid in the schedule for concrete in inlet structures for outer diversion tunnels and bulkhead gates.

117. **Concrete in outlet structures for diversion tunnels.**—The item of the schedule, "Concrete in outlet structures for diversion tunnels," includes, for each inner diversion tunnel, the concrete in the Stoney gate structure, including the operating towers and house, the counterweights, and all concrete outside of the tunnels and downstream from a vertical plane normal to the center line of the tunnel and 15 feet upstream from the gate seat. It also includes the concrete in the outlet portal wall of the outer tunnels. Great care shall be taken to construct all parts of the gate structure to accurate lines, grades, and dimensions so that the gates will fit properly. The contractor shall fabricate and install the well casings for draining the tunnels, as shown on the drawings or as directed by the contracting officer. The well casings will be furnished by the Government under the provisions of paragraph 27. Payment for fabricating and installing the well casing will be made to the contractor at the unit price per pound bid in the schedule for installing standard steel and cast iron pipe, fittings, and valves.

118. **Concrete in linings of diversion tunnels.**—As to each outer diversion tunnel, the item of the schedule, "Concrete in linings of diversion tunnels," includes all concrete placed in the outer diversion tunnels between the inlet and outlet structures, as defined in paragraphs 116 and 117, except that included in the item of the schedule, "Concrete in diversion tunnel plugs," and limited in the vicinity of the connecting inclined spillway shaft by a horizontal plane at an elevation 64 feet above the center line of the diversion tunnel. As to each inner diversion tunnel, the item of the schedule, "Concrete in linings of diversion tunnels," includes all concrete placed in the inner diversion tunnels between the inlet and outlet structures, as defined in paragraphs 115 and 117, except that included in the item of the schedule, "Concrete in diversion tunnel plugs," and limited in the vicinity of the connecting inclined tunnel from the upstream intake tower by a horizontal plane at an elevation 64 feet above the center line of the diversion tunnel and in the vicinity of the diverting power penstock tunnels and riser shaft to the canyon wall outlet works by the theoretical excavation surfaces in the diversion tunnel, as determined by the specified average thickness of concrete. The item for concrete in linings of diversion tunnels shall also include the lining of the galleries or adits from the upstream plugs in the inner diversion tunnels to the inspection galleries in the dam at the excavated foundation surface for the dam.

119. Concrete in paving for upstream cofferdam.—The entire upstream slope of the upstream cofferdam shall be surfaced with a 6-inch thickness of continuous reinforced concrete paving, as shown on the drawings or as directed by the contracting officer. The paving shall terminate in the concrete cut-off wall, into which the top of the steel sheet-piling at the upstream toe of the cofferdam shall extend. The top of the sheet-piling shall be encased in the concrete at the bottom of the cut-off wall so as to form a continuous structure. The concrete paving shall be placed on the rock blanket which has previously been prepared for paving, as provided under paragraph 79 of these specifications. The concrete paving shall be laid in strips not over 16 feet in width running up and down the slope of the cofferdam, and construction joints, across which the reinforcement bars shall be continuous, shall be provided between the strips, as shown on the drawings or as directed by the contracting officer. When, for any reason, it is necessary to interrupt the placing of concrete in a strip for a sufficient length of time to permit the concrete taking a permanent set, thereby forming a definite construction joint, the contractor shall provide a suitable temporary form which will produce a clean, unbroken keyed surface normal to the slope of the cofferdam, which surface shall intersect the face of the paving in a horizontal line. The steel reinforcement shall be continuous across the construction joint. After the removal of the temporary form at the joint, and immediately before placing of the concrete in the strip is resumed, the contractor shall carefully clean and wet the surface of the joint to insure a good bond between the fresh concrete and the concrete previously placed. Feather-edged or irregular construction joints will not be permitted. The surface of the concrete paving shall be floated to a uniform and dense finish by means of wooden floats. Measurement of the concrete paving for payment will be made to the neat lines, as shown on the drawings or as prescribed by the contracting officer. No additional compensation will be paid for the slightly thicker paving necessary to fill such irregularities as may exist on the surface of the rock blanket. Payment for concrete in the cut-off wall and for the paving described in this paragraph will be made at the unit price per cubic yard bid in the schedule for concrete in paving for upstream cofferdam, which unit price shall include the cost of furnishing all labor, machinery, tools, and materials, except cement, required in the mixing, placing, curing, and protecting of the paving until acceptance.

120. Concrete in dam.—The item of the schedule, "Concrete in dam," includes all concrete within the upstream cut-off trench and within the lines of the theoretical or regular sections of the dam above the foundations, as shown on the drawings, and does not include any attached concrete above the roadway elevation or outside of the regular section of the dam. The placing of concrete in the dam shall begin in the panel having the lowest foundation. The concrete shall be placed in horizontal layers not exceeding 5 feet in thickness: *Provided*, That the placing of individual layers in alternate panels bounded by contraction joints, or contraction joints and outside faces of the dam, will be required: *And provided further*, That in placing the concrete the top of any two of these panels or columns outside of the slot on line of centers shall at no time differ in elevation more than 35 feet. The forms for surfaces between adjacent panels or columns may be removed as soon as the concrete has sufficiently hardened, as determined by the contracting officer. The rate of placing concrete in any panel or column of the dam shall be such that not more than 5 feet in depth shall be placed in 72 hours, and not more than 35 feet in depth shall be placed in thirty (30) days unless otherwise specifically authorized in writing by the contracting officer. All concrete in the dam shall be permitted to set for a period of not less than 6 days before cooling is started, as provided in paragraph 121. After the concrete in any 100-foot grouting lift has been satisfactorily cooled, as determined by the contracting officer, all contraction joints in this grouting lift may be grouted, as provided in paragraph 91. The limitations on the placing of concrete, as stated in this paragraph, will be modified only when approved in writing by the contracting officer. In mixing concrete that is to be placed in the upstream 6-foot layer of concrete in the dam, the contractor shall, if directed by the contracting officer, add to the regular mix an additional one-half or full sack of cement for each cubic yard of concrete. The drawings do not show any reinforcement steel around the inspection and other galleries in the dam. However, the Government reserves the right at any time before these galleries have been formed to require that reinforcement steel be placed around them. The contractor shall be entitled to no additional allowance above the unit price bid in the schedule for concrete in dam by reason of such steel being required, but the placing of this steel, if required, will be paid for at the unit price bid in the schedule for placing reinforcement bars and rails. A curve showing the estimated volume of concrete in the dam for all elevations to the top of the roadway is shown for the convenience of the contractor.

121. Cooling concrete in dam.—After any portion of the concrete in the dam and tunnel plugs has set for a minimum period of 6 days, it shall be cooled by removing the excess heat above 72° F. The temperature of the concrete shall be reduced by running water of lower temperature through pipes placed in the concrete, as provided in paragraph 149. The contractor shall furnish, install, and operate a complete refrigeration plant for removing the excess heat. This plant shall have a capacity sufficient to reduce from 47° F. to 40° F. the temperature of a flow of 2,100 gallons of water per minute. Water may leave the embedded pipes at any temperature between 42° F. and 65° F., and the quantity of cooling water may vary from 350 to 2,100 gallons per minute, but the temperature of the cooling water entering the embedded pipes shall in no case be lower than 35° F. The capacity of the cooling water circulating water pump and the condensing water pumps shall be such that, with one unit out, the remaining units will deliver not less than 75 per cent of the total water required. If river water is used for condensing purposes the plant shall be designed for condensing water at a temperature of 82° F. The refrigeration plant shall have a capacity sufficient to provide for all transmission losses and to deliver the above-mentioned quantity of refrigeration to the cooling pipes embedded in the concrete. The refrigeration plant shall be divided into three units, each of which shall be complete in itself, but all units shall be interconnected so that they may be used in combination as well as separately. Installation of the plant shall include the excavation for and the building for housing the necessary machinery. The building shall be sufficiently large to accommodate the installation of an additional unit including auxiliaries, and the design of the 3-unit plant shall be such as to permit the furnishing and installing of an additional unit at minimum cost. In addition to the refrigeration plant the contractor shall furnish, install, and operate all piping, pumps, tanks, and equipment necessary for the satisfactory operation of the 3-unit refrigeration plant described in this paragraph and the circulation of the cooling water through the pipes placed in the dam. The average temperature rise due to setting of concrete is approximately 40° F. above placing temperatures. The amount of heat to be removed is approximately 700 B. T. U. per degree per cubic yard of concrete. The estimated amount of heat to be removed from a cubic yard of concrete and the time required are shown in the tabulation following, but the actual amounts may vary considerably from these estimates in any one year.

Estimate of Temperatures, Heat to be Extracted, and Time to Cool

Month	Mean monthly temperature	Maximum temperature concrete	Heat to be extracted	B. T. U. to be extracted per cubic yard	Cooling water must be applied
	° *F.*	° *F.*	° *F.*		*Months*
January	52.0	92.0	20.3	14,200	1.14
February	57.2	97.2	25.5	17,900	1.33
March	63.6	103.6	31.9	22,400	1.60
April	71.2	111.2	39.5	27,700	1.83
May	78.6	118.6	46.9	32,900	2.06
June	87.6	127.6	55.9	39,200	2.28
July	93.8	133.8	62.1	43,500	2.40
August	91.9	131.9	60.2	42,200	2.37
September	83.0	123.0	51.3	35,900	2.17
October	70.8	110.8	39.1	27,400	1.83
November	59.4	99.4	27.7	19,400	1.39
December	51.5	91.5	19.8	13,900	1.10
Average	71.7	111.7	40.0	28,000	1.79

Cooling of concrete, in which the necessary pipes for this purpose have been placed, shall begin as soon as the concrete has set for a period of 6 days and shall be completed as soon as possible and by using the full capacity of the refrigeration plant unless otherwise directed by the contracting officer. The velocity of water in the cooling pipes shall be not less than 2 feet per second. Arrangements shall be made by the contractor for reversing the direction of flow in the pipe loops in the concrete in order to equalize the temperatures if considered advisable as determined by the contracting officer. The method of applying the cooling water to the pipes placed in the dam shall be such that the pressures in the pipes are nowhere in excess of 100 pounds per square inch. Cooling water shall be applied until the mean temperature of the concrete around each embedded pipe is reduced to 72° F. or less. The refrigeration plant and all other cooling equipment required to be furnished by the contractor and the operation of the plant and method of applying the cooling water shall at all times be subject to the approval of the contracting officer. Payment for furnishing, installing, and operating the cooling plant will be made at the lump sum price bid therefor in the schedule, which price shall include the cost of furnishing and installing the 3-unit plant with required auxiliaries as described in this paragraph, the cost of excavating for and providing a building sufficiently large to house the 3-unit plant and an additional unit, and the cost of operating the 3-unit plant and cooling all concrete, as required by the provisions of this paragraph. The cooling plant and all cooling equipment shall be and remain the property of the contractor.

122. Concrete in parapets.—The item of the schedule, "Concrete in parapets," covers all concrete attached to the dam, except the power house and outlet tower bridges, which is above the roadway elevation or outside of the regular or theoretical section of the dam, as shown on the drawings, and includes, in addition to parapets, the elevator and special stairway houses, balconies, electroliers, curbs, and other architectural features on or attached to the dam, as shown on the drawings or as directed by the contracting officer. Casts, molds, or special forms to produce the intricate relief work of the architectural decorations will be furnished by the Government under the provisions of paragraph 27. Exceptional care shall be used in all concrete construction covered by this paragraph to insure high quality of workmanship, accurate dimensions, and strict adherence to alignment and grade, and no irregularities in alignment due to inaccurate finishing of top surfaces, bulging of forms, or other defects will be permitted. Excessive troweling of surfaces while concrete is yet plastic will not be permitted. All necessary precautions shall be taken to keep the concrete described in this paragraph thoroughly wet for at least 14 days after placing.

123. Special finishing of walls in power house, parapets, and other concrete surfaces.—It is contemplated that it may be desirable to finish, by rubbing, the inside and top surfaces of the parapets, the surfaces of other architectural features on the dam, power house, and other buildings, possibly some of the walls of the power house, and portions of other concrete surfaces of the dam or appurtenant works. An item for this work has accordingly been placed in the schedule. This work shall be done only on the surfaces designated by the contracting officer. The Government does not guarantee that any concrete surfaces of the dam or appurtenant works will be required to be so finished by rubbing, and the contractor will not be entitled to any additional compensation by reason of no work being required under the item of the schedule covering the special finishing of concrete surfaces. Where and if this finishing is required the forms may be removed while the concrete is yet green but not earlier than 24 hours after the placing of the concrete. Immediately after stripping the forms, any required patching shall be done and major imperfections of finish removed or corrected. The entire surface shall then be thoroughly rubbed with a carborundum stone using plenty of clean water in the process. After this rubbing the surface shall be thoroughly cleaned by washing. A sand-cement wash of a mixture determined by the contracting officer shall be applied during the rubbing process if directed by the contracting officer. A perfect finish of smooth uniform surface and color will be required. The cost of all work described in this paragraph shall be included in the unit price bid in the schedule for special finishing of walls in power house, parapets, and other concrete surfaces.

124. Concrete in spillway structures.—The item of the schedule, "Concrete in spillway structures," includes all concrete in the spillway crests and spillway channel linings, the latter terminating at the upstream face of the portals of the spillway tunnels and all concrete in the Stoney gate structures. Vertical joints in the concrete of the crest, normal to the axis of the crest, will be provided for convenience in construction and to provide for the expansion and contraction of the concrete. The contraction joints will divide the spillway crests into sections. The entire face of each vertical joint in the crests shall be painted with one thin coat of water-gas tar and allowed to dry before the adjacent concrete is placed against it. The water-gas tar for this purpose will be furnished by the Government under the provisions of paragraph 27. The provisions of paragraph 114 shall apply in the placing of the concrete in the channel linings. No part of the concrete channel lining shall be placed until all grouting of the foundation of the adjacent spillway crest within a radius of 100 feet has been completed. The contractor shall construct the drains through the lining, as shown on the drawings or as directed by the contracting officer. The pipe for this purpose will be furnished by the Government in random lengths and shall be cut and placed by the contractor so that the mouth of the pipe is flush with the surface of the concrete lining. Payment for cutting and placing the pipe will be made at the unit price per pound bid in the schedule for installing standard steel, cast-iron pipe, fittings, and valves. The coarse gravel at the head of the drains shall be furnished and placed by the contractor and the cost thereof shall be included in the unit price per cubic yard bid in the schedule for concrete in spillway structures.

125. Concrete in linings of inclined spillway tunnels.—The item of the schedule, "Concrete in linings of inclined spillway tunnels," includes all concrete in each inclined spillway tunnel from the upstream face of the portal wall to a horizontal plane passing through the inclined spillway tunnel at an elevation 64 feet above the center line of the connecting outer diversion tunnel.

126. Concrete in diversion tunnel plugs.—The item of the schedule, "Concrete in diversion tunnel plugs," includes all concrete required to be placed for the solid plugs in the outer diversion tunnels and for the upstream and downstream plugs and for the installation of gates and valves therein in the inner diversion tunnels. After the concrete linings in the diversion tunnels along the reaches of the plugs have been placed in the wedge-shaped steps or depressions, as shown on the drawings, the depressions shall be filled up with timber lining or a lean mixture of concrete to the normal circular section of the tunnel. At the option of the contractor the concrete surface on which this filled concrete is placed may be painted with a water-gas tar paint to prevent a bond between the old and new concrete, and to aid in the later removal of this filled concrete. The paint for this purpose will be furnished by the Government. After the filling of timber or concrete has been removed and the other necessary excavations have been made for the various plugs at the proper time in the construction program, the surfaces of the concrete tunnel linings against which the concrete in the plugs are placed shall be thoroughly cleaned and roughened by tooling or otherwise to the satisfaction of the contracting officer so as to insure an effective bond between the concrete of the linings and the plugs. The wedge-shaped depressions shall be carefully filled with concrete integral with the concrete in the plugs to key the plugs and linings together. A system of grout pipes shall be set, as directed by the contracting officer, in the surfaces of contact between the plugs and the tunnel lining or at other points, and after the concrete in the plugs has hardened and cooled, grout under high pressure, as provided in paragraph 153, shall be forced into the grout connections to insure a water-tight connection at all points between the plugs and the lining. If the character of the rock permits, as determined by the contracting officer, the diversion tunnel lining along the reaches of the tunnel plugs may be omitted and the excavated keyways built up to the normal circular section by timbering. The cost of filling the wedge-shaped keyways with timber or with lean concrete shall be included in the unit price per cubic yard bid in the schedule for concrete in diversion tunnel plugs: *Provided,* That cement for the concrete will be furnished by the Government. If timber is used for this purpose it shall be furnished by the contractor. The contractor shall furnish all drainpipe required for keeping the work unwatered while placing the tunnel plugs.

127. Concrete in outlet and penstock tunnels.—The item of the schedule, "Concrete in linings of outlet and penstock tunnels," includes all concrete in the inclined tunnels between the bottom of the upstream intake towers and the inner diversion tunnels, as limited by the concrete in these structures as provided in paragraphs 118 and 130, and all concrete in the penstock tunnels between the bottom of the downstream intake towers and the beginning of the metal lining plates in the 7-foot 7-inch diameter tunnel to the farthest downstream valve in the lower tier of the canyon wall outlet works, and further limited in the vicinity of the 15-foot 9-inch diameter riser shaft and of the diverting power penstocks and the other three 7-foot 7-inch diameter diverting outlet tunnels by the theoretical excavation surfaces in the penstock tunnel, as determined by the specified average thicknesses of concrete. It also includes the concrete lining in the horizontal portions of this tunnel after it leaves the 15-foot 9-inch riser shaft, this portion of the lining being limited by a vertical plane through the point of tangency with the elbow to the riser pipe, by the beginning of the metal lining plates in the 7-foot 7-inch diameter tunnel to the farthest downstream valve in this upper tier, and further limited in the vicinity of the other three 7-foot 7-inch diameter diverting outlet tunnels by the theoretical excavation surfaces in the main penstock tunnel, as determined by the specified average thicknesses of the concrete. It also includes the corresponding concrete lining for the upper tier of valves in the horizontal section above the 15-foot 9-inch riser shaft from the 50-foot inner diversion tunnel, and the corresponding concrete in the horizontal section for the lower tier of valves, except that the limiting vertical plane passes in this case through the point of tangency with the elbow to the 24-foot 3-inch diameter riser pipe.

128. Concrete in linings of shafts for outlet works and connecting galleries.—The item of the schedule, "Concrete in linings of shafts for outlet works and connecting galleries," includes all concrete in the 24-foot 3-inch diameter riser shafts from the inner diversion tunnels and in the 15-foot 9-inch diameter riser shafts, as limited by the descriptions of other items of concrete in paragraphs 118 and 127. It also includes all concrete in the elevator shafts for the canyon wall outlet works and the adits leading to these elevators from the lower canyon wall outlet works and from the power house, as limited by the concrete in the walls of the upper canyon wall valve houses and in the walls of the power house. It also includes all concrete in the adits from the downstream inner diversion tunnel plugs to the elevators for the canyon wall outlet works.

129. Concrete in canyon-wall outlet works.—The item of the schedule, "Concrete in canyon-wall outlet works," includes all concrete in both the upper and lower canyon-wall valve houses, including concrete around slide gates and needle valves, and all concrete in the 7-foot 7-inch diameter tunnels leading directly to the slide gates and valves, as limited by the description of the concrete in outlet and penstock tunnels as given in paragraph 127. In constructing the valve houses, special care shall be used to insure a high quality of workmanship, accurate dimensions, and strict adherence to alignment and grade, and no irregularities in alignment due to inaccurate finishing of surfaces, bulging of forms, or other defects will be permitted.

130. Concrete in intake towers, foundations, and superstructure.—The item of the schedule, "Concrete in intake towers, foundations, and superstructure," includes all concrete in the towers and the foundations thereof above the inlets to the 30-foot diameter outlet and penstock tunnels, all concrete in the gate houses, parapets, and other features on top of the towers, and in the seats to serve as supports for the movable ends of the intake tower bridges. Extreme care shall be taken by the contractor to construct all parts of the intake towers, including the gate houses on top, accurately to the lines and dimensions as shown on the drawings or directed by the contracting officer. No irregularities in alignment due to inaccurate finishing of surfaces, bulging of forms, or other defects will be permitted. All anchor bolts, gate guides and seats, and other metal parts to be embedded in concrete shall be carefully cleaned and firmly and accurately anchored in place before the placing of concrete. Uniting of the outside surface of the towers below the elevation of the gate-house floors shall be done by the contractor under the provisions of paragraph 136.

131. Concrete in bridges to intake towers.—After the structural steel through plate girder bridges from the top of the dam to the downstream intake towers and from the latter to the upstream intake towers have been completed and all supports removed, they shall be partly encased in concrete, as shown on the drawings or as directed by the contracting officer. Prior to placing concrete, all parts of the structural steel to be in contact with the concrete covering shall be thoroughly cleaned of all paint, rust, scale, and other loose particles which might interfere in any way with an effective bond between the steel and the concrete. Should any reinforcement fabric or metal lath be used in addition to bar reinforcement, as determined by the contracting officer, in the concrete covering these bridges, these materials will be furnished by the Government under the provisions of paragraph 27. Payment for placing reinforcement fabric or metal lath, if required, in the concrete of these bridges will be made at the unit price bid in the schedule for placing reinforcement bars and rails. The item of the schedule, "Concrete in bridges to intake towers," includes all concrete in each bridge between the fixed and movable end.

132. Concrete in power house and penstocks.—For the purposes of payment the concrete in the power house and penstocks is separated into two items in the schedule; viz., "Concrete in power house above generator floor," and "Concrete in power house below generator floor and in penstocks." The first item is self-explanatory but includes, in addition to the concrete in columns, walls, and other members of the building, concrete in pedestals, anchors, and foundations for machinery. The second item includes, in addition to all the concrete in the power house and concrete anchors and foundations for machinery below the elevation of the generator floor, all concrete in the power penstocks from their diversions from the inner diversion tunnels and the penstock tunnels, as limited by the description of other concrete items in paragraphs 118 and 127, respectively. The concrete in both of the above items is limited or bounded upstream by the theoretical downstream face of the dam. In constructing the power house, exceptional care shall be used to insure high quality of workmanship, accurate dimensions, and strict adherence to alignment and grade, and no irregularities in alignment due to inaccurate finishing of surfaces, bulging of forms, or other defects will be permitted. It is contemplated that the parapets and other parts may be required to be specially finished, as provided in paragraph 123.

133. Concrete for switching station and steel tower footings.—The item of the schedule, "Concrete in switching station and steel tower footings," includes all concrete for the footings of structural steel switch structures, bases for mounting oil circuit breakers, and other apparatus as may be required for the switching station, and also includes all concrete in footings for steel towers which will support the transmission lines from the power house to the switching station. The switching station shall be located as shown on the drawings or as directed by the contracting officer. The footings for the transmission line steel towers are not shown on the drawings, but shall be constructed at the locations, and to the lines, grades, and dimensions as directed by the contracting officer. The steel towers will be erected by the Government.

134. Concrete in inclined freight elevator structures.—The item of the schedule, "Concrete in inclined freight elevator structures," includes all concrete in the guide structure for the elevator, loading and unloading platforms, the foundation for the spur track from the bottom of the elevator to the power house and the concrete in the hoist house, and any other concrete that may be required to be placed, as determined by the contracting officer, for permanent construction of the inclined freight elevator. The sections of the guide structure and spur track foundation shall be as shown on the drawings or directed by the contracting officer.

135. Concrete in highway structures.—The concrete in all highway structures, including parapets, retaining walls, collars, and headwalls for corrugated metal culverts, and in a reinforced concrete arch culvert, if required, shall conform to the requirements of paragraphs 96 to 112, inclusive, and of paragraph 114, where applicable, as determined by the contracting officer. Measurement for payment and the costs to be included in the price bid for concrete in highway structures shall conform to the provisions of paragraphs 111, 112, and 114.

136. Gunite surfacing on concrete.—The entire upstream face of the dam up to the bottom of the coping, the outside surface of the intake towers up to the elevation of the gate house floor and the upstream face of all plugs in the inner diversion tunnels, shall be surfaced with gunite placed as shown on the drawings or as directed by the contracting officer. Unless otherwise directed by the contracting officer, the total thickness of the completed surfacing shall be 1 inch, measured normal to the exposed surface. The gunite surfacing shall be continuous without construction joints, except as otherwise provided in this paragraph. Gunite shall usually be a mixture of 1 part cement by volume, measured loose with 3 parts of sand, but the relative proportions of sand and cement used will be subject to change by the contracting officer as the materials used or results obtained indicate desirable at any time during the progress of the work, and the contractor will not be entitled to any additional compensation by reason of such changes. The sand and cement shall be thoroughly mixed in a relatively dry state before being placed in the gunite machine or its hopper. Machine mixing will be required unless specific authority to use hand mixing is given by the contracting officer. The machine and its operation shall be subject to the approval of the contracting officer. The mixing operation shall continue for a period of not less than one minute after all sand and cement are placed in the mixer. If there is an excessive amount of moisture in the sand, the sand shall be dried before mixing or it shall be mixed with the cement immediately before placing in the hopper, to insure that partial setting of the cement has not taken place. Cement for gunite will be furnished to the contractor by the Government, as provided in paragraph 27. The requirements for cement for use in gunite shall be the same as those for cement for concrete, as given in paragraph 97. Sand for gunite shall be furnished by the contractor and shall meet the requirements of paragraph 98. In placing gunite the contractor shall employ as foremen and nozzlemen only men who can show to the satisfaction of the contracting officer that they have been employed in a similar capacity on at least two other similar jobs, and that they are fully qualified to do the work properly and carry out the terms of these specifications. Gunite shall be placed with the machines operating at an air pressure of not less than 35 pounds per square inch and a water pressure of not less than 50 pounds per square inch. In case of increase of air pressure, the water pressure shall be increased proportionately. Care shall be taken by the nozzlemen to direct the line of flowing material as nearly normal to the surface being covered as possible, and the nozzle shall generally be held about 3 feet and not more than 5 feet from the surface. The nozzlemen shall also take precaution to use only sufficient water necessary to properly hydrate the cement. Care shall be taken to prevent the occurrence of sand pockets, and if any should develop they shall be immediately cut out and replaced with perfect gunite at the expense of the contractor. No hand patching will be allowed. The gunite shall be applied in a continuous sheet for the full length of section in lifts approximately equal in height to the lifts of concrete. The joints of the gunite surfacing for the dam at the radial contraction joints and at the top and bottom edges of each lift shall be as shown on the drawings or as directed by the contracting officer. The contractor shall apply the surfacing in such a manner that no sloughing of the gunite occurs at any time during or following its application. If the required total thickness of surfacing is built up by layers, the intervening time between the application of each layer shall not be such as to permit the gunite to take a permanent set. When, for any reason, it is necessary to interrupt the placing of gunite for a sufficient length of time to permit the gunite taking a permanent set, thereby forming a definite construction joint, the contractor shall cut back the irregular edges of the gunite last placed with a trowel or other suitable tool to a clean unbroken surface perpendicular to the face of the dam or intake tower, such as will provide a suitable connection or construction joint between such gunite and the gunite to be subsequently placed. Care shall be taken in performing this work not to shatter the remaining gunite or to disturb or destroy the bond between the gunite and the concrete. Before gunite is placed against the surfaces of such joints, these surfaces shall be carefully cleaned and wetted by the contractor to insure a good bond between the fresh gunite and the gunite previously placed. Feather-edged construction joints will not be permitted. The contractor shall take such steps as the contracting officer may deem necessary to prevent injury to the completed gunite surfacing by particles of rebound from the guniting operations at higher elevations falling on such completed surfacing. The finished surfacing shall be free from cavities or angular projections and shall have a uniformity and smoothness, as directed by the contracting officer. At the option of the contractor the gunite surfacing on the upstream face of the dam and on the intake towers may be placed from barges after storage of water in the reservoir is begun, but the Government assumes no responsibility for the rate of rise in the water level or for any interference with the guniting operations on this account, and permission to use this method will not relieve the contractor from the obligation to complete the gunite surfacing in full compliance with the specifications. Before placing the gunite the surface of the concrete shall be throughly cleaned and roughened by sand blasting or other methods, as directed by the contracting officer. The concrete surface shall then be thoroughly wetted immediately before the placing of the gunite. During the period immediately following the placing of the gunite, it shall be protected against injury by freezing, by waste water flowing down over the gunite, or from other causes which, in the opinion of the contracting officer, may result in a weakening of the bond between the gunite and the concrete. As soon as the gunite has hardened sufficiently, in the opinion of the contracting officer, it shall receive the same treatment and protection as specified for concrete, as provided in paragraph 108. No gunite surfacing shall be placed in freezing weather except with the approval of the contracting officer and then only under such restrictions and regulations as the contracting officer may prescribe. Any gunite damaged by freezing or otherwise before final acceptance shall be removed and replaced at the expense of the contractor. Measurement of gunite surfacing for payment will be made of the entire surface area of the completed surfacing. The unit of measure shown in the schedule is a square yard of surface area for gunite one (1) inch in thickness. No additional compensation will be paid for the slightly thicker gunite necessary at re-entrant angles. The contractor will be charged for any cement wasted due to improper mixing or other fault of the contractor. Payment for gunite will be made at the unit price per square yard bid in the schedule for 1-inch gunite surfacing on concrete, which unit price shall include the cost of furnishing all labor, machinery, tools, and materials, except cement, required in the preparation of the concrete to receive the gunite, and in mixing, placing, curing, and protecting the gunite until acceptance. The Government reserves the right to increase or decrease the thickness of all gunite surfacing, and no increase or reduction in payment shall be made on account of such changes, except that where thicknesses other than 1 inch are required the payment to be made therefor will be in direct proportion to the required thickness based on the unit price bid in the schedule for gunite surfacing on concrete, 1 inch thick.

137. Rough finish for tile floors.—The top of the concrete in all floors in the power house and such other structures as may be designated by the contracting officer shall be left approximately two and one-half (2½) inches below the finished floor elevation, unless otherwise directed by the contracting officer. When anchor bolts and pipes are placed, proper allowance shall be made for floor finish to be placed later. The type of floor finish has not yet been determined and where a special finished floor is required, as determined by the contracting officer, such special finished floor will either be placed later by the Government or if required to be placed by the contractor will be ordered in writing by the contracting officer and paid for as extra work under the provisions of article 5 of the contract and paragraph 10 of these specifications.

138. Cement mortar finish for concrete floors.—Floor finish, consisting of mortar in the proportions of one part of cement to two parts of clean, well-graded sand which will pass a No. 8 sieve, shall be applied to all concrete floors in the outlet valve houses and such other structures as may be designated by the contracting officer, after the installation of machinery is completed. The top of the concrete shall be left approximately ¾ inch below the finished floor elevation shown on the drawings, and allowance shall be made for this finish when anchor bolts, pipes, and other metal parts are placed. Before applying the floor finish the surface of the concrete shall be thoroughly washed and roughened. The finished surfaces shall be given a slope for drainage, as directed by the contracting officer. The floor finish shall be at least ¾-inch thick, and shall be brought to a true and even surface by means of a straight-edge and then carefully floated to close all voids and hollows. The surface shall be finished by sprinkling dry cement evenly over it by means of a fine sieve, after which it shall be carefully floated and troweled. A second steel troweling shall be given after the cement has set sufficiently to finish hard and smooth. The floors shall be marked into 30-inch squares by means of a small expansion joint tool or other means satisfactory to the contracting officer. Cement floor finish will be measured for payment to the required neat lines and all openings will be deducted. Payment for placing the ¾-inch finish for concrete floors, as described in this paragraph, will be made at the unit price per square yard bid therefor in the schedule.

139. Thin walls of metal lath and plaster.—Thin walls of metal lath and plaster having a finished thickness of approximately 3 inches shall be constructed in the power plant and other buildings where and as directed by the contracting officer. The framing shall consist of vertical steel channels spaced on about 24-inch centers, bent on each end and fastened to inserts in the floor and ceiling. Expanded metal lath sheets, similar or equal to Hy-rib, with the ribs in a horizontal position, shall be fastened to the vertical channels with soft iron wire ties at six-inch centers, and the ends of the sheets placed in grooves in the walls. All metal lath sheets shall start at the ceiling, be staggered with one another, and lap around corners. The laps at sides shall be formed by nesting outside ribs and the sheets shall lap not less than one inch at ends. The sheets shall be braced temporarily on the channel side at intervals not exceeding five feet vertically before the application of plaster. Grounds and bucks shall be set as directed by the contracting officer. The plastering shall first be applied on the side on which the expanded metal is fastened, with about ¼ inch over the ribs, and pushed through to form a good key; and this operation shall be carried on continuously from the bottom up without allowing the plaster to dry at the edge. When this coat has set dry, a similar coat shall be applied on the other side of the partition with ¼-inch covering over the vertical channels. To the materials for these first coats shall be added sufficient hair or fiber to bond the mortar. As soon as the first coat has become firm, but not fully dry or hard, the entire surface shall be cross scratched diagonally. Scratching shall be deep enough to provide good bond for the following plaster coat but not deep enough to injure the keys. Before applying the finish coat the plaster shall be wetted to saturation to prevent absorption of water from the fresh mortar. The finish coat shall then be applied, using for this purpose one part of cement to two parts of fine sand with hydrated lime, but without hair or fiber. The finish coat shall be troweled smooth with as little rubbing as necessary to produce a workmanlike finish reasonably free from irregularities, and matching in color and texture the adjoining concrete walls to the satisfaction of the contracting officer. The material composing the plaster shall be as follows: Portland cement, 1 part; sand, which is practically free from organic matter and uniformly graded in size from coarse to fine, all to pass through a sieve having eight (8) meshes per inch for the ground coats and 12 meshes per inch for the finish coats, 3 parts; hydrated lime, which is uniform in quality and perfectly hydrated,

$\frac{1}{10}$ part; hair or fiber sufficient to bond the mortar. The cement and screened hydrated lime, after being thoroughly dry-mixed to a uniform color, shall be added to the dry sand and the whole manipulated until evenly mixed. Water shall then be added to secure proper consistency. The mortar shall then be thoroughly worked until perfectly homogeneous. Mortar shall be made up only in lots that can be immediately applied, and any material that has been mixed with water longer than 30 minutes shall be rejected. The cement, lime, and hair used in any rejected plaster will be charged to the contractor at its cost to the Government at the point of delivery. Measurement for payment of the completed walls will be made of one side only, to the neat required dimensions and all openings will be deducted. Sand and water for plastered partitions shall be furnished by the contractor and all other materials in the finished partitions will be furnished by the Government under the provisions of paragraph 27. Payment for all work described in this paragraph will be made at the unit price per square yard bid in the schedule for thin walls of metal lath and plaster, which unit price shall include the cost of hauling, handling, and placing all materials required for the completed walls, furnishing all sand and water required, and constructing the wall as described in this paragraph.

METAL WORK AND PAINTING, GENERAL

140. Installing metal work.—The high-pressure gates with their operating mechanisms, metal conduits, needle valves, Stoney gates, frames and hoists, power intake cylinder gates and shutter gates, traveling cranes, trash-rack metal work, structural steel, elevator guide inserts, metal stairways, handrails, hatchways, manholes, floor plates, pipe and fittings, valves, tubing, metal doors and sash, crane runway rails, inclined elevator guides, track in floor of power house and for inclined elevator spur track, anchor bolts, and other miscellaneous metal work required as parts of the completed structures, will be furnished to the contractor by the Government, as provided in paragraph 27. The contractor shall attach to or build into the dam, power house, and appurtenant works all such metal work, and shall install all such gates, valves, hoists, and machinery in a workmanlike manner, as shown on the drawings or as directed by the contracting officer. The installation of the two electrically operated elevators in the dam will not be required under these specifications. All gates, gate hoists, and valves will be completely assembled and tested for operation before shipment from the factory and will be marked and match-marked to facilitate assembly in the field. All moving parts and control mechanisms and other machinery shall be carefully installed, tested for operation, and adjusted so that all parts move freely within each other and properly function to secure satisfactory operation, as determined by the contracting officer. Any changes or adjustments required to secure satisfactory operation shall be made by the contractor at his own expense: *Provided*, That if any part of the machinery or mechanisms is found to be defective due to no fault of the contractor, as determined by the contracting officer, the contracting officer may order the contractor to correct such defects, and payment therefor will be made as extra work under the provisions of article 5 of the contract and paragraph 10 of these specifications. A part of the metal work as furnished will have been given one or more shop coats of paint. This paint coating shall be protected as much as practicable during the handling and storing of metal work, and after installation all unfinished surfaces not to be in contact with concrete shall be painted as provided in paragraph 142. Except as otherwise provided in these specifications, payment for installing and painting all metal work and machinery will be made at the unit prices bid in the schedule for installing the various items of metal work, which unit prices shall include the cost of unloading, hauling, storing, handling, assembling, installing, erecting, adjusting, and painting all metal work and machinery furnished by the Government, and maintaining the same in position and proper operating condition until final acceptance by the Government. The cost of unloading, hauling, storing, handling, installing, and painting miscellaneous items of metal work, not directly appurtenant to gates, valves, or other features specifically provided for, such as brackets, anchor bolts, and any other metal work to be permanently installed as parts of the completed work, will be paid for at the unit price bid in the schedule for "Installing miscellaneous items of metal work." The unit price bid for installing gates, valves, control mechanisms, piping, and other miscellaneous items of metal work shall include the cost of making minor changes and the cost of correcting such minor errors and inaccuracies in the various parts as may be expected to occur in the ordinary commercial grade of shop work and manufacture of such materials, as determined by the contracting officer.

141. Weights of machinery and metal parts.—The weights of metal and other parts, the handling and placing of which is to be paid for on the basis of weight, will be determined by the contracting officer. The weights of these items given in the schedule are advance estimates for the purpose of comparing bids only, and the actual weights may vary widely therefrom. The contracting officer will determine the weight of each part or item involved in the most practicable manner, and will use for that purpose, where possible, weights obtained from such sources as railroad shipping weights, manufacturers' weights, catalog weights, and estimated weights, subject to the provisions of article 15 of the contract, in case of dispute. In estimating weights of metal parts, the unit weights of the various materials as given in Carnegie Pocket Companion, 1923 edition, will be used, and the method of computing such weights will be in accordance with the current "Specifications for Steel Railroad Bridges" of the American Railway Engineering Association. Net weights only will be paid for and the weight of all tare, packing, blocking, etc., will be deducted.

142. Painting.—All exposed, unmachined metal surfaces shall be painted by the contractor unless otherwise directed by the contracting officer. All painting shall be done by the contractor in accordance with these specifications or as directed by the contracting officer for each part of the work, and the contractor shall be entitled to no additional compensation on account of the kind of paint, number of coats, or method of application prescribed by the contracting officer. Where metal parts have been painted before delivery to the contractor, care shall be taken in unloading, handling, hauling, and installing such parts to preserve the shop paint in best practicable condition. After installation, the contractor shall thoroughly clean all painted surfaces and repair all damaged places in the original paint film, as directed by the contracting officer. After these repaired areas have thoroughly set, one or more field coats of paint shall be applied to the exposed surfaces as herein provided. The unmachined surfaces of conduit linings, leaves, and other exposed submerged parts of high-pressure gates, 50-foot by 50-foot Stoney gates, cylinder gates in the intake towers, the interior of needle valves, gate guides, trash-rack bars and castings or frames, and similar miscellaneous metal work, not in contact with concrete, shall be given one coat of water-gas tar, if not painted in the shop, followed by two coats of coal-gas tar applied hot, or, where so directed by the contracting officer, painted with one or more coats of an equivalent metal preservative paint applied hot or cold according to the specifications of the paint manufacturer. The outside surfaces of needle valves, machinery, piping, handrails, metal trim around doors and windows, and other metal work not to be coated with coal-gas tar shall be carefully cleaned of all rust, scale, and oil and given one or more coats of paint or enamel, as directed by the contracting officer. All painting shall be performed in a skillful and workmanlike manner and thoroughly brushed, satisfactory to the contracting officer, and each coat of paint shall be permitted to dry thoroughly before the succeeding coat is applied. Application of paint by dipping or air-brush may be used by the contractor if approved by the contracting officer. All tar and other paint materials will be furnished to the contractor by the

Government, as provided in paragraph 27. The cost of unloading, hauling, storing, handling, and applying the paint, and the cost of all work, operations, and equipment required for painting shall be included in the unit prices bid in the schedule for installing the various items of metal work and machinery.

PIPES AND STRUCTURAL STEEL

143. Standard steel and cast-iron pipe, fittings, and valves.—All pipe, fittings, couplings, companion flanges, hangers or supports, valves, and specials used in control, drain, bypass, and vent-pipe lines, pipe for concrete cooling system, pipe and fittings for grouting operations, pipe and fittings for draining foundations of dam, steel and cast-iron plumbing, piping, pipe and fittings for handrailings, and any other piping not otherwise specifically mentioned in the schedule or specifications, to be attached or built into the dam and related works, complete with bolts, screws, packing, gaskets, white lead, and other accessories, will be furnished to the contractor by the Government, as provided in paragraph 27. All standard steel pipe in sizes 12-inch and smaller will be furnished in random lengths, threaded and coupled, and it shall be cut, threaded, fitted, and placed by the contractor in a workmanlike manner, as shown on the drawings or as directed by the contracting officer. Flanged valves and fittings will be furnished faced and drilled. Flanged cast-iron pipe will be furnished to the required lengths, faced and drilled. Bell and spigot cast-iron pipe, if used, will be furnished in standard lengths, and shall be cut, if required, by the contractor. Pipe and fittings to be embedded in the concrete shall be firmly held in position and protected from damage during the depositing of concrete. Pipe hangers or supports shall be placed as shown on the drawings or as directed by the contracting officer. Care shall be taken to insure that all pipes are clean and to avoid clogging from any cause during the progress of the work, and should any pipe become clogged before final acceptance of the work it shall be cleaned out in a manner satisfactory to the contracting officer or replaced by, and at the expense of, the contractor. Pipe and fittings to be buried in concrete shall not be painted on the outside, but shall be thoroughly cleaned of all excessive rust, dirt, and grease before being embedded in concrete. The cost of installing and painting the materials described in this paragraph will be paid for at the unit price per pound bid in the schedule for "Installing standard steel and cast-iron pipe, fittings, and valves." Steel pipe or tubing in sizes larger than 12-inch will as far as practicable be furnished cut to length and with flanges fitted in place, or with ends prepared for couplings, but any cutting or fitting of such larger pipe or tubing shall be done by the contractor, as shown on the drawings or as directed by the contracting officer, and the cost thereof included in the unit price per pound bid in the schedule for installing and painting standard steel and cast-iron pipe, fittings, and valves.

144. Pipe handrailing.—Pipe and fittings for handrailings with bolts, pins, rivets, flanges, and all other accessories will be furnished by the Government, as provided in paragraph 27. Pipe will be furnished in random lengths and shall be cut to the required lengths and threaded by the contractor. The contractor shall assemble, install, and paint this material wherever it may be required on any part of the work, as shown on the drawings or as directed by the contracting officer. Railings to be set in concrete shall either be completely assembled and placed when concrete is poured, or recesses shall be left, or holes drilled in the concrete to receive the railing posts and the railings completely assembled and accurately grouted in position and alignment at some later time. Payment for all work described in this paragraph will be made at the unit price per pound bid in the schedule for installing standard steel and cast-iron pipe, fittings, and valves, which price shall include the cost of setting the railing in concrete and grouting it in where required. The estimated amount of standard steel and cast-iron pipe and fittings required for pipe handrailing is 31,500 pounds.

145. Pipe for grouting tunnels, adits, and shafts.—Except for considerable portions of the diversion tunnels upstream from the tunnel plugs in the outer diversion tunnels and upstream from the upstream plugs in the inner diversion tunnels, the contractor shall place metal pipes for grout connections and for vent pipes in the diversion tunnels, adits, and shafts at such points as may be designated by the contracting officer. As provided in paragraph 86, pipe for high-pressure grout connections may be set either before or after placing concrete. If the grout connection pipe is set in the drilled hole after the placing of concrete, the contractor shall completely fill all space, if any, between the pipe and the concrete with grout or mortar, or shall otherwise provide a perfectly tight fit between the pipe and the concrete. No high-pressure grout pipe connections shall extend nearer than 6 inches to the excavated surface of the surrounding rock. All vent and low pressure grout pipes shall be set in position prior to the placing of concrete. This may be done by anchoring one end of the pipe to the forms, using temporary pipe fittings, or by other suitable means. The length, location, and direction of each vent pipe and of each low pressure grout pipe connection shall be as directed by the contracting officer. All grout and vent pipes and pipes for the concrete linings of tunnels, adits, and shafts shall end not less than 1 inch back of the finished inside surface of the concrete lining, and at this point a recess shall be provided in the lining which shall be filled with concrete after the grouting is done. The size of the grout pipe for each hole will be determined by the contracting officer to meet the requirements of the drilling and grouting equipment used. Pipe and fittings for grout connections and vent pipes will be furnished by the Government under the provisions of paragraph 27, only as required for the permanent installations. All other pipe and fittings and all equipment used for grouting shall be furnished by the contractor. The pipe furnished by the Government will be in random lengths, and it shall be cut, threaded, and fabricated as required and placed by the contractor. Payment for all work described in this paragraph will be made at the unit price per pound bid in the schedule for installing standard steel and cast iron pipe, fittings, and valves, and only for the amount of pipe and fittings required to be left in place, as determined by the contracting officer. The estimated amount of standard steel and cast-iron pipe and fittings required for permanent installation is 120,000 pounds.

146. Pipe for grouting foundations for dam and spillway crests.—Metal pipe for grout holes shall be placed in the concrete of the upstream cut-off wall in the foundation and abutments of the dam, in the foundations of the spillway crests and inlet structures for the outer diversion tunnels, and elsewhere if required, as shown on the drawings or as directed by the contracting officer. Pipes for grouting shall also be set over springs or crevices in the rock or other foundation defects wherever directed by the contracting officer. As the work progresses the development of leakage or the condition of the surrounding foundations may indicate that parts of the foundations already covered require grouting, in which event holes shall be drilled through the concrete and into the underlying foundations, if required by the contracting officer, and pipes for grout connections placed as directed by the contracting officer. The size of grout pipe for each hole will be determined by the contracting officer to meet the requirements of the drilling and grouting equipment used. The space between grout pipes and the rock or concrete into which they are inserted shall be carefully caulked with oakum or other suitable material to prevent entry of concrete or other materials prior to grouting. All oakum or other suitable material shall be furnished by the contractor. Where a pipe grout connection is to be grouted before being solidly embedded in concrete, the space around the pipe shall be thoroughly filled with grout or mortar. Pipe and fittings required for the work described in this paragraph will be furnished by the Government under the provisions of paragraph 27, only as required for the permanent installations. All other pipe and fittings and all equipment used for grouting shall be furnished by the contractor. The pipe furnished by the Government will be in random lengths, and it shall be cut, threaded, and fabricated as required and placed by the contractor. Payment for installing the pipe and fittings, as required by this paragraph, will be made at the unit price per pound bid in the schedule for installing standard steel and cast-iron pipe, fittings, and valves, and only for the amount of pipe and fittings that are required to be left in place, as determined by the contracting officer, which amount is estimated to be 34,000 pounds.

147. Pipe for grouting contraction joints in dam.—A system of pipes and fittings shall be placed in the contraction joints in the dam, as shown on the drawings or as directed by the contracting officer. All pipe, fittings, and parts, except nails and tie wire required for the grouting systems, will be furnished by the Government under the provisions of paragraph 27. The pipe furnished will be in random lengths, and it shall be threaded, cut, and fabricated ready for installation as required. The pipe and fittings shall be carefully assembled and placed and shall be firmly held in position during the construction of the dam. Great care shall be exercised to insure that the two companion members of each conduit box cover grouting unit are maintained in accurate alignment and position with respect to each other, and that each member becomes an integral part of and moves with the concrete mass to which it is anchored. The method of attaching the first member of each unit to the forms and, in turn, the second member to the first is shown on the drawings. This method shall be accurately adhered to unless it is modified by the specific instructions of the contracting officer. Great care shall also be taken to insure that all parts of the system are maintained free from dirt or any foreign substance whatever. After each grouting system is placed and the concrete around it completed and at such other times as the contracting officer may direct, the pipe shall be tested by forcing a current of air under pressure through it to the satisfaction of the contracting officer, after which it shall be immediately temporarily capped or otherwise closed to avoid the possibility of any foreign substance entering it until it is pressure grouted. Any pipe that is found to be or becomes clogged due to any cause during the construction of the dam and before it is pressure grouted, shall, if practicable, be cleaned or opened up to the satisfaction of the contracting officer. For any pipe which the contractor fails to open up or to replace to meet this test the contractor shall pay to the Government as fixed, agreed, and liquidated damages the sum of two dollars ($2) per linear foot of the total length of that pipe which is thereby made ineffective as determined by the contracting officer. Payment for all work described in this paragraph, except as otherwise provided, will be made at the unit price per pound bid in the schedule for installing standard steel and cast-iron pipe, fittings, and valves. Payment will be made only for the pipe and fittings, including conduit box covers actually installed, and the computed weight for payment will not include the weight of nails or tie wire. The estimated amount of standard steel and cast-iron pipe, fittings, and conduit box covers required for permanent installation in contraction joints is 1,155,000 pounds.

148. Pipe for draining foundation of dam.—The contractor shall install all metal pipe and fittings for draining the foundation and abutments of the dam, as shown on the drawings or as directed by the contracting officer. All required pipe and fittings for this drainage will be furnished by the Government under the provisions of paragraph 27. The pipe furnished will be in random lengths and it shall be cut, threaded, and fabricated ready for installation as required. The pipe shall be held firmly in position and protected from damage during the depositing of the concrete. Care shall be taken to avoid clogging of the pipe from any cause during the progress of the work, and should any pipe become clogged from any cause before final acceptance of the work it shall be cleaned out in a manner satisfactory to the contracting officer or replaced by and at the expense of the contractor. Payment for installing the pipe and fittings described in this paragraph will be made at the unit price per pound bid in the schedule for installing standard steel and cast-iron pipe, fittings, and valves. Payment will be made only for the pipe and fittings actually installed. The estimated amount of standard steel and cast-iron pipe, fittings, and valves required for permanent installation for draining foundation of dam is 121,000 pounds.

149. Pipe for cooling concrete.—As provided in paragraph 121 and as shown on the drawings or directed by the contracting officer, the contractor shall install metal pipe in the concrete of the dam and tunnel plugs, through which water of a low temperature will be run for the purpose of cooling the concrete. It is contemplated that 2-inch standard pipe and fittings or boiler tubing of approximately the same diameter will be used and that there will be required the installation of about 800,000 linear feet of pipe, involving about 16,000 couplings. Pipe loops may be connected in series up to a total length of approximately 1,600 feet. All pipe or tubing and fittings required for embedding in the concrete for cooling purposes will be furnished by the Government under the provisions of paragraph 27. The pipe furnished will be in random lengths and it shall be cut, threaded, and fabricated ready for installation as required. Couplings of the expansion type will be furnished for use where the cooling pipe crosses contraction joints. All screw joints shall be made up with a standard joint compound. The joint compound shall be furnished by the contractor and shall be subject to the approval of the contracting officer. All pipe joints shall be made tight and so that they will withstand a pressure of 100 pounds per square inch. The pipe spacing, length of pipe, diameter of pipe, and amount of concrete to be cooled may be changed to meet changed conditions which may develop during the progress of the work, and the contractor shall be entitled to no additional allowance above the unit prices bid in the schedule by reason of such changes. Payment for installing the pipe and fittings, or tubing, as required by the provisions of this paragraph will be made at the unit price per pound bid in the schedule for installing standard steel and cast-iron pipe, fittings, and valves, and only for the amount of pipe and fittings that is embedded in the concrete.

150. Control piping for high-pressure gates.—All pipe, fittings, hangers, valves, gauges, oil tanks, and accessories, for controlling the operation of high-pressure slide gates, will be furnished by the Government, as provided in paragraph 27. The pressure pipe will be 2-inch and smaller, double extra-strong, black pipe, and will be furnished in random lengths, with an assortment of nipples, couplings, and other fittings. Fittings will be steel hydraulic screwed fittings, and control valves will be of the straightway plug type. A comparatively small part of the piping will be standard weight. The pipe shall be cut to the required lengths and threaded, and the control-pipe system shall be carefully installed in a workmanlike manner, as shown on the drawings or as directed by the contracting officer. The control pipe system will be operated under a pressure of 1,500 pounds per square inch, and special care shall be taken to insure that all threads are full cut and free from torn and ragged surfaces. The control-pipe system will be tested at the above pressure, and any leaky joints or other defective work shall be repaired or made over to the satisfaction of the contracting officer. A mixture of litharge and glycerine, or similar compound satisfactory to the contracting officer, shall be furnished and used by the contractor on all threaded pipe joints in all high-pressure control piping. Care shall be used in cutting and fitting to have pipe run parallel and to have the complete control-pipe systems neat in appearance and securely fastened in place. Exposed control piping shall be painted as directed by the contracting officer. Payment for installing control piping will be made at the unit price per pound bid in the schedule for installing control piping for high-pressure gates, which price shall include the cost of all work required in carrying out the provisions of this paragraph.

151. Metal pipe for highway drains and culverts.—The corrugated metal pipe and connecting bands for highway drains and culverts and plain metal pipe for drainage of the highway on the top of the dam will be furnished to the contractor under the provisions of paragraph 27. No damaged pipe shall be placed in the trenches or structures except as permitted by the contracting officer. For all pipe damaged in handling by the contractor to such an extent that, in the judgment of the contracting officer, it is unfit for use, the contractor will be charged the same amount that the pipe cost the Government at the point of delivery to the contractor. The trench in which the culvert pipe is to be laid shall be excavated carefully to line and grade, so that the pipe will be fully supported at all points by the unexcavated ground over the bottom quarter of its circumference: *Provided*, That where rock is encountered in the bottom of the trench, the trench shall be excavated to a depth of at least four (4) inches below the grade established for the bottom of the pipe, and this additional excavation shall be back filled with material satisfactory to the contracting officer, which material shall be thoroughly tamped in place before the pipe is placed. All pipe shall be laid to the lines and grades established by the contracting officer, with separate sections firmly jointed together. All back filling around the pipe up to three-quarters of the height of the pipe shall be made of selected material carefully compacted to the satisfaction of the contracting officer by puddling or tamping. Travel over the culverts shall not be permitted until back fill has been placed to a depth of at least 1 foot over the top of the pipe. All corrugated metal pipe culverts 48 inches or more in diameter shall be strutted with timber, as shown on the drawings or as directed by the contracting officer, before any back fill is placed around the pipe. All struts shall remain in place until the embankment over the pipe is completed. All lumber required for struts shall be furnished by the contractor. In constructing highway drains, corrugated metal drainpipe shall be laid along the rim of the canyon below the highway and immediately above the rubble masonry wall and elsewhere, as shown on the drawings or as directed by the contracting officer. An even bedding for the drainpipe shall be prepared by excavating or by filling in with gravel or small rock fragments to the prescribed grade for the pipe invert, as established by the contracting officer. After laying, the drainpipe shall be back filled with gravel or small rock fragments to a minimum depth of one foot over the top of the pipe. Payment for laying metal pipe for highway drains and culverts will be made at the unit price per pound bid therefor in the schedule, which price shall include the cost of all labor, materials, and plant required in unloading, hauling, handling, storing, preparing an even bedding, laying, attaching the connecting bands, and strutting of culvert pipes, in accordance with the provisions of this paragraph. Required excavation for corrugated metal drain and culvert pipes will be paid for at the unit price per cubic yard bid in the schedule for excavation for highway structures, which price shall include the cost of all required back fill, including that around the corrugated metal pipe along the rubble masonry walls.

152. Conduit lining castings.—A portion of the metal conduit linings in the upper and lower canyon wall outlets and tunnel plug outlets will be steel or semisteel castings, made in sections not over 6 feet in length. These conduit lining sections will be circular, square, and rectangular in cross section, with conduit lining transitions from circular at one end to square or rectangular at the other end, and will, in all cases, be embedded in concrete. All flanges will be faced and drilled for bolted joints. All conduit lining castings, with bolts and gaskets, will be furnished by the Government as provided in paragraph 27. The contractor shall assemble and install these cast conduit linings, as shown on the drawings or as directed by the contracting officer, with finished surfaces of all joints smoothly coated with white lead, which will be furnished by the Government, or gaskets inserted, if specified, before being bolted together. The metal conduit linings shall be held rigidly in place, true to line and grade, until the placing of concrete is completed. All offsets at joints shall be chipped to present a smooth flow line. All bolts shall be drawn tight, and shall be tightened several times at intervals until it is positively assured that there will be no leakage. The contractor shall also close the joints between sections by arc-welding at the point of contact to insure watertightness, and secure a continuous inside surface, if required by the contracting officer. After acceptance by the contracting officer the inside surfaces only of conduit linings shall be given two coats of preservative paint applied hot, if so specified. The outside surfaces of conduit linings in contact with concrete shall not be painted, but shall be cleaned of all excessive rust, grease, and dirt before concrete is placed. Rich concrete, free from cobbles or coarse stone, shall be thoroughly spaded around all conduit linings, pipe connections, and reinforcement steel to secure proper adhesion and prevent leakage. Pressure grouting shall be used, if required by the contracting officer, to secure this result. Payment for pressure grouting, if required, will be made at the unit price bid in the schedule for pressure grouting in tunnels, adits, and shafts. Payment for installing conduit lining castings will be made at the unit price per pound bid therefor in the schedule, which price shall include the cost of all work, except pressure grouting, required in hauling, assembling, installing, arc-welding, cleaning, and painting the conduit lining castings in accordance with the provisions of this paragraph.

153. Plate-steel conduit linings for outlet works.—A portion of the metal conduit linings in the upper and lower canyon wall outlet works and in the tunnel plug outlets will be plate-steel pipes embedded in concrete. It is contemplated that these plate-steel linings will have an inside diameter of 91 inches, with the plate thickness varying from 1¼ inches to ¾-inch, fabricated in lengths convenient for shipment, with welded longitudinal seams and bolted flanged joints. All plate-steel conduit linings, with flanges, bolts, and gaskets, will be furnished to the contractor by the Government under the provisions of paragraph 27. The contractor shall assemble and install plate-steel conduit linings, as shown on the drawings or as directed by the contracting officer. Gaskets shall be carefully placed and, if so directed by the contracting officer, flanges shall be smoothly coated with white lead, which will be furnished by the Government. All bolts shall be drawn tight, and shall be tightened several times at intervals until it is positively assured that there will be no leakage. The contractor shall close the joints between pipe sections by arc-welding at the point of contact of flanges to insure watertightness and secure a continuous inside surface, if required by the contracting officer. The plate-steel conduit linings shall be held rigidly in place, true to line and grade, until the placing of concrete is completed. After acceptance by the contracting officer, the inside surface only of the conduit linings shall be given two coats of preservative paint, applied hot, if so specified by the contracting officer. The outside surface of conduit linings in contact with concrete shall not be painted, but shall be cleaned of all grease, dirt, and excessive rust before concrete is placed. Rich concrete, free from cobbles or coarse stone, shall be thoroughly spaded around all plate-steel conduit linings to secure proper adhesion and prevent leakage. Pressure grouting, if required by the contracting officer, will be paid for at the unit price bid in the schedule for pressure grouting in tunnels, adits, and shafts. Payment for installing plate-steel conduit linings for outlet works will be made at the unit price per pound bid therefor in the schedule, which unit price shall include the cost of all work except pressure grouting, required in hauling, assembling, installing, arc-welding, cleaning, and painting the plate-steel conduit lining, in accordance with the provisions of this paragraph.

154. Plate-steel conduit linings for power penstocks.—The power penstocks connecting the turbines with the 30-foot penstock tunnels and the inner diversion tunnels will be lined with plate steel embedded solidly in concrete. The inside diameter of the power penstocks will be 11 feet, with plate-steel lining varying from ¾ inch to 2 inches in thickness. The lining will have welded longitudinal seams and bolted flanged joints, and will be furnished to the contractor in lengths convenient for shipment, complete with flanges, bolts, and gaskets. All requirements and provisions of paragraph 153 for plate-steel conduit linings for outlet works shall apply to plate-steel conduit linings for power penstocks.

155. Structural steel, general.—All structural steel building framework, crane rail supports, roof trusses, purlins and girders, column bases, temporary end walls, and other structural materials, with a supply of rivets and erection bolts for field erection, will be furnished by the Government, as provided in paragraph 27. Built-up members will be completely fabricated and assembled in the shop and knocked down for shipment. Erection in the field may be by riveting or by arc-welding, and the contractor shall be prepared to perform both classes of work.

(*a*) *Assembling.*—All parts shall be accurately assembled and erected, as shown on the drawings or as directed by the contracting officer, and all match-marks shall be carefully followed. The material shall be carefully handled so that no parts will be bent, broken, or otherwise damaged, and hammering that will injure or distort the members will not be permitted. Members shall not be over-stressed during the process of erection. Bearing surfaces and surfaces to be in permanent contact shall be carefully cleaned, and all contact surfaces of riveted joints shall be painted immediately before members are assembled. All bases or columns having bases fabricated as integral parts of the columns shall be set level in exact position, and shall be given full and even bearing by means of cement grout. In bolted connections, bolts shall be drawn tight and threads butted so that nuts can not become loosened. Where bolted connections are specified, the bolt holes shall be reamed in the field to provide a light drive fit. Field connections shall have one-half of the holes filled with erection bolts and cylindrical erection pins before riveting. All drilling and other work required for connection of door and window frames, ornamental metal work, pipe hangers, and similar purposes shall be done by the contractor. For main columns and columns adjacent to elevator shafts, the total error from plumb shall not exceed 1 to 1,000 for the total column height. For other individual parts the error from level, line, and plumb shall not exceed 1 to 500. The plumbing of columns shall be done before riveting. Compression joints depending on contact surfaces for bearing shall have full and even bearing after alignment and riveting are completed. Corrections of minor misfits and a reasonable amount of reaming and cutting of excess stock from rivets shall be considered a legitimate part of erection. For the purpose of determining what constitutes a reasonable amount of reaming, it shall be considered that where the opening in any rivet hole is not more than ⅛ inch off of correct center after the connection is temporarily assembled, the same is a minor error in shop work. Cutting of members with a cutting-torch will not be permitted unless approved by the contracting officer. Structural steel to be embedded in concrete shall not be painted. After erection is completed and accepted by the contracting officer, all structural steel not to be embedded in concrete shall be given one or two coats of paint, as directed by the contracting officer. Only expert riveters or welders shall be used to perform the riveting or welding, and, if required by the contracting officer, they shall submit suitable evidence of ability, by sample of work or otherwise, before being allowed to perform this work.

(*b*) *Riveting.*—Riveting shall be done with pneumatic riveters and buckers. All connections shall be accurately and securely fitted up before the rivets are driven. Light drifting to bring the parts together will be allowed, but drifting to match unfair holes will not be permitted. All unfair holes shall be reamed or drilled. An unfair hole is considered as one in which a cold rivet of the size specified will not enter with light tapping after light drifting has been resorted to. Rivets shall be heated to a light cherry red color, and when driven shall completely fill the holes and shall firmly grip the connected parts together. Rivet heads shall be of the same shape and size as the shop rivets, full and symmetrical, concentric with the shank, and shall have full bearing on the plate. Recupping or caulking of rivets will not be permitted. Loose, burned, or otherwise defective rivets shall be removed. When removing rivets the surrounding metal shall not be injured, and, if necessary, rivets shall be drilled out. Cup-faced dollies, fitting the rivet heads closely to insure good bearing, shall be used. Field rivets shall not be painted until they have been inspected and accepted by the contracting officer.

(c) *Arc welding.*—In assembling and during welding, the component parts of a built-up member shall be held by sufficient clamps or other adequate means to keep parts straight and in close contact. Surfaces to be welded shall be well cleaned, by wire brushing, chipping, or hammering, of loose scale, rust, paint, or other foreign matter, except that a thin coat of linseed oil need not be removed before welding. Weld metal deposited in two or more layers shall have each layer brushed with a wire brush or otherwise cleaned before subsequent layers are deposited. In welding, precautions shall be taken to minimize stresses due to expansion or contraction and distortion due to heat. Upon completion, welds shall be brushed with wire brushes, and shall show uniform section, smoothness of weld metal, feather-edges without overlaps, and freedom from porosity and clinkers. Visual inspection at edges and ends of fillets and butt-joint welds shall indicate good fusion with and penetration into base metals. Welding shall not be covered with paint until after inspection and acceptance by the contracting officer.

(d) *Installation.*—The cost of assembling, installing, erecting, and painting structural steel materials as described herein will be paid for at the unit price per pound bid in the schedule for installing structural steel, except bridges to intake towers.

156. Structural steel for bridges.—Plate-steel girder bridges, encased in concrete, for connecting the intake towers with the dam, shall be constructed as shown on the drawings or as directed by the contracting officer. The girders will be fabricated in the shop in sections, with provision for all necessary field connections. All structural steel girders, floor beams, pedestals, pins, checkered plates, and other members and connections, with a supply of rivets and erection bolts for field erection, will be furnished by the Government as provided in paragraph 27. The assembling and riveting of structural steel for bridges shall be in accordance with the requirements of these specifications for the erection of "Structural steel, general," paragraph 155. The bearing areas on the concrete abutments under pin and roller pedestals shall be uniform and level. Pedestal castings shall be set level in exact position and shall have full and even bearing on the masonry. Unless otherwise directed by the contracting officer they shall be placed on a layer of canvas and red lead applied by first coating each bearing area with red lead paint, then placing upon it 3 layers of 12 to 14-ounce duck, each layer being thoroughly coated on its top surface with red lead paint, then placing the pedestal castings in position while the paint is still plastic. The surfaces of all structural steel shall be thoroughly cleaned of all loose mill scale, rust, grease, paint, and dirt, and only those surfaces not encased in concrete shall be given one priming coat, if required, and two coats of preservative paint, applied hot, if so specified. The contractor shall haul, assemble, erect, and paint the structural steel girders, floor beams, stringers, and other metal work for bridges, as shown on the drawings or as directed by the contracting officers, and the cost thereof shall be included in the unit price per pound bid in the schedule for installing structural steel in bridges to intake towers.

157. Trash rack metal work.—Trash bars, castings, and structural steel supports for trash racks for intake towers and inner diversion tunnel inlets and elsewhere, if required, will be furnished by the Government, as provided in paragraph 27. Castings or steel anchorages for the structural steel supports shall be securely anchored to the structures with anchor bolts or bars provided for this purpose. For the trash racks at the tunnel inlets, the bars shall be set into place in the spacers and supports which are set into the concrete. For the trash racks on the intake towers, the bars will be shipped separately and shall be assembled into trash-rack sections of several bars, by bolting the bars together, with suitable pipe spacers, or by welding to spacing members, as shown on the drawings or as directed by the contracting officer. All exposed metal work in trash racks shall be painted with one or two coats of paint, applied hot if so specified, as directed by the contracting officer. Payment for hauling, handling, installing, and painting metal work in trash racks will be paid for at the unit price per pound bid in the schedule for installing trash rack metal work. Dipping of trash bars will be permitted in lieu of brush painting.

158. Steel sheet piling for upstream cofferdam.—Steel sheet piling shall be driven by the contractor at the upstream toe of the upstream cofferdam. The piling shall be driven to bedrock or to a depth satisfactory to the contracting officer. The piles will have a continuous rolled interlock integral with the pile throughout its entire length, so designed as to permit an angular movement between adjoining piles of at least 15 degrees on either side of the center line. The piling shall be driven as closely as practicable to lines established by the contracting officer. The piles shall be so driven as to insure perfect interlocking throughout their entire length. Methods of driving shall be subject to the approval of the contracting officer. Assembling frames of capped wooden piles or other suitable guide structure shall be used and the steel piling shall be assembled against the guides so that they are plumb at both edge and side. A protecting cap shall be used for all driving. Piles ruptured in the interlock or otherwise injured in driving shall be pulled and replaced at the expense of the contractor: *Provided*, That the contractor will not be charged for the damaged piles. Should bowlders be encountered above bedrock, the contractor shall make every effort to drive the piling to bedrock, either by moving or shattering the bowlder or by deviations in the line of the piling. If at any time the forward edge of the steel piling wall is found to be out of plumb, the piling already assembled and partly driven shall be driven to rock or to a depth satisfactory to the contracting officer and taper piles shall then be used to bring the forward edge plumb before additional piling is assembled or driven. The maximum permissible taper in a single pile shall be 6 inches in 50 feet of length. Spliced piles shall be fabricated and driven by the contractor where the standard lengths furnished by the Government are inadequate, as determined by the contracting officer: *Provided*, That where piling less than 50 feet in length is adequate, no splicing will be permitted. The steel sheet piling in lengths up to 50 feet, splice plates for taper piles, and plates and channels for spliced piles, together with required rivets and bolts for making the splices, will be furnished to the contractor by the Government under the provisions of paragraph 27. The contractor shall give the contracting officer not less than 90 days' notice in writing of requirements for piles and splicing materials and shall state his requirements in so far as practicable in carload lots. After the sheet piling has been driven to bedrock or to a depth satisfactory to the contracting officer, any piles extending above the line of the upper surface of the concrete paving, as established by the contracting officer, shall be cut off by the contractor. Any piles of which the top elevation after completion of driving is more than 24 inches below the specified top grade shall have an additional section of suitable length spliced to the driven section by methods satisfactory to the contracting officer. In determining the weight for payment, all materials in the completed and accepted work, including splice plates, and channels, bolts, and rivets, will be included. Payment will be made at the unit price per pound bid in the schedule for driving steel sheet piling for upstream cofferdam, which unit price shall include the cost of all labor and plant required in hauling and driving the piling, fabricating taper piles and spliced piles, pulling and replacing unsatisfactory piling, and cutting off or splicing on top sections of the piling after completion of driving in accordance with the provisions of this paragraph.

159. Track rails.—All track rails, with splice plates, rail clips, anchor bolts, bearing plates, and spikes if used, for crane runways and permanent tracks in the power plant, adits, or other structures, will be furnished by the Government as provided in paragraph 27. Track rails may vary in weight from 40 to 100 pounds per yard. Circular crane runway rails for the intake towers will be furnished bent to the required diameter. Crane runway rails for the larger cranes shall be placed on metal plates and bolted in place. The rails for the 5-ton crane in the Stoney gate structures shall be placed on wooden sleepers and held in place with anchor bolts and rail clips. Timber for the wooden sleepers will be furnished by the Government. Rails for the spur track from the foot of the inclined freight elevator into the power plant and in adits shall be embedded in the concrete floors. The contractor shall install all track rails in permanent structures, as shown on the drawings or as directed by the contracting officer. Special care shall be taken in installing crane runway rails to insure that the gauge is accurately maintained, the rails truly level and at the same elevation, and firmly held in place. Payment for installing track rails will be made at the unit price per pound bid in the schedule for installing track rails, which unit price shall include the cost of placing the wooden sleepers in the Stoney gate structures.

160. Metal work in inclined freight elevator guide structure.—All track rails, structural-steel guides, anchor bolts, inserts, and other metal work to be attached or built into the concrete guide structure for the inclined freight elevator will be furnished by the Government, as provided in paragraph 27. The contractor shall assemble, install, and paint all such metal work, as shown on the drawings or as directed by the contracting officer. Metal work in contact with concrete shall not be painted. All metal work not in contact with concrete shall be given one or more coats of preservative paint, applied hot if so specified, as directed by the contracting officer. Payment for installing and painting the materials described in this paragraph will be made at the unit prices per pound bid in the schedule for installing metal work in inclined freight elevator guide structure.

161. Metal floor plates.—All metal floor plates with metal frames set in concrete where used will be furnished by the Government, as provided in paragraph 27. Floor plates will be steel plates with raised pattern tread, or open grating of the subway type, made to the proper dimensions before shipment from the factory. The contractor shall paint this equipment and place it in position wherever required on the work, as shown on the drawings or as directed by the contracting officer. Dipping or air brushing of metal floor plates or grating will be permitted in lieu of brush painting. Payment for installing metal floor plates will be made at the unit price bid therefor in the schedule.

162. Metal stairways.—All straight-run and spiral metal stairways, with metal landings, treads, columns, rails, hatchways, anchor bolts, and other accessories for metal stairways, will be furnished by the Government completely fabricated for installation, as provided in paragraph 27. The contractor shall haul, assemble, erect, and paint this material, as shown on the drawings or as directed by the contracting officer. All exposed metal shall be given one or two coats of paint, applied hot, if so specified, as directed by the contracting officer. Payment for installing metal stairways will be made at the unit price per pound bid therefor in the schedule.

GATES AND OTHER MECHANICAL MACHINERY

163. Stoney gates and hoists.—The four 50-foot by 50-foot structural steel Stoney gates with their hoists, counterweights, structural steel guides, and other appurtenances, will be furnished under the provisions of paragraph 27. One of these gates shall be installed in the upstream end of each spillway structure. The other two gates shall be installed at the downstream end of the inner diversion tunnels. Each gate will be 50 feet in height by 54 feet 7½ inches in width, made up of structural-steel plate girders approximately 72 inches in depth, and mounted on caterpillar roller trains, running on heavy structural H-beams attached to the concrete structure. The cross and end girders, caterpillar roller trains, chains, frames, counterweight hangers, and principal assembled sections of the hoists will be shipped as separate units. The contractor shall assemble and install these gates, hoists, counterweights, and appurtenances, complete in accordance with the specifications and drawings or as directed by the contracting officer. The field joints in the gates shall be connected by riveting or arc welding or by both methods, as specified on the drawings. Special care shall be taken in installing the gate frames and guides to insure that they are adjusted for proper alignment and contact with the gate seats. Each hoist shall be accurately placed and aligned with relation to its gate and counterweights, and after the control wiring for the hoist motors has been installed by the Government each gate and hoist shall be properly adjusted and operated by the contractor, to the satisfaction of the contracting officer. The concrete counterweights shall be carefully installed by the contractor and lowered into place in such a manner as to avoid damage to the gates or hoists, preferably by the use of "sand jacks." This method consists in filling the counterweight wells in the gate structures with clean, dry sand to an elevation that will permit installation of each counterweight slightly higher than its suspended position. After the chains are properly connected to the gate and hoist, the counterweights are connected to the chains and lowered until they are properly suspended by slowly withdrawing sand from the wells through a small pipe at the bottom of each well provided for that purpose. After installation of counterweights is completed, the wells shall be thoroughly cleaned of all sand and the drainpipes capped or plugged with concrete. The construction of the concrete counterweights is provided for in paragraph 117 of these specifications. All wiring and open conduits for the hoist motor and control apparatus will be furnished and installed by the Government. Payment for hauling, assembling, and installing the bulkhead gates, frames, hoists, and counterweights, and painting all metal parts will be made at the unit price per pound bid in the schedule for installing 50-foot by 50-foot Stoney gates and hoists.

164. High-pressure, hydraulically operated gates.—The hydraulically operated high-pressure gates, which include the emergency gates in the upper and lower canyon wall outlet works and the slide gates in the upper concrete plugs in the inner tunnels, with their automatic hangers and other appurtenant metal work required for installation and operation of the gates, and oil, including that for operation, will be furnished complete ready for installation under the provisions of paragraph 27. It is contemplated that 56 such gates will be required. The gates, hoist cylinders, automatic hangers, and appurtenant metal work shall be assembled and installed by the contractor, as shown on the drawings or as directed by the contracting officer. The finished surfaces of all joints shall be smoothly coated with white lead, to be furnished by the Government, or gaskets placed, before being bolted together. Rich concrete, free from cobbles or coarse stone, shall be thoroughly spaded around gates, conduit linings, by-pass and vent piping, and reinforcing steel, as directed by the contracting officer, to secure proper adhesion and prevent leakage. Pressure grouting shall be used, if required by the contracting officer, to secure this result. Payment for pressure grouting, if required, will be made at the unit price bid in the schedule for pressure grouting in tunnels, adits, and shafts. After the gates, control apparatus, and piping have been installed, the control system shall be filled with oil and each gate shall be tested by the contractor by being raised and lowered several times throughout its full stroke, until the operation of each gate and of the control piping and machinery is satisfactory to the contracting officer. An automatic gate hanger is provided for each gate, designed for installation on the head of the hoist cylinder, for the purpose of automatically holding the gate leaf in the open position or in any intermediate position, if desired. These hangers are so designed that oil from the pressure pump must pass through them before entering the hoist cylinder for raising or lowering the gate, thus causing the hanger to function without fail. Payment for installing high-pressure hydraulically operated gates will be based on the weight of the gates only, which will include for each gate the upstream and downstream frames, bonnet, leaf, stem, hoist cylinder, hanger, and other parts integral with the gate, but will not cover metal conduit linings or transitions connected above or below the gates. Payment for installing and painting high-pressure hydraulically operated gates will be made at the unit price per pound bid in the schedule for installing high-pressure hydraulically operated gates. Payment for installing control piping for the gates will be made at the unit price per pound bid in the schedule for installing control piping for high-pressure gates.

165. Cylinder gates and hoists in intake towers.—The cylinder gates in the intake towers, with their water-passage liners, stems, stem guides, hoists, shutter gates, and accessories, will be furnished by the Government under the provisions of paragraph 27. Four concrete intake towers will be constructed above the dam; two near each end of the dam, the nominal inside diameter of the towers being 30 feet. One cylinder gate will be installed in each tower. The cylinder gates will be steel castings, each gate being made in 12 sections, bolted together. The stems will be 6-inch diameter shafting. Stem guides, connected to the tower by anchor bolts, will be placed on about 14-foot centers. The hoist will be of the worm-gear type, with one central motor-driven driving unit operating the three worm-gear stem hoists. Semisteel liners for the 12 water passages will each be made in four sections, bolted together. Twelve 8-foot by 10-foot metal shutter gates will be provided for each tower, to be used for closing the water passages for repairs to the cylinder gates. They will be lowered by a movable hoist not shown on the drawing, and installation will consist in placing a gate in each bay of each tower underneath the floor, as shown on the drawings. The contractor shall haul, assemble, install, and paint the cylinder gates, water-passage liners, stems, guides, hoists, and accessories, ready for operation, complete as shown on the drawings or as directed by the contracting officer. The hoists shall be carefully installed, filled with lubricating oil, and tested for operation to insure that all parts move freely within each other and are in proper adjustment. Gate-stem guides shall be accurately installed and plumbed, for which purpose shims will be provided to insure that the stems move freely and are in proper alignment. After gates, stems, and hoists are installed, and before being put into service, all gates shall be raised and lowered several times to insure that all of the apparatus is functioning properly and to the satisfaction of the contracting officer. Rich concrete, free from cobbles and coarse stone, shall be thoroughly spaded around the water-passage liners, to secure proper adhesion and prevent leakage. Pressure grouting shall be used, if required by the contracting officer, to secure this result. Payment for pressure grouting, if required, will be made at the unit price bid in the schedule for pressure grouting in tunnels, adits, and shafts. Payment for installing the gates and hoists will be made at the unit price per pound bid in the schedule for installing cylinder gates and hoists in intake towers, which unit price shall include the cost of all work required in hauling, assembling, installing, painting, adjusting, and testing cylinder gates, hoists, stems, guides, water-passage liners, shutter gates, and accessories, in accordance with the provisions of this paragraph.

166. Needle valves.—All 72-inch needle valves, with their control mechanisms, and control, drain, and pressure piping, will be furnished by the Government under the provisions of paragraph 27. It is contemplated that forty (40) of these valves will be installed. The contractor shall assemble and install the needle valves with their control mechanisms, as shown on the drawings or as directed by the contracting officer. Special care shall be taken in handling and installing to avoid damage to the finished surfaces of the various parts, and to install and lubricate all control mechanisms so that all parts move freely within each other and are in proper position and adjustment. The finished surfaces of joints shall be smoothly coated with white lead, or gaskets inserted if specified, before being bolted together. The pistons shall be moved full stroke several times to insure freedom from binding, by means of water applied under not to exceed 15 pounds pressure per square inch through means provided in the control mechanism. Payment for assembling, installing, and painting these needle valves will be made at the unit price bid in the schedule for installing needle valves. Payment for installing all control, drain, and pressure piping for needle valves is provided for in paragraph 143.

167. Traveling cranes.—Fourteen traveling cranes will be furnished by the Government under the provisions of paragraph 27, for use for installation and maintenance of gates, hoists, and valves in the intake towers, upper and lower canyon wall outlets, and Stoney gate structures. The cranes in the four intake towers will be of 15-ton capacity, 36-foot span, designed for operation on a circular track, with hand-operated bridge and trolley travel and motor-operated rope-drum hoist. The four cranes in the upper and lower canyon wall outlets will be of 20-ton capacity, 36.5-foot span, with motor-operated bridge travel, hand-operated trolley travel, and motor-operated hoist. The cranes in the two tunnel plug outlets will be similar to those in the canyon wall outlets except that the span will be 22 feet. The cranes in the Stoney gate structures will be of 5-ton capacity, 12-foot span, with hand-operated bridge and trolley travel and motor-operated rope-drum hoist. The crane capacities and spans stated herein are approximate and may be revised. All cranes will be shipped in sections convenient for loading on freight cars. The contractor shall haul, assemble, paint, and install the cranes on the runway rails, ready for operation, as shown on the drawings or as directed by the contracting officer, except that all electric wiring for crane operation will be furnished and installed by the Government, and the cost of all work required to be performed by the contractor, described in this paragraph, shall be included in the unit price per pound bid in the schedule for installing traveling cranes. All cranes will be delivered at the site of the work in time for installation and use by the contractor for placing gates and valves.

ELECTRICAL INSTALLATIONS

168. Electrical equipment, general.—Electrical conduit and fittings, conduit boxes, distribution cabinets where embedded in concrete, anchor bolts, and any other materials entering into the installation, but not in the nature of construction equipment and supplies, will be furnished by the Government under the provisions of paragraph 27. The contractor shall install all electrical equipment, as directed by the contracting officer, in a workmanlike manner and in accordance with the current National Electric Code rules. In case of a conflict between the National Electric Code and these specifications, the specifications shall govern. Payment for installing electrical equipment will be made to the contractor at the unit prices bid for the various items in the schedule, which unit prices shall include the cost of unloading, storing, handling, installing, painting, and maintaining in position and good condition until final acceptance by the Government. The contractor shall provide all necessary tools and equipment for performing the work. The Government will install all wiring, lighting fixtures, ball globes, lamp globes, transformers, and switch boards, and will make all electrical connections.

169. Resistance thermometers.—Resistance thermometers for measuring the temperatures in the concrete of the dam shall be installed by the contractor, as directed by the contracting officer. These thermometers will consist of a resistance coil inclosed and sealed into a section of standard pipe and will weigh not to exceed ten pounds each. These will be furnished by the

Government with two leads, a splicing chamber for attaching leads, and sealing compound for making the splice waterproof. The cable, which shall be attached by the contractor, will be three-conductor, No. 16, A. W. G., with suitable protective covering to minimize mechanical injury while placing and to keep out water and moisture. These cables will be of sufficient length to reach from each thermometer to the downstream face of the dam, at which point the cable will enter a junction box and thence be connected by a conduit system to a central point, or points. Thermometers will be located in groups as a rule, each group being placed at a common elevation, as directed by the contracting officer. Each cable shall be placed in a shallow groove, which may be made as soon as the concrete has taken its initial set, with two inches minimum distance between grooves. After the thermometers, leads, and junction boxes are in place they shall be covered with concrete. Payment will be made at the unit price per lineal foot of cable bid therefor in the schedule for installing electrical cable for resistance thermometers embedded in concrete, which unit price bid shall include the cost of the complete installation of the cable, as described in this paragraph, and the installation of thermometers and junction boxes. Any conduit installed by direction of the contracting officer in connection with the installation of the thermometer will be paid for separately at the unit prices bid for installation of electric conduits.

170. Electrical conduits.—Electrical conduits and conduit fittings will be furnished by the Government, as provided in paragraph 27. The contractor shall install all electrical conduits and conduit fittings in the various structures, as shown on the drawings or as directed by the contracting officer. Conduits or fittings embedded in concrete shall be securely held in position while concrete is being placed. All exposed conduits shall be rigidly supported in place, and the runs shall be straight and parallel with each other and with the center lines of the galleries, shafts, or rooms in which they are located, unless otherwise indicated on the drawings or directed by the contracting officer, and all bends shall be of standard radii and shall be free from kinks, indentations, or flattened surfaces. After exposed conduits are placed in permanent position and fastened, they shall be given one coat of paint, neatly applied. Burrs and sharp corners on the end of each piece of steel conduit shall be removed with a taper reamer. At outlet boxes and fittings, lock nuts and bushings shall be used to protect the wires from abrasion. Provision shall be made for draining conduit, as directed by the contracting officer. The joints in fiber conduit shall be painted with hot asphaltum, then wrapped with burlap dipped in the asphaltum, and the wrapping again painted with asphaltum. All wires and cables will be installed by the Government. All other work described in this paragraph will be paid for at the unit prices bid in the schedule for placing the different sizes of steel and fiber conduit and fittings.

WINDOWS, DOORS, AND OTHER MISCELLANEOUS ITEMS

171. Metal-sash windows and partitions.—The contractor shall install metal-sash windows and partitions in the various buildings and structures in connection with the dam and power house where directed by the contracting officer. All metal-sash windows and partitions, together with hardware, glass, clips, paint, and putty, will be furnished by the Government under the provisions of paragraph 27. The contractor shall install and grout the windows and partitions in grooves, complete in accordance with the drawings, in a workmanlike manner and to the satisfaction of the contracting officer. Metal-sash windows and partitions will be measured for payment to the neat lines of the openings before the sash is placed. Payment for installing metal-sash windows and partitions will be made at the unit price per square foot bid therefor in the schedule, which price shall include the cost of unloading, hauling, storing, handling, installing, glazing, and painting as required.

172. Metal-sash window operators.—The contractor shall install hand or motor-driven window operators in various buildings and structures in connection with the dam and power house, where directed by the contracting officer. All window operators, together with motors, gears, hardware, shafts, paint, and other necessary accessories, will be furnished by the Government under the provisions of paragraph 27. The contractor shall install the window operators, complete in accordance with the drawings, in a workmanlike manner and to the satisfaction of the contracting officer. If the window operators are electrically operated, the Government will install the necessary electrical wiring and connections. Payment for installing metal-sash window operators will be made at the unit price per pound bid therefor in the schedule, which price shall include the cost of unloading, hauling, storing, handling, and erecting and painting the window operators as required.

173. Metal swing doors.—The contractor shall install metal swing doors in various buildings and structures in connection with the dam and power house, where directed by the contracting officer. All metal swing doors, together with metal casings, hardware, paint, and other necessary accessories, will be furnished by the Government under the provisions of paragraph 27. The contractor shall install the doors, complete in accordance with the drawings, in a workmanlike manner and to the satisfaction of the contracting officer. Metal swing doors will be measured for payment to the neat lines of the openings before the doors are placed. Payment for installing metal swing doors will be made at the unit price per square foot bid therefor in the schedule, which price shall include the cost of unloading, hauling, storing, handling, installing, and painting the doors as required.

174. Metal rolling doors.—The contractor shall install metal rolling doors in the various buildings and structures in connection with the dam and power house, where directed by the contracting officer. All metal rolling doors will be furnished to the contractor by the Government under the provisions of paragraph 27. The contractor shall install the doors, complete with operating mechanisms, in a workmanlike manner and to the satisfaction of the contracting officer. If the doors are electrically operated, the Government will install the necessary electrical wiring and connections. Metal rolling doors will be measured for payment to the neat lines of the openings before the doors are placed. Payment for installing metal rolling doors will be made at the unit price per square foot bid therefor in the schedule, which price shall include the cost of unloading, hauling, storing, handling, installing, and painting the doors as required.

175. Wooden doors.—The contractor shall install all wooden doors in the various buildings and structures in connection with the dam and power house, as directed by the contracting officer. All wooden doors will be furnished to the contractor by the Government under the provisions of paragraph 27. The contractor shall properly trim, fit, and install the doors, complete with casings and hardware, in a workmanlike manner and to the satisfaction of the contracting officer. After installation the doors shall be given one priming coat and two additional coats of paint to be furnished by the Government under the provisions of paragraph 27. All painting shall be done in a workmanlike manner and each coat shall be allowed to dry before the succeeding coat is applied. Payment for installing wooden doors will be made at the unit price per square foot bid therefor in the schedule, which unit price shall include unloading, hauling, handling, storing, installing, and painting as required. Wooden doors will be measued for payment to the neat lines of the openings before the doors are placed.

176. Hollow tile.—The contractor shall install hollow tile walls and ceilings in passageways in the dam and in other structures, as shown on the drawings and as directed by the contracting officer. It is contemplated particularly that the galleries from the power house to the foot of the elevator shafts in the dam will be thus lined. All hollow tile shall be installed as shown on the drawings or as directed by the contracting officer. All tile shall be soaked in clean water before setting. Tile shall be set to true surfaces and with uniform joints of not more than 3/16 inch in width. Buttered joints will not be allowed. Before mortar is set, joints shall be raked out 1/8 inch deep to allow for grouting. Mortar for setting tile shall be in the proportion of one part Portland cement, one part lime putty or plastic fire clay, and six parts clean sharp sand, by volume. Joints shall be grouted with equal parts of white Portland cement and fine sifted clean sand or marble dust, mixed with water to consistency of thick cream and colored as directed by the contracting officer. Grout shall be forced or brushed into joints and brought to level of face of tile. When directed by the contracting officer, the entire surface shall be given a thorough cleaning with muriatic acid of a strength not to affect cement grouting, and the surface shall then be rinsed with clean water. To insure perfect joints all cutting and fitting and pipe chases shall be cut on a tile cutting machine. No rough cuts will be allowed. The contractor shall provide all necessary tools for installing the clay tile and shall protect it from injury until final acceptance by the contracting officer. The hollow clay tile, lime, putty or plastic fire clay, and white Portland cement will be furnished by the Government under the provisions of paragraph 27. The muriatic acid shall be furnished by the contractor. The contractor shall use care in handling the tile to avoid breakage and will be charged for all tile in excess of two per cent (2%) of the total amount delivered to the contractor that is damaged in handling to such an extent that, in the judgment of the contracting officer, it is unfit for use. The tile will be measured for payment in place and the area determined by measurement of the inside face only. Payment for placing hollow clay tile will be made at the unit price per square yard bid therefor in the schedule, which unit price shall include the cost of unloading, handling, hauling, and storing materials furnished by the Government, furnishing materials required to be furnished by the contractor, and placing the tile as provided in this paragraph.

177. Ceramic-tile walls and floors.—The contractor shall install ceramic-tile walls and floors in rooms in the various buildings, where directed by the contracting officer. All ceramic tile and cement will be furnished to the contractor by the Government, as provided in paragraph 27. Sand and water shall be furnished by the contractor. The contractor shall use care in handling the tile to avoid breakage and will be charged for all tile in excess of one per cent (1%) of the total amount delivered to the contractor that is damaged in handling to such an extent that, in the judgment of the contracting officer, it is unfit for use. The floor tile will be hexagonal in shape and of 1 inch standard size, and wall tile will be 6 inches by 3 inches in size, although special sizes and shapes may be used for corners and caps. The contractor shall install the tile in walls and floors in a workmanlike manner, in accordance with the manufacturer's specifications and to the satisfaction of the contracting officer. The tile will be measured for payment in place and the area determined by the measurement of the exposed area only. Payment for placing ceramic-tile walls and floors will be made at the unit price per square yard bid therefor in the schedule, which unit price shall include the cost of unloading, hauling, handling, and storing the tile and cement, furnishing sand and water, the preparation of the necessary mortar bed to bring the finished floor to the proper elevation, and the necessary scratch coats for wall tiling, cutting and drilling the tile if required, and placing the tile, as provided in this paragraph.

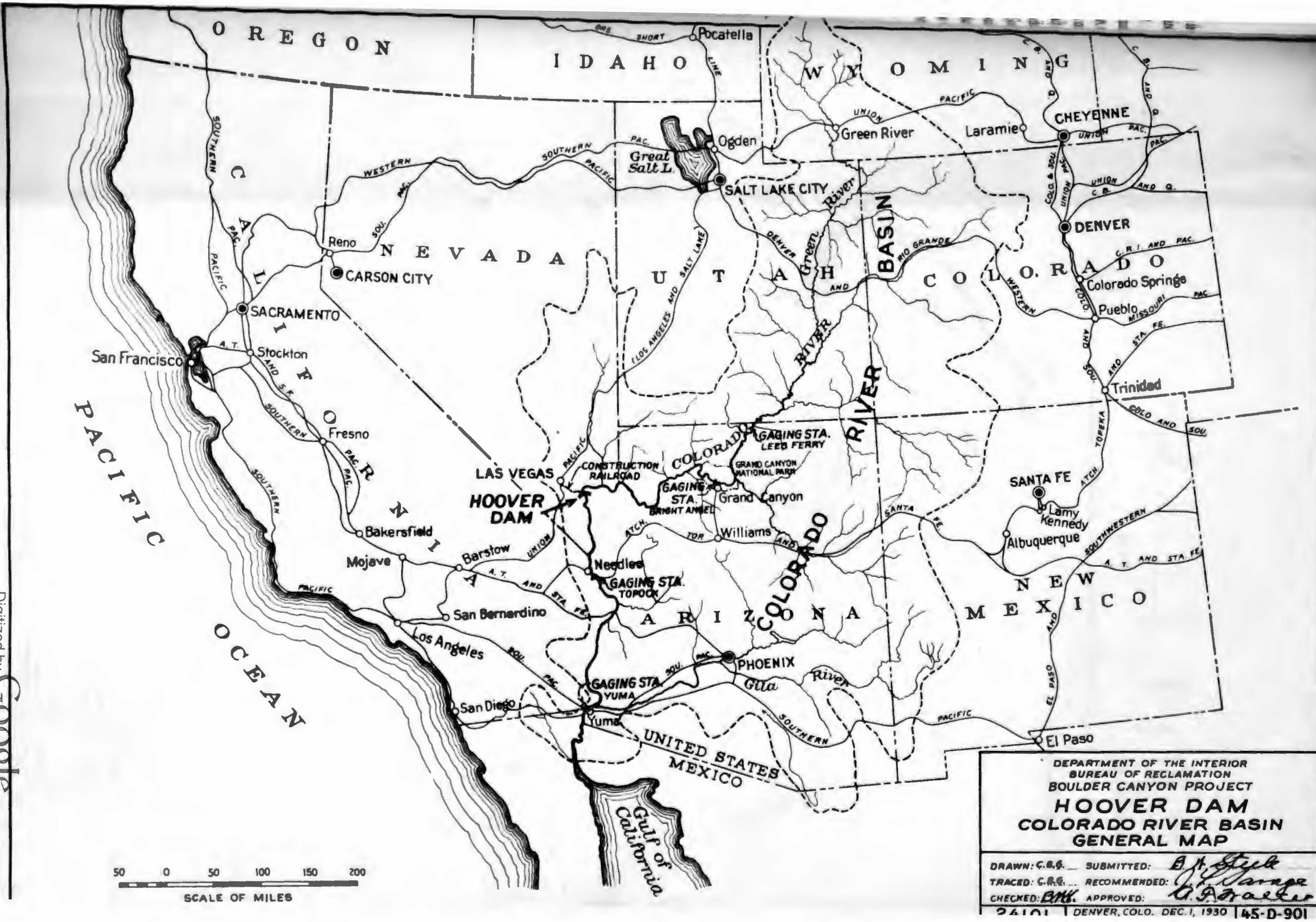
178. Plumbing and hardware.—The contractor shall install all plumbing fixtures and hardware accessories including lavatories, sinks, closets, shower baths, urinals, hot water heaters, hot water storage tanks, and drinking fountains and other plumbing fixtures in the various buildings and structures in connection with the dam and power plant. All plumbing fixtures and hardware, as shown on the drawings or as directed by the contracting officer, will be furnished by the Government under the provisions of paragraph 27 and will be of standard commercial types. The contractor shall install this apparatus in a workmanlike manner satisfactory to the contracting officer. The Government will install the necessary electrical wiring and connections for electric water heaters. At the completion of the work the water supply systems to the plumbing fixtures shall be tested to a hydrostatic pressure of 100 pounds per square inch. All defects in the work disclosed by the tests or prior to acceptance by the Government shall be corrected or the work replaced by and at the expense of the contractor and to the satisfaction of the contracting officer. The test pump and gauge for testing shall be provided by the contractor. Except as otherwise provided in this paragraph, payment for installing plumbing fixtures and hardware accessories will be made at the unit price per pound bid in the schedule for installing plumbing fixtures and hardware accessories, which unit price shall include the cost of unloading, hauling, handling, storing, and the complete installation of the plumbing fixtures and hardware accessories. The installation of all pipe and fittings required in connection therewith will be paid for separately at the unit price bid in the schedule for installing standard steel and cast-iron pipe, fittings, and valves.

179. Steel partitions.—The contractor shall install steel partitions in toilets, lavatories, and elsewhere in the various structures in connection with the dam and power house, as directed by the contracting officer. These partitions will be furnished by the Government, as provided in paragraph 27, and will be baked enamel steel or similar construction, and will be furnished by the Government in proper sizes for the required installations. The contractor shall install these partitions in a workmanlike manner in accordance with the manufacturer's standards and to the satisfaction of the contracting officer and shall carefully protect them against cracking or scratching of the enamel or other injury until final acceptance by the Government. Payment for installing steel partitions will be made at the unit price per pound bid therefor in the schedule, which unit price shall include the cost of unloading, hauling, storing, handling, and the complete installation of the steel partitions, as provided in this paragraph.

180. Sheet metal work.—Sheet metal work consisting of gutters, downspouts, louvres, and other sheet metal accessories in the various structures in connection with the dam and power house, and metal cornices, protected metal, or similar corrugated covering, for the temporary end walls in the power house will be furnished by the Government, as provided in paragraph 27, and shall be installed by the contractor. The contractor shall provide all necessary tools and equipment and shall install all such metal work in a workmanlike manner and to the satisfaction of the contracting officer. Payment for installing sheet metal work will be made at the unit price per pound bid therefor in the schedule, which unit price shall include the cost of unloading, storing hauling, handling, painting where required, and the complete installation of the sheet metal work, as provided in this paragraph.

181. Temporary end walls in power house.—The contractor may be required to install temporary end walls in the power house to isolate and weatherproof portions of the building in which machinery is to be installed and operated prior to the completion of the entire structure. These walls will consist of structural steel members covered with galvanized or protective covered corrugated metal. The structural steel members and metal covering will be furnished to the contractor by the Government, as provided in paragraph 27. The walls shall be installed as directed by the contracting officer. Payment for installing the structural steel in end walls will be made at the unit price bid in the schedule for installing structural steel, except bridges to intake towers. Payment for installing the covering of the end wall will be made at the unit price bid in the schedule for installing sheet-metal work. The unit prices bid in the schedule shall include the cost of unloading, storing, hauling, handling, painting where required, and the complete installation of the temporary walls, as directed by the contracting officer.

182. Miscellaneous items of metal work.—Installing and painting hatchways, manholes, oil tanks, metal ladders, ladder rungs in concrete, grating, stair nosings, anchor bars, rods and bolts set in concrete for installation of permanent equipment, elevator rail inserts and ladders, drain boxes and covers, brackets, and other miscellaneous metal work not specifically included in other items of the schedule, for which installation and payment has not been specifically provided for elsewhere in these specifications and which are to be furnished by the Government and become a part of the completed work, will be paid for at the unit price per pound bid in the schedule for "Installing miscellaneous items of metal work," which unit price shall include the cost of unloading, storing, hauling, handling, painting where required, and the complete installation of this metal work, as shown on the drawings or as directed by the contracting officer.



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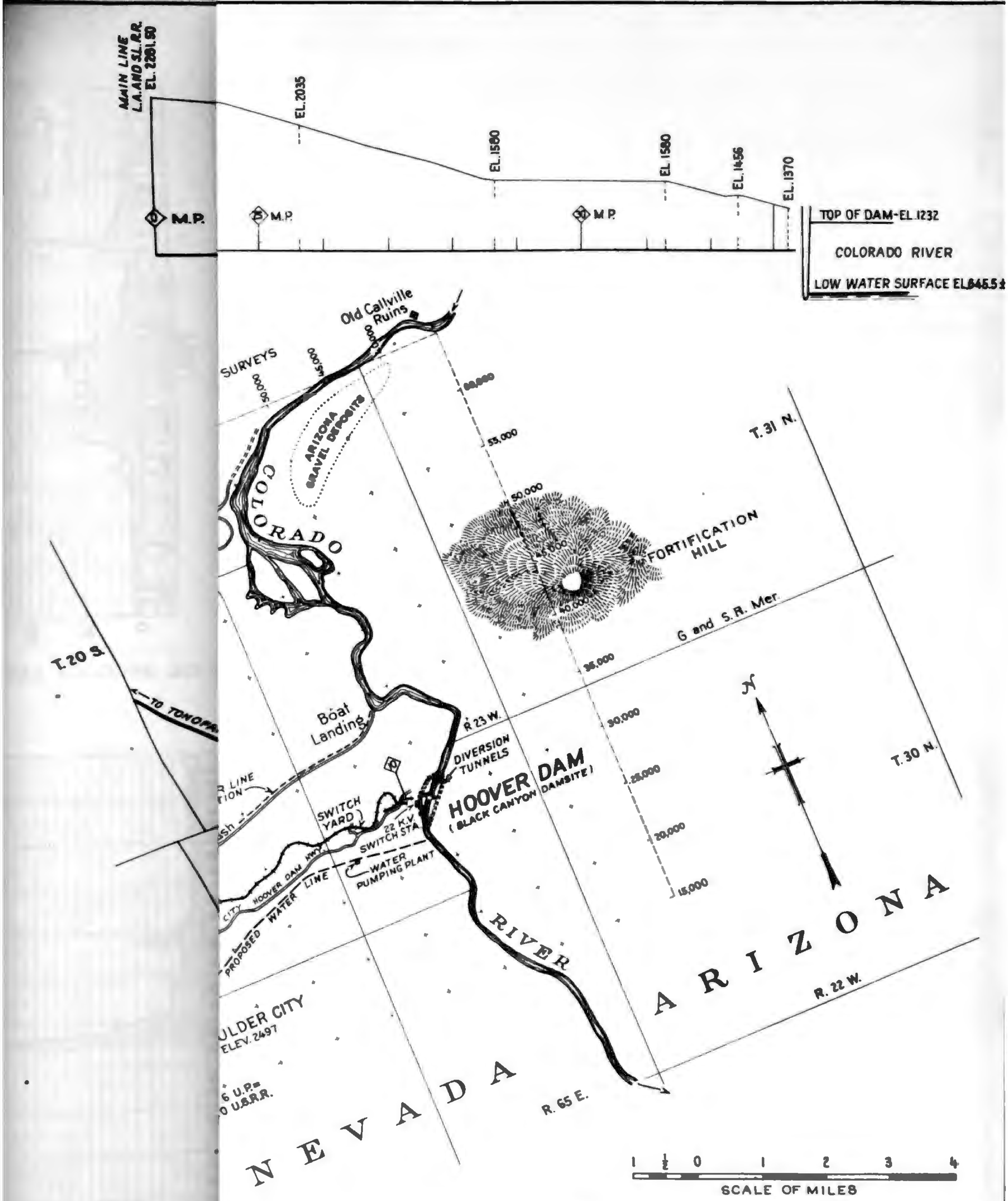


NOTE

Railroad and Highway to be Constructed from Summit to Damsite by U.S. Government.

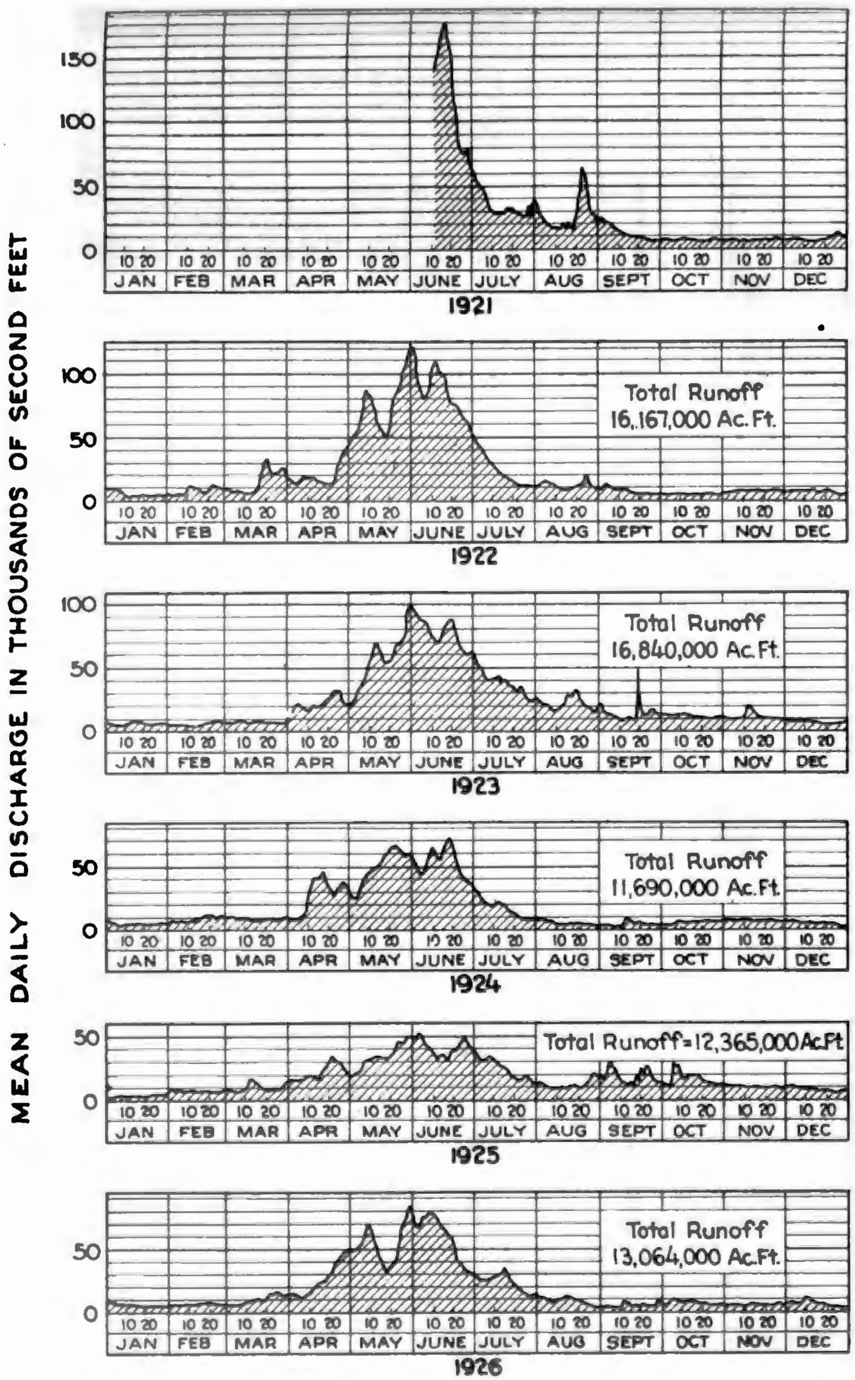
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
BOULDER CANYON PROJECT

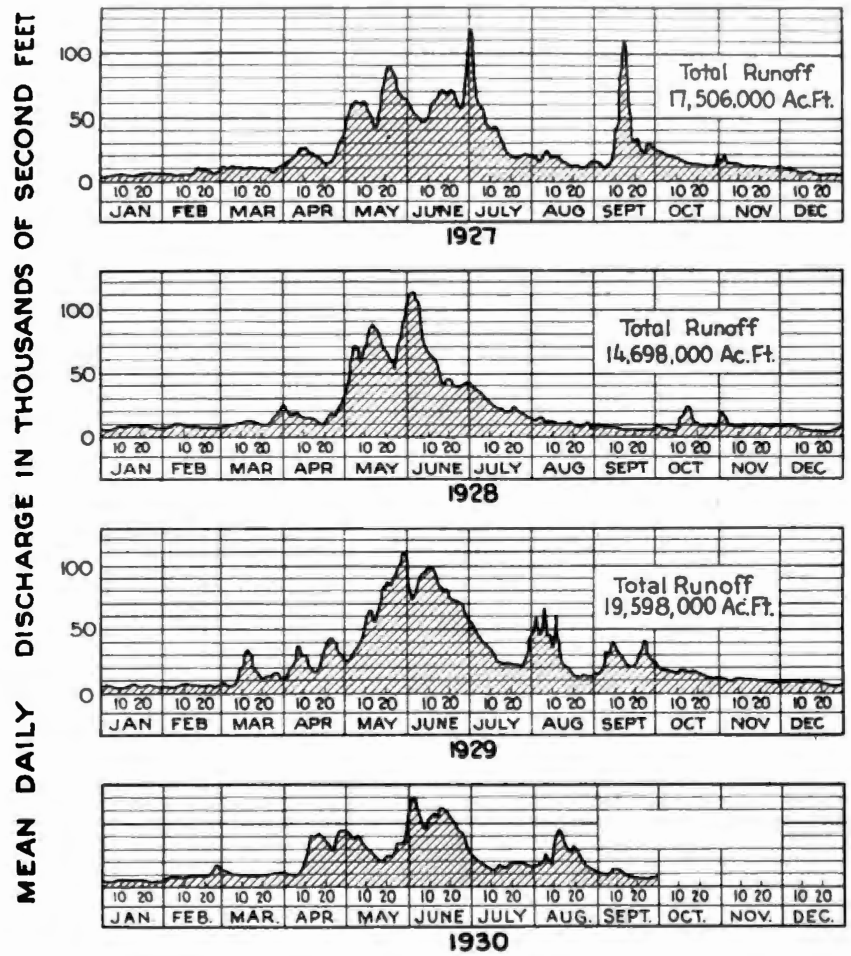
HOOVER DAM

DAM AND APPURTENANT WORKS LOCATION MAP

DRAWN: C.R.	SUBMITTED: B. W. Steele
TRACED: C.B.G.	RECOMMENDED: J. L. Savage
CHECKED: W.E.B.	APPROVED: R. F. Walter

24102	DENVER, COLORADO, DEC. 1, 1930	45-D-902





NOTES

Gaging Station located at Lees Ferry about 350 Miles upstream from Black Canyon Damsite.
Mean yearly Runoff, 1922 to 1929 incl. 15,241,000 Acre Feet.

DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
BOULDER CANYON PROJECT

HOOVER DAM

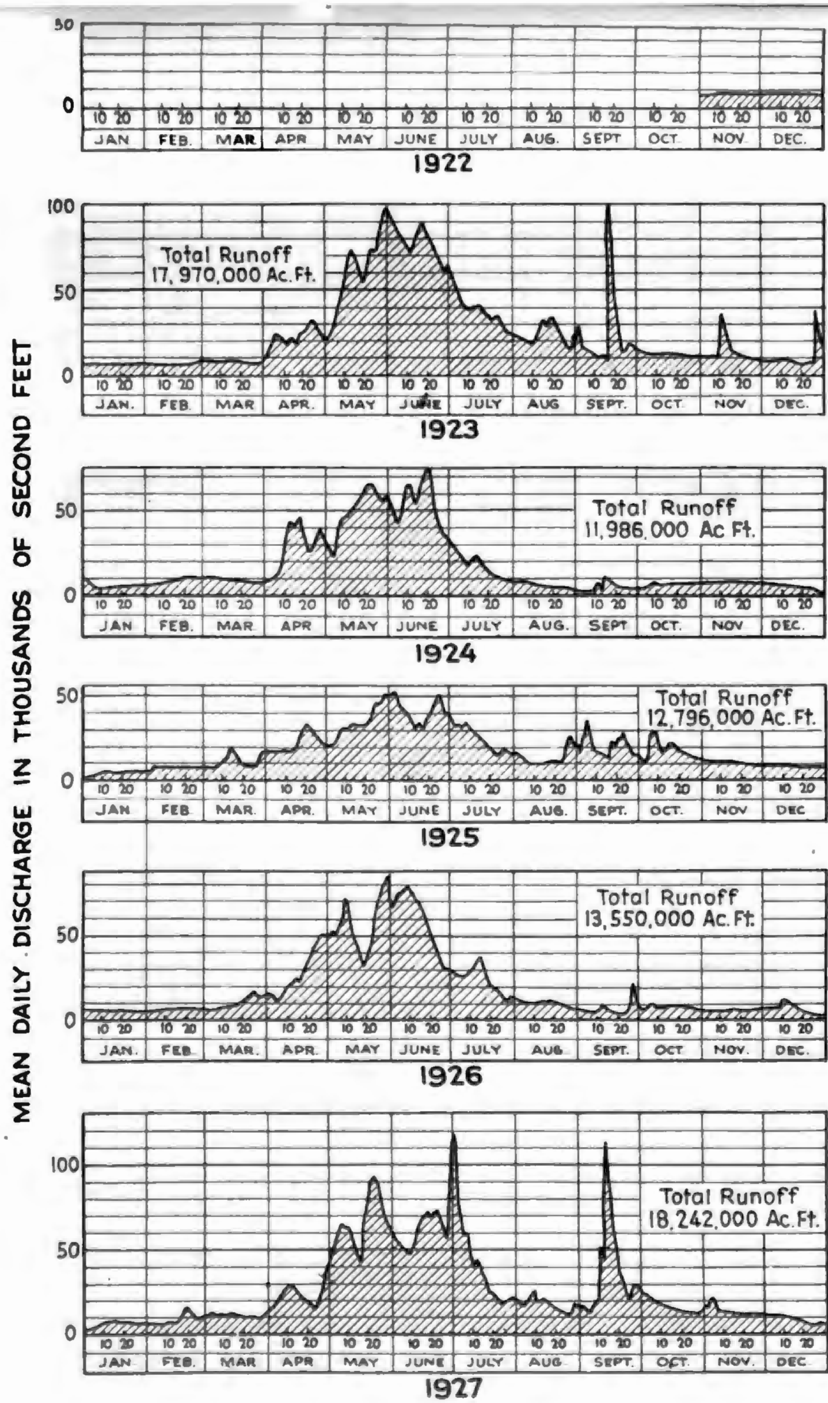
HYDROGRAPH OF THE COLORADO RIVER
LEE'S FERRY

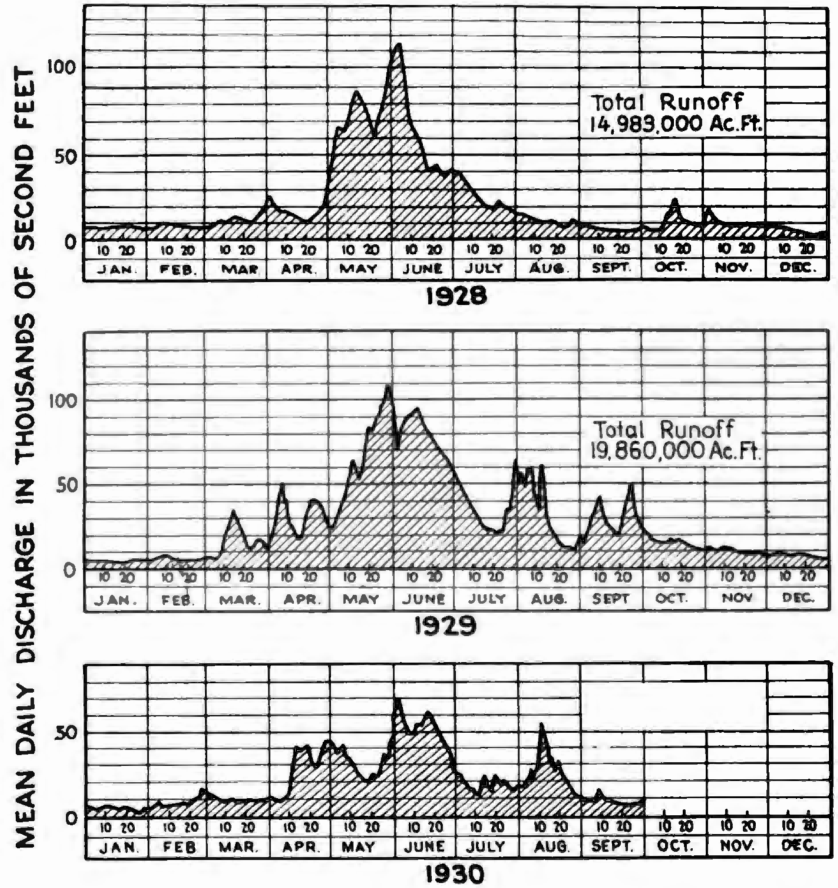
DRAWN: O.L.R. SUBMITTED: B. H. [signature]
TRACED: P.M.W. RECOMMENDED: J. L. Savage
CHECKED: E.R.S. APPROVED: R. F. Walter

24103 | DENVER, COLO. DEC. 1, 1930 | 45-D-903

...ICATIONS NO. 519

DRAWING NO.





NOTES

Gaging Station located above confluence of Bright Angel Creek and Colorado River about 275 miles upstream from Black Canyon Damsite.
Mean yearly runoff 1923 to 1929 incl. 15,627,000 A.F.

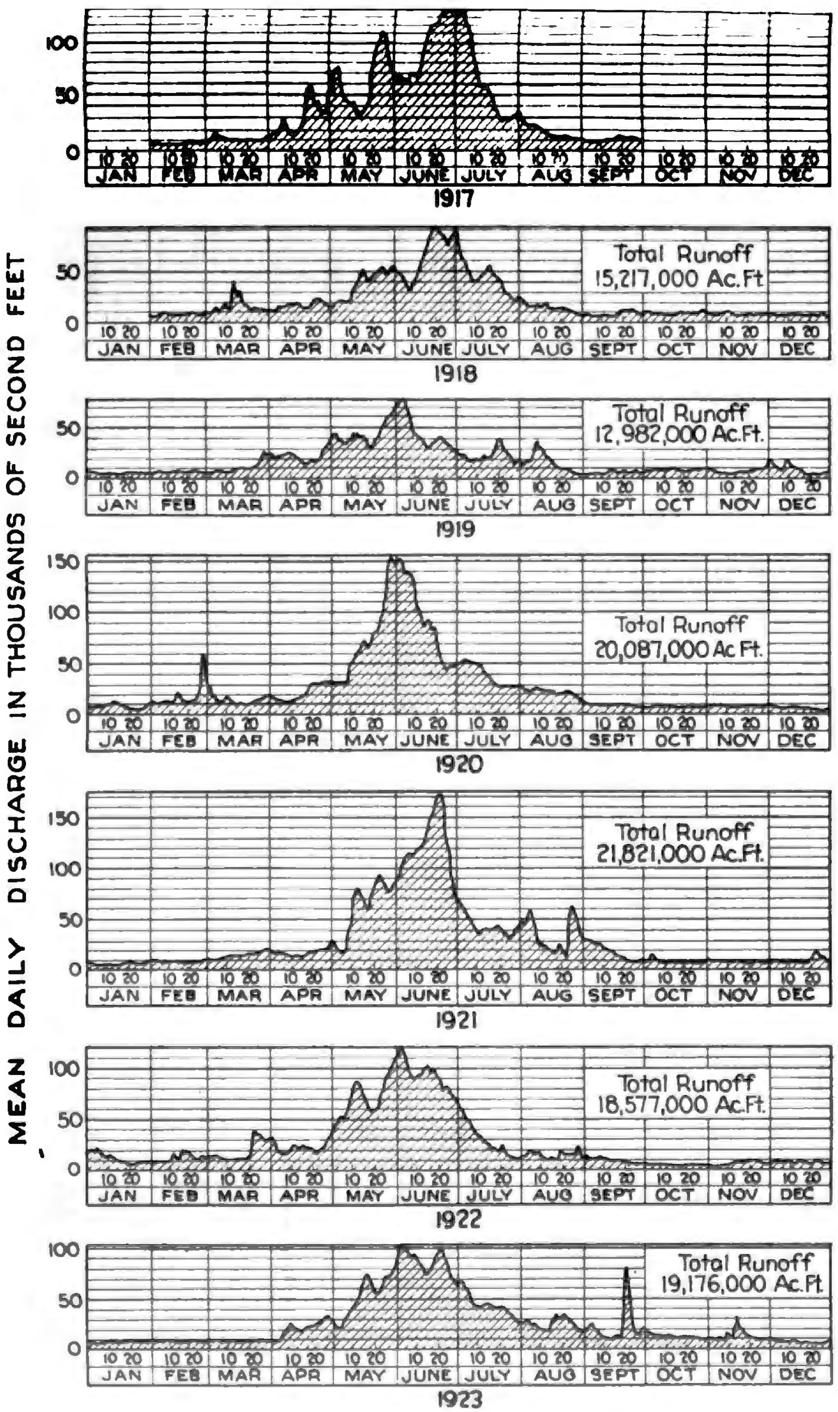
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
BOULDER CANYON PROJECT

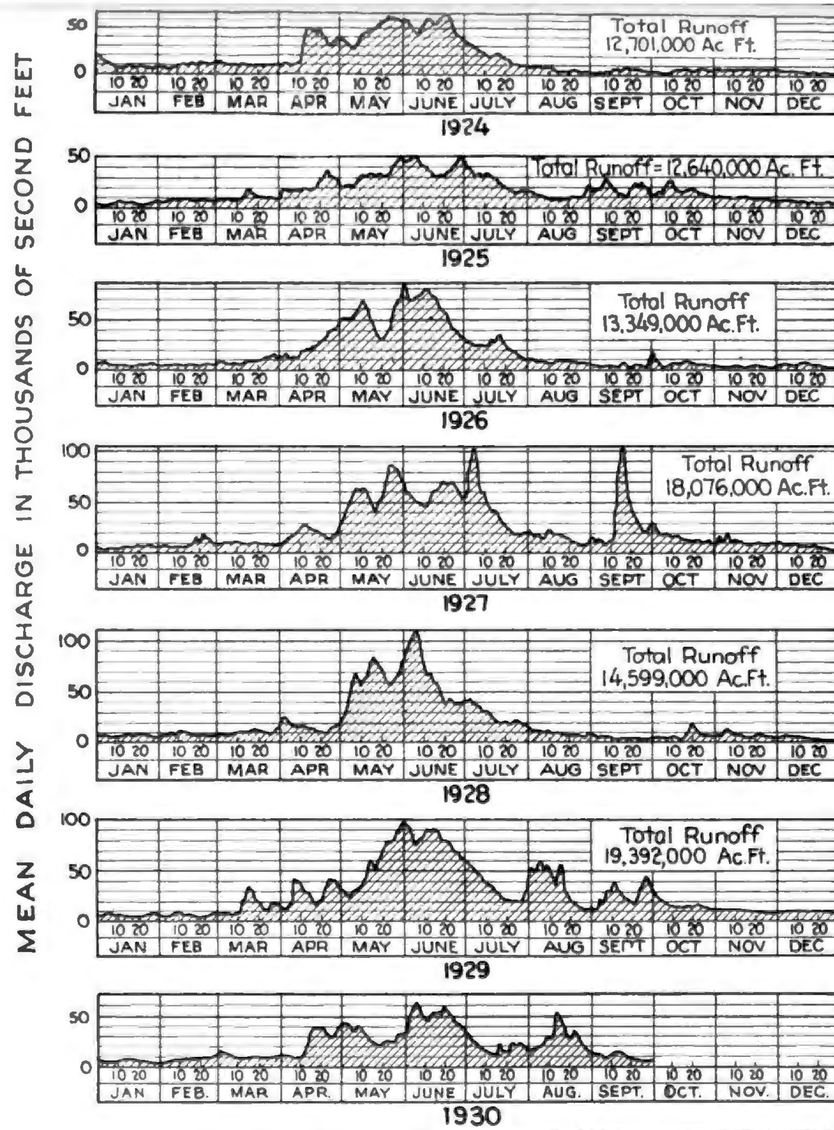
HOOVER DAM

HYDROGRAPH OF THE COLORADO RIVER BRIGHT ANGEL CREEK

DRAWN: O.L.R. SUBMITTED: B.W. Steele
TRACED: R.McC. RECOMMENDED: J.L. Savage
CHECKED: E.R.S. APPROVED: R.F. Walter

24104 | DENVER, COLO. DEC. 1, 1930 | 45-D-904





NOTES

Gaging Station located near Topock, Ariz. about 110 Miles downstream from Black Canyon Damsite.

Mean yearly runoff, 1918 to 1929 inclusive 16,551,000 Acre Feet.

DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
BOULDER CANYON PROJECT

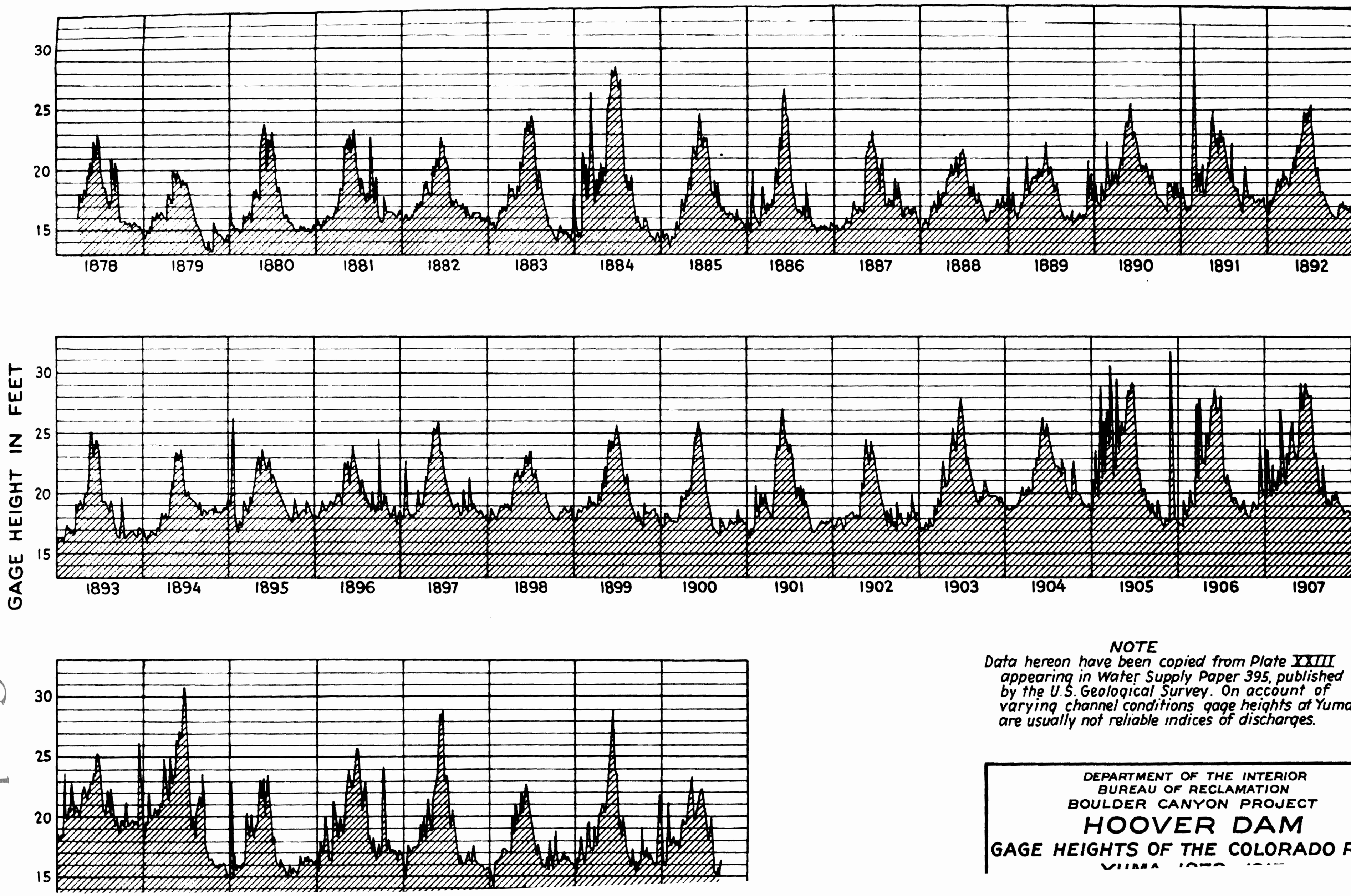
HOOVER DAM
HYDROGRAPH OF THE COLORADO RIVER TOPOCK

DRAWN: O.L.R.	SUBMITTED: B. W. Steele
TRACED: P.M.W.	RECOMMENDED: J. L. Savage
CHECKED: E.R.S.	APPROVED: R. F. Walter

24105 | DENVER, COLO. DEC. 1, 1930 | 45-D-905

SPECIFICATIONS NO. 519

DRAWING NO. 5



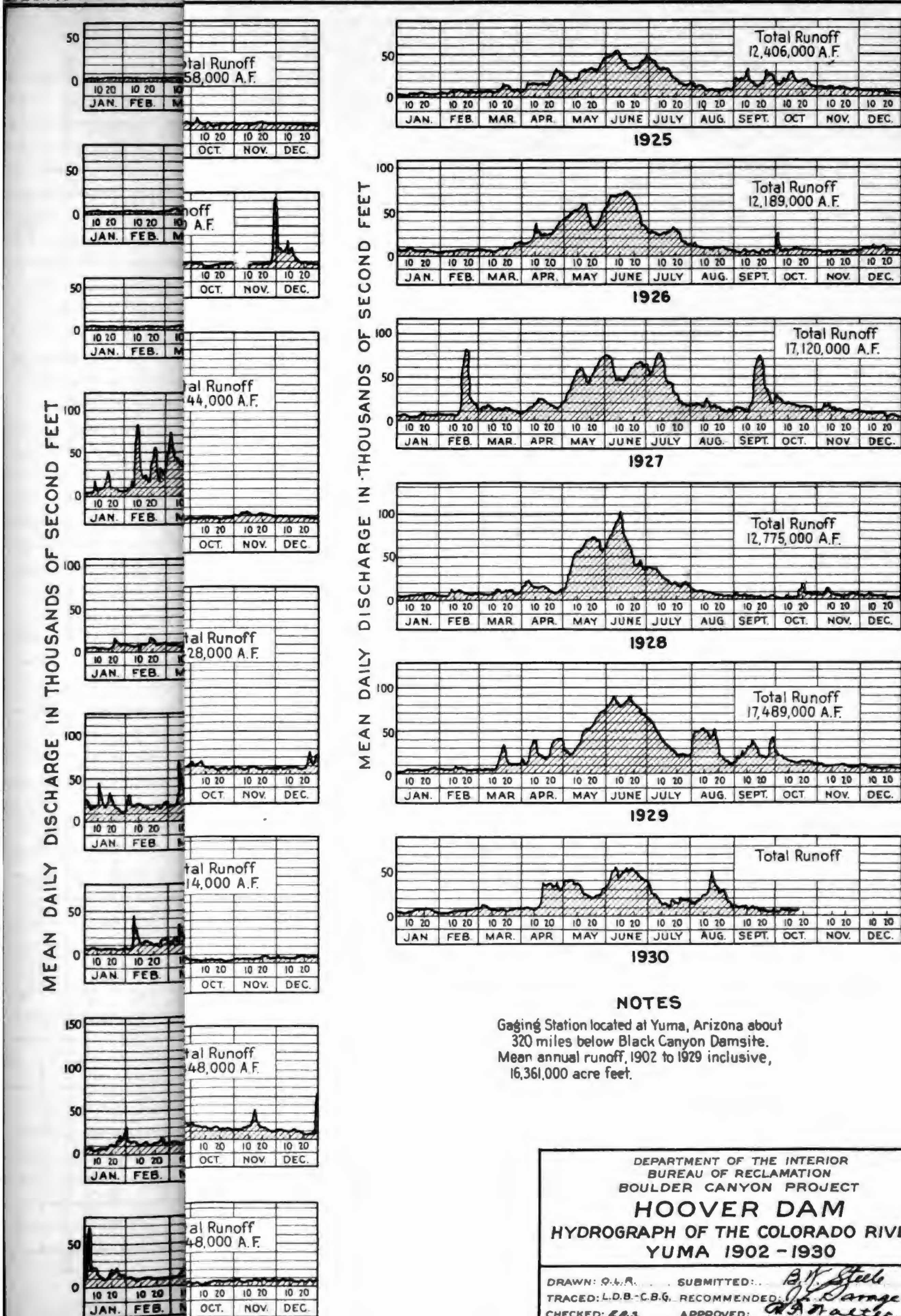
NOTE

Data hereon have been copied from Plate XXIII appearing in Water Supply Paper 395, published by the U.S. Geological Survey. On account of varying channel conditions gage heights at Yuma are usually not reliable indices of discharges.

DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
BOULDER CANYON PROJECT

HOOVER DAM

GAGE HEIGHTS OF THE COLORADO RIVER



NOTES

Gaging Station located at Yuma, Arizona about 320 miles below Black Canyon Damsite.
Mean annual runoff, 1902 to 1929 inclusive, 16,361,000 acre feet.

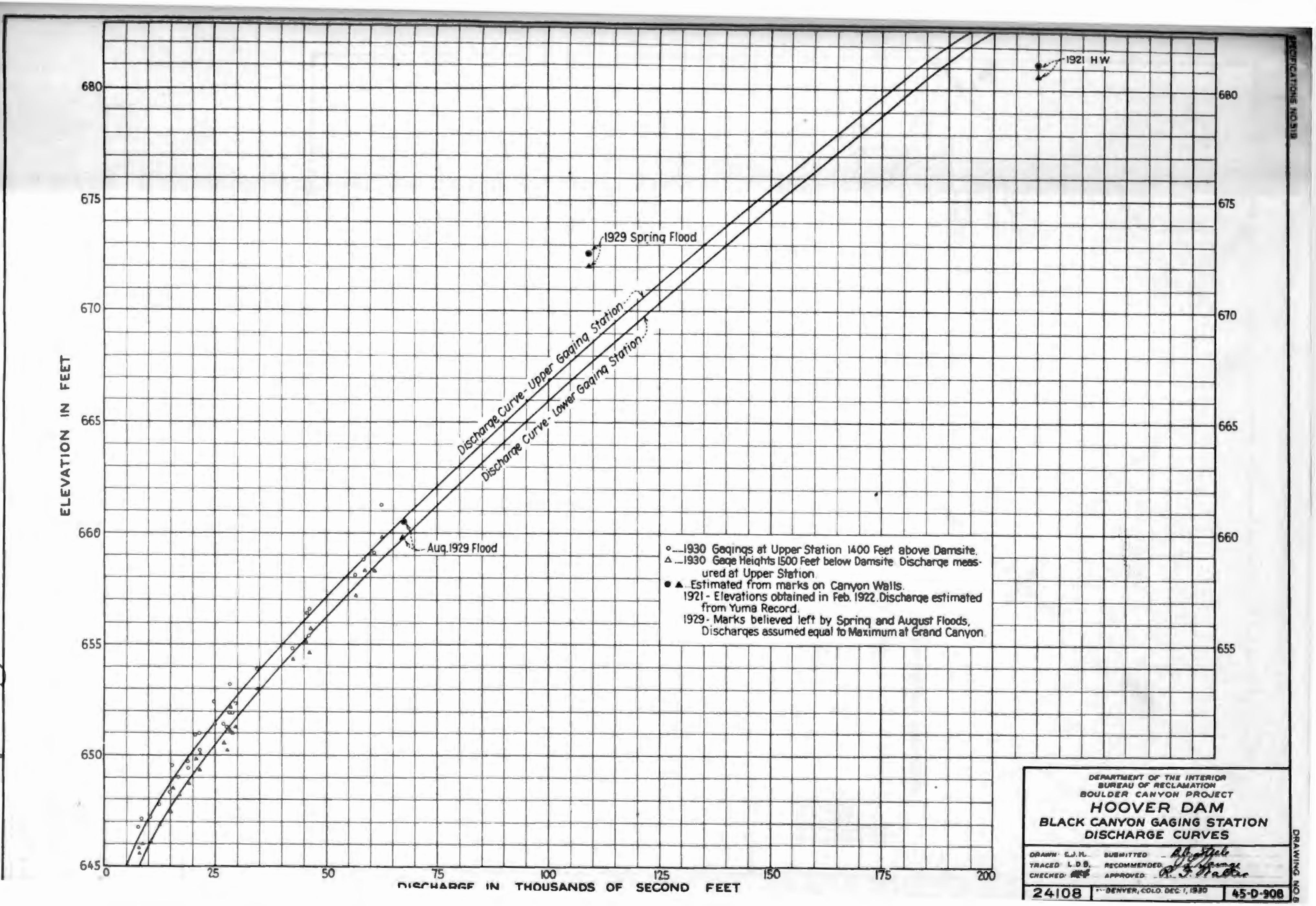
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
BOULDER CANYON PROJECT

HOOVER DAM

HYDROGRAPH OF THE COLORADO RIVER YUMA 1902 - 1930

DRAWN: G.L.R. SUBMITTED: B.W. Steele
TRACED: L.D.B.-C.B.G. RECOMMENDED: J.L. Savage
CHECKED: E.A.S. APPROVED: R.F. Walter

24107	DENVER, COLO. DEC. 1, 1930	45-D-907



DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
BOULDER CANYON PROJECT

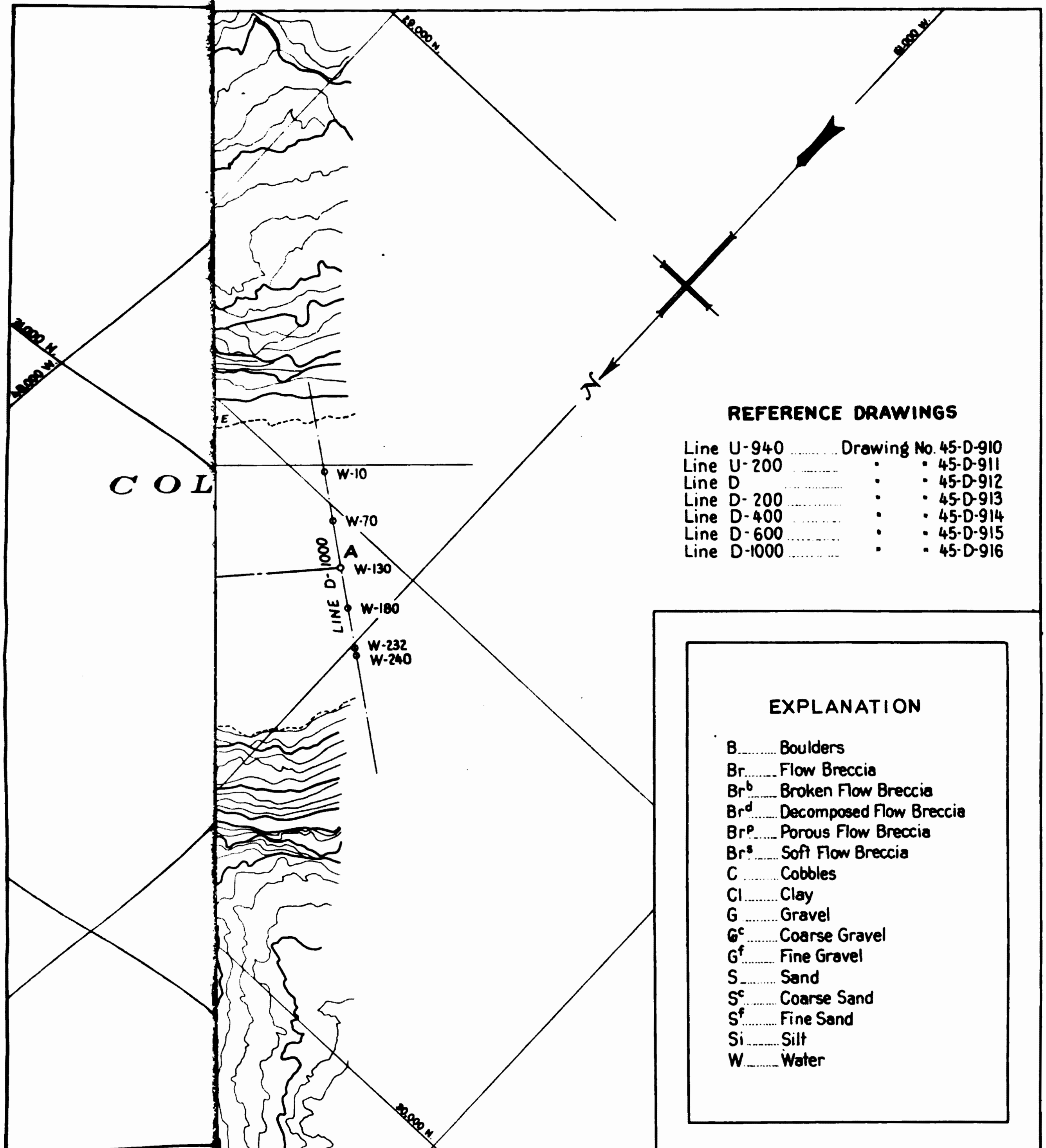
HOOVER DAM

BLACK CANYON GAGING STATION DISCHARGE CURVES

DRAWN: E.J.H. SUBMITTED: [signature]
TRACED: L.D.B. RECOMMENDED: [signature]
CHECKED: [initials] APPROVED: [signature]

24108 DENVER, COLO. DEC. 1, 1930 45-D-908

DRAWING NO.

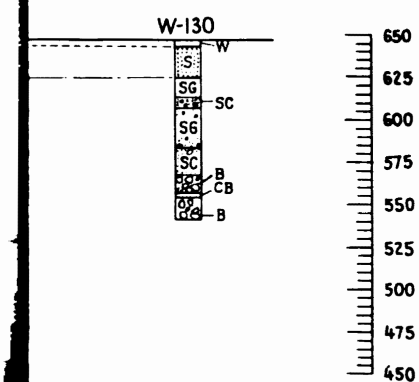


REFERENCE DRAWINGS

Line U-940	Drawing No. 45-D-910
Line U-200	" 45-D-911
Line D	" 45-D-912
Line D-200	" 45-D-913
Line D-400	" 45-D-914
Line D-600	" 45-D-915
Line D-1000	" 45-D-916

EXPLANATION

B	Boulders
Br	Flow Breccia
Br^b	Broken Flow Breccia
Br^d	Decomposed Flow Breccia
Br^p	Porous Flow Breccia
Br^s	Soft Flow Breccia
C	Cobbles
Cl	Clay
G	Gravel
G^c	Coarse Gravel
G^f	Fine Gravel
S	Sand
S^c	Coarse Sand
S^f	Fine Sand
Si	Silt
W	Water



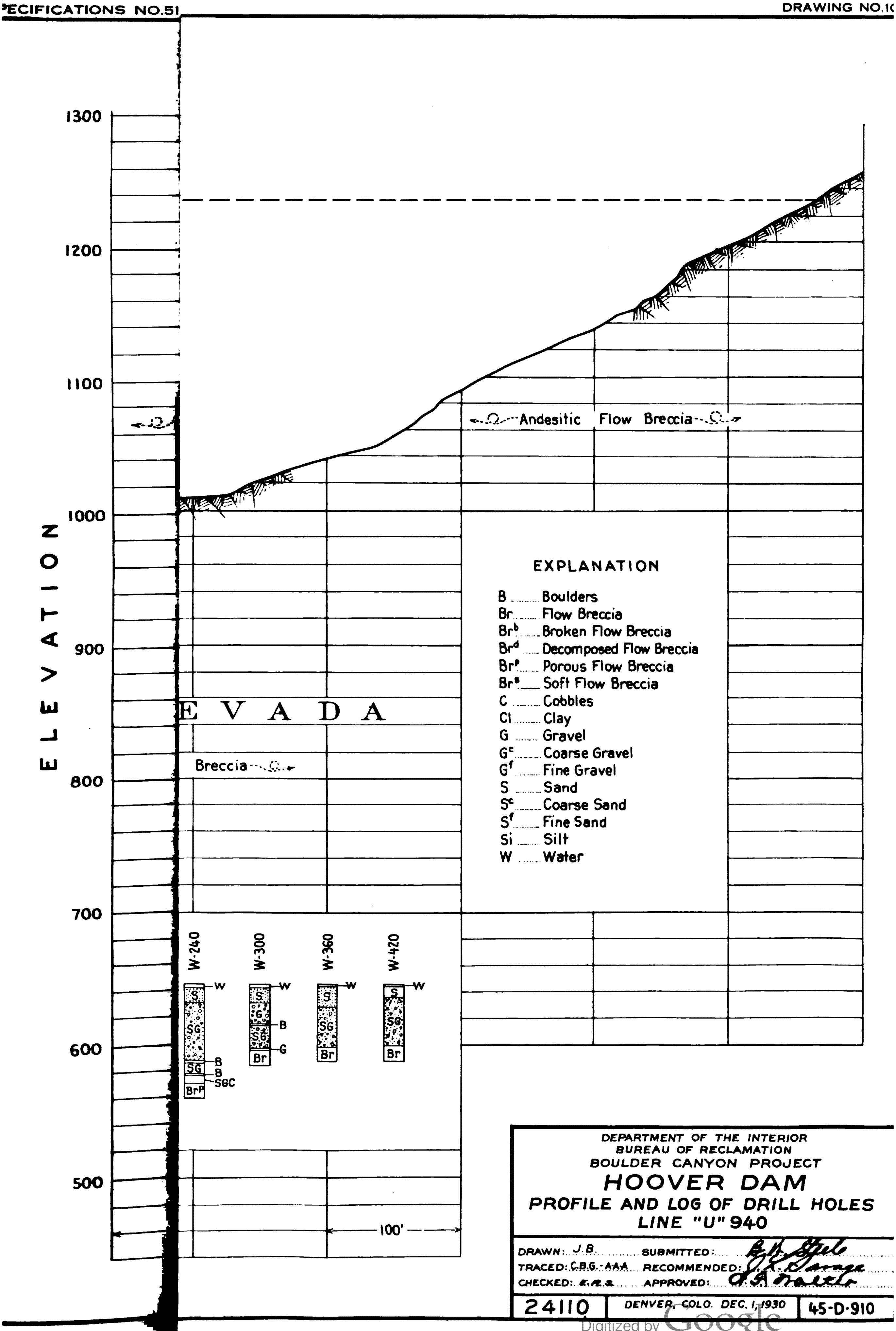
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
BOULDER CANYON PROJECT

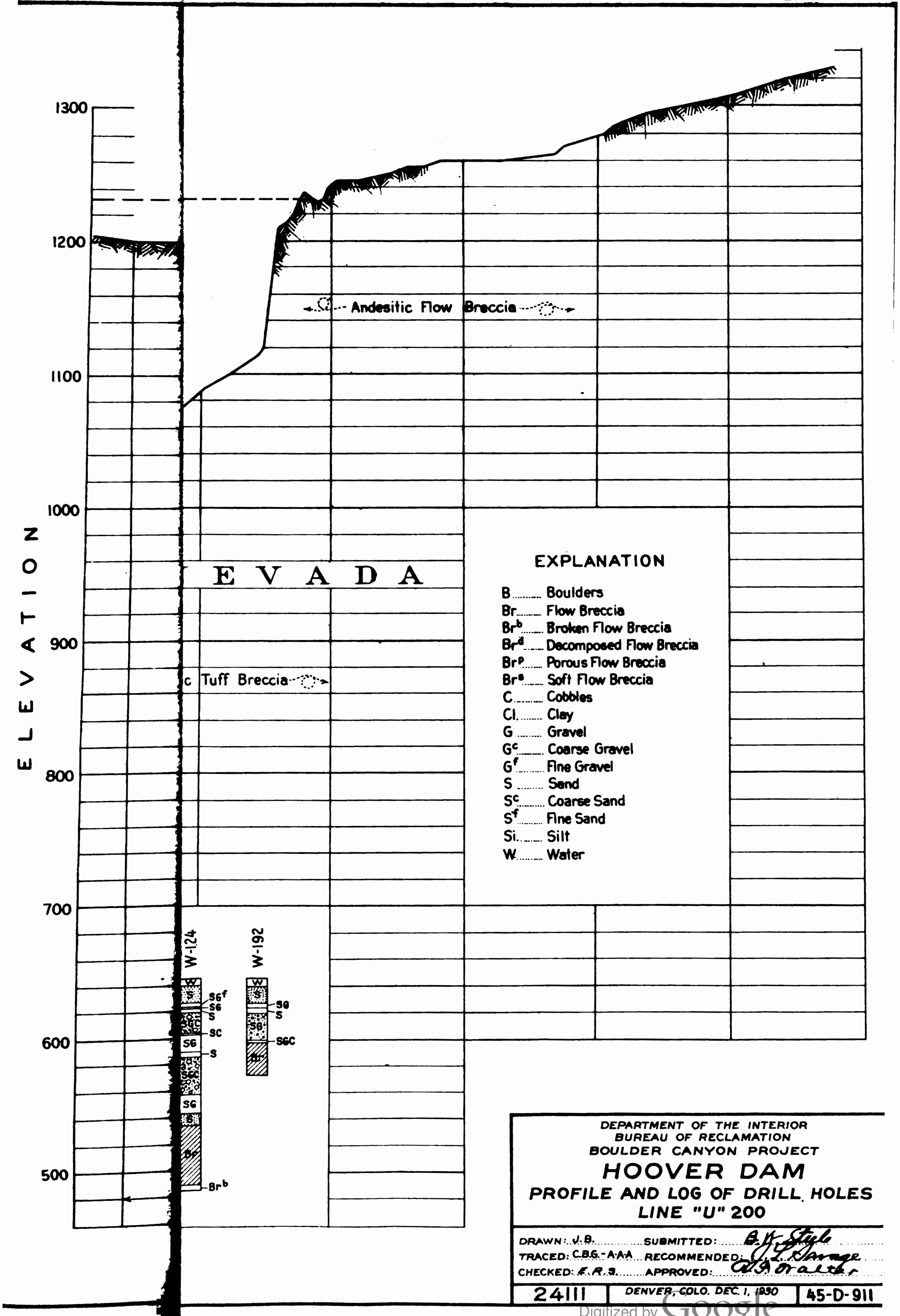
HOOVER DAM

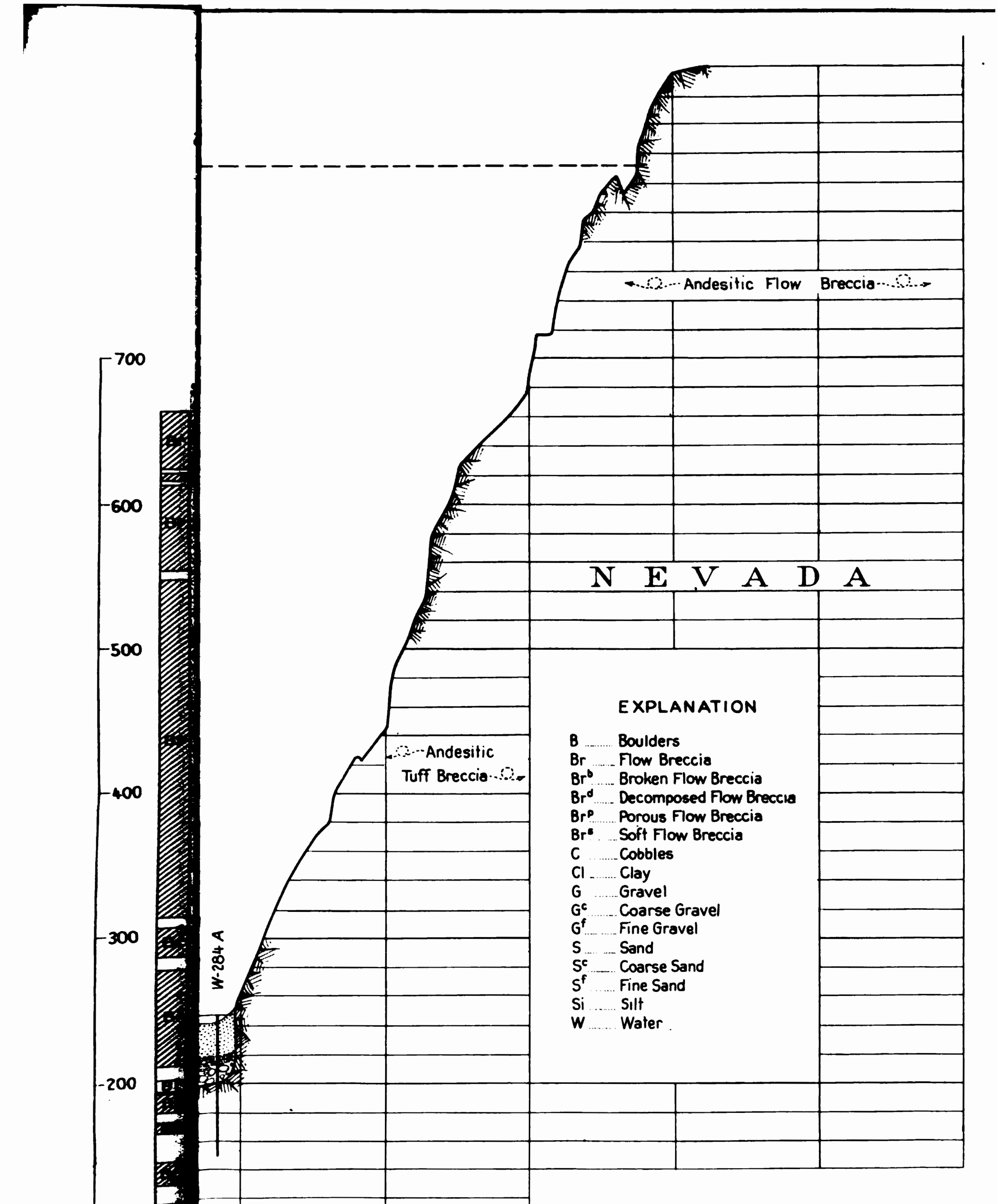
PROFILE AND LOG OF DRILL HOLES CENTERLINE OF RIVER

DRAWN: W.F.B. SUBMITTED: [signature]
TRACED: C.B.G. RECOMMENDED: [signature]
CHECKED: Q.L.B. P.B. APPROVED: [signature]

24109	DENVER, COLO. DEC. 1, 1930	45-D-909


ELEVATION
1300
1200
1100
1000
900
800
700
600
500
Andesitic Flow Breccia
EVADA
Breccia
EXPLANATION
B Boulders
Br Flow Breccia
Br^b Broken Flow Breccia
Br^d Decomposed Flow Breccia
Br^p Porous Flow Breccia
Br^s Soft Flow Breccia
C Cobbles
Cl Clay
G Gravel
G^c Coarse Gravel
G^f Fine Gravel
S Sand
S^c Coarse Sand
S^f Fine Sand
Si Silt
W Water
W-240
W-300
W-360
W-420
W
S
SG
B
SGC
Br^p
G
Br
100'
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
BOULDER CANYON PROJECT
HOOVER DAM
PROFILE AND LOG OF DRILL HOLES
LINE "U" 940
DRAWN: J.B. SUBMITTED:
TRACED: C.B.G.-A.A.A. RECOMMENDED:
CHECKED: APPROVED:
24110
DENVER, COLO. DEC. 1, 1930
45-D-910


ELEVATION
1300
1200
1100
1000
900
800
700
600
500
Andesitic Flow Breccia
EVADA
c Tuff Breccia
W-124
W-192
EXPLANATION
B....... Boulders
Br....... Flow Breccia
Br^b....... Broken Flow Breccia
Br^d....... Decomposed Flow Breccia
Br^p....... Porous Flow Breccia
Br^s....... Soft Flow Breccia
C....... Cobbles
Cl....... Clay
G....... Gravel
G^c....... Coarse Gravel
G^f....... Fine Gravel
S....... Sand
S^c....... Coarse Sand
S^f....... Fine Sand
Si....... Silt
W....... Water
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
BOULDER CANYON PROJECT
HOOVER DAM
PROFILE AND LOG OF DRILL HOLES
LINE "U" 200
DRAWN: J.B.
SUBMITTED:
TRACED: C.B.G.-A.A.A.
RECOMMENDED:
CHECKED: F.R.S.
APPROVED:
24111
DENVER, COLO. DEC. 1, 1930
45-D-911



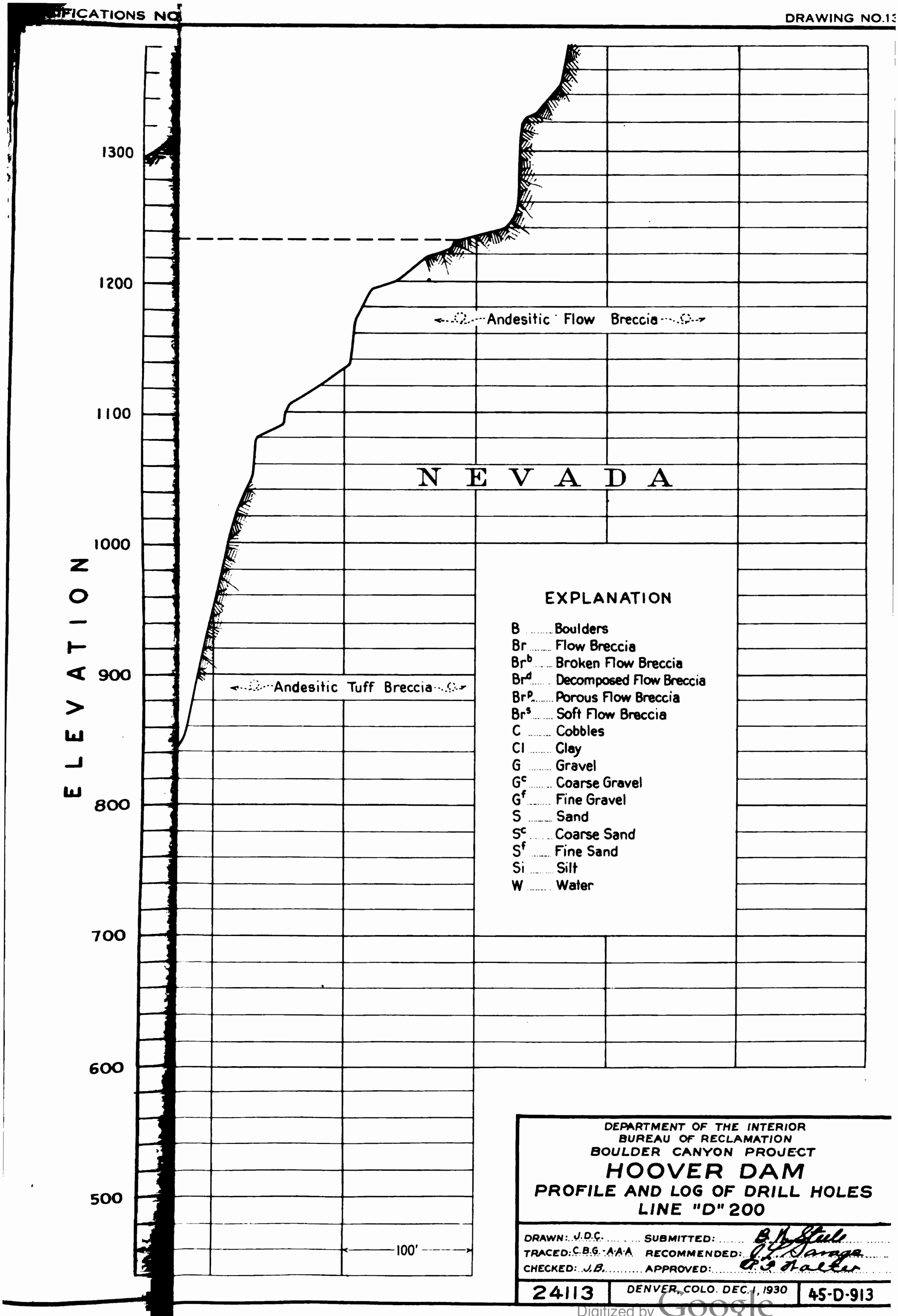
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
BOULDER CANYON PROJECT

HOOVER DAM

PROFILE AND LOG OF DRILL HOLES LINE "D"

DRAWN: J.D.C. SUBMITTED: [signature]
TRACED: C.B.G.-A.A.A. RECOMMENDED: [signature]
CHECKED: E.R.S. APPROVED: [signature]

24112 | DENVER, COLO. DEC. 1, 1930 | 45-D-912



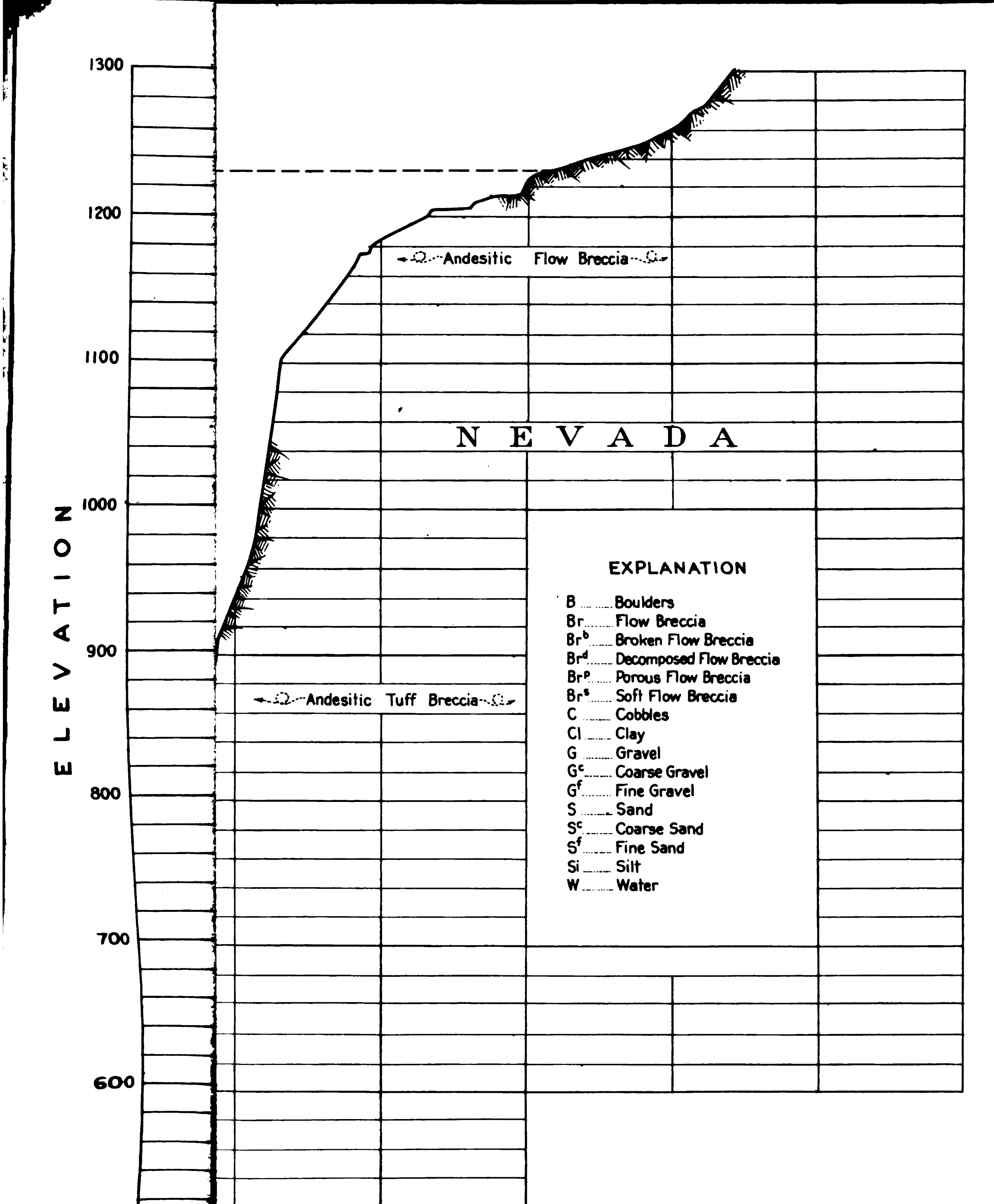
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
BOULDER CANYON PROJECT

HOOVER DAM

PROFILE AND LOG OF DRILL HOLES LINE "D" 200

DRAWN: J.D.C. SUBMITTED:
TRACED: C.B.G. A.A.A. RECOMMENDED:
CHECKED: J.B. APPROVED:

24113 DENVER, COLO. DEC. 1, 1930 45-D-913



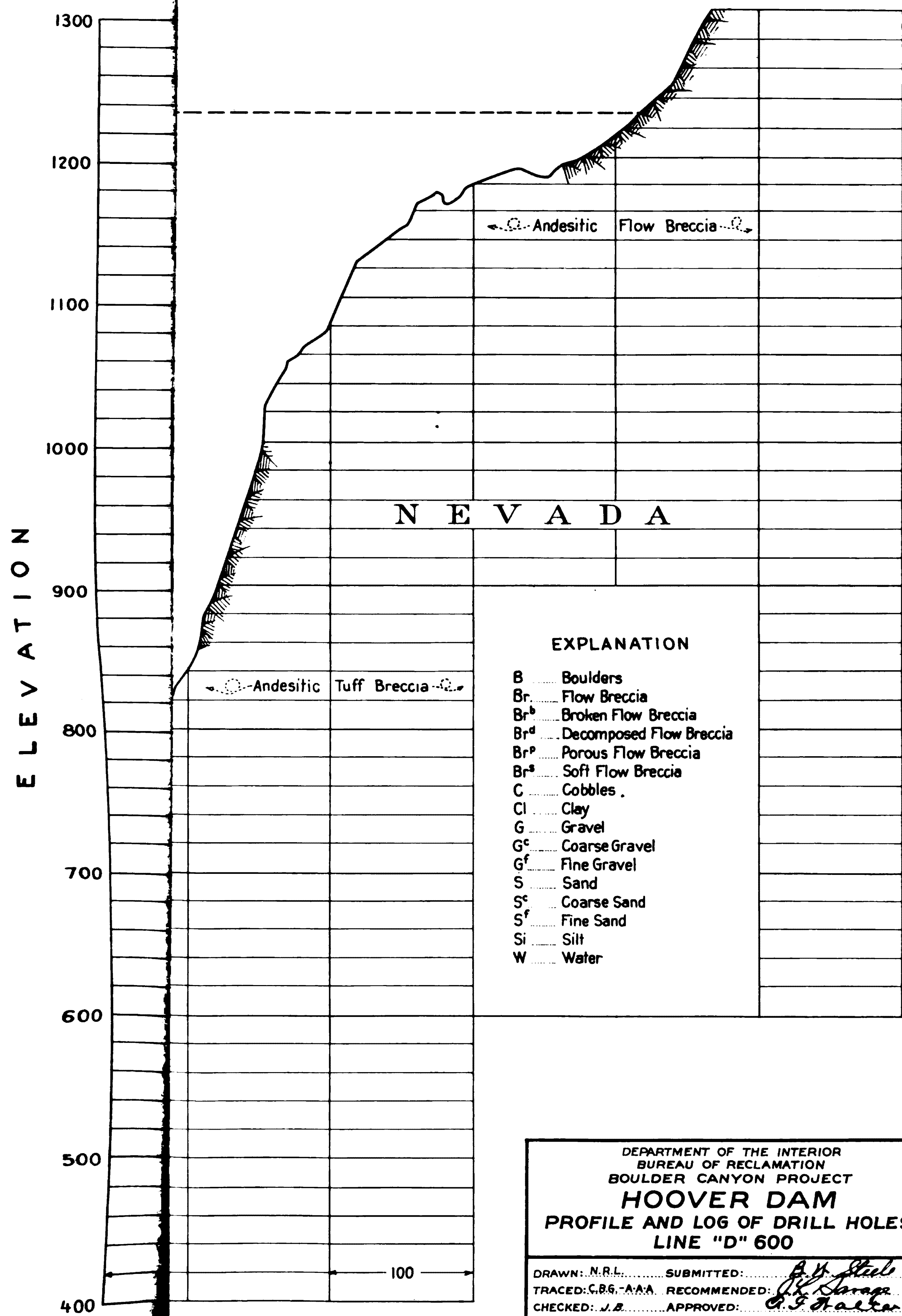
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
BOULDER CANYON PROJECT

HOOVER DAM

PROFILE AND LOG OF DRILL HOLES
LINE "D" 400

DRAWN: E.R.C. SUBMITTED:
TRACED: C.B.G.-A.A.A. RECOMMENDED:
CHECKED: H.R.L. APPROVED:

24114 DENVER, COLO. DEC. 1, 1930 45-D-914



DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
BOULDER CANYON PROJECT

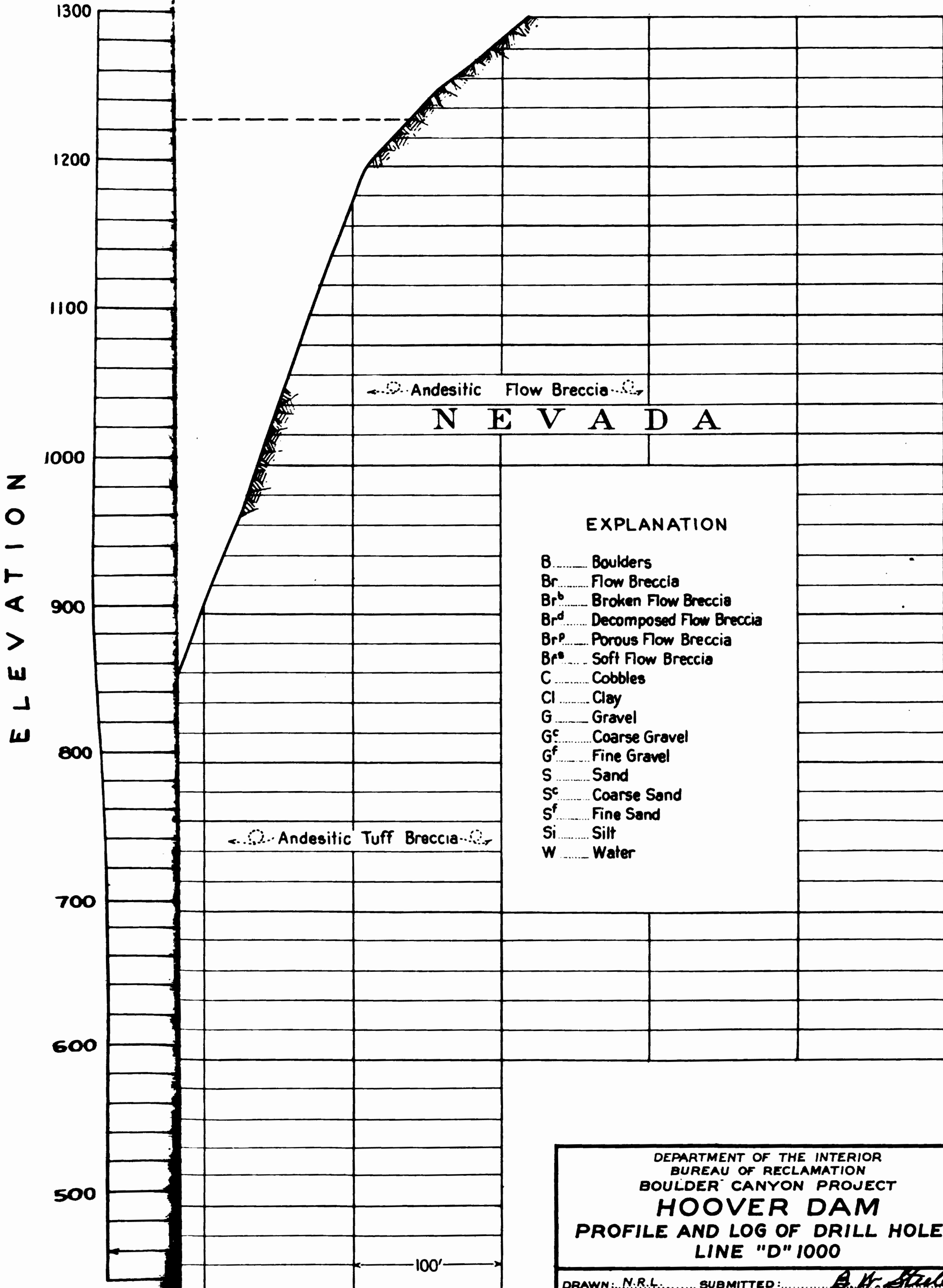
HOOVER DAM

PROFILE AND LOG OF DRILL HOLES
LINE "D" 600

DRAWN: N.R.L. SUBMITTED: [signature]
TRACED: C.B.G.-A.A.A. RECOMMENDED: [signature]
CHECKED: J.B. APPROVED: [signature]

24115 DENVER, COLO. DEC. 1, 1930 45-D-915

SPECIFICATIONS NO.51[illegible] DRAWING N[illegible]



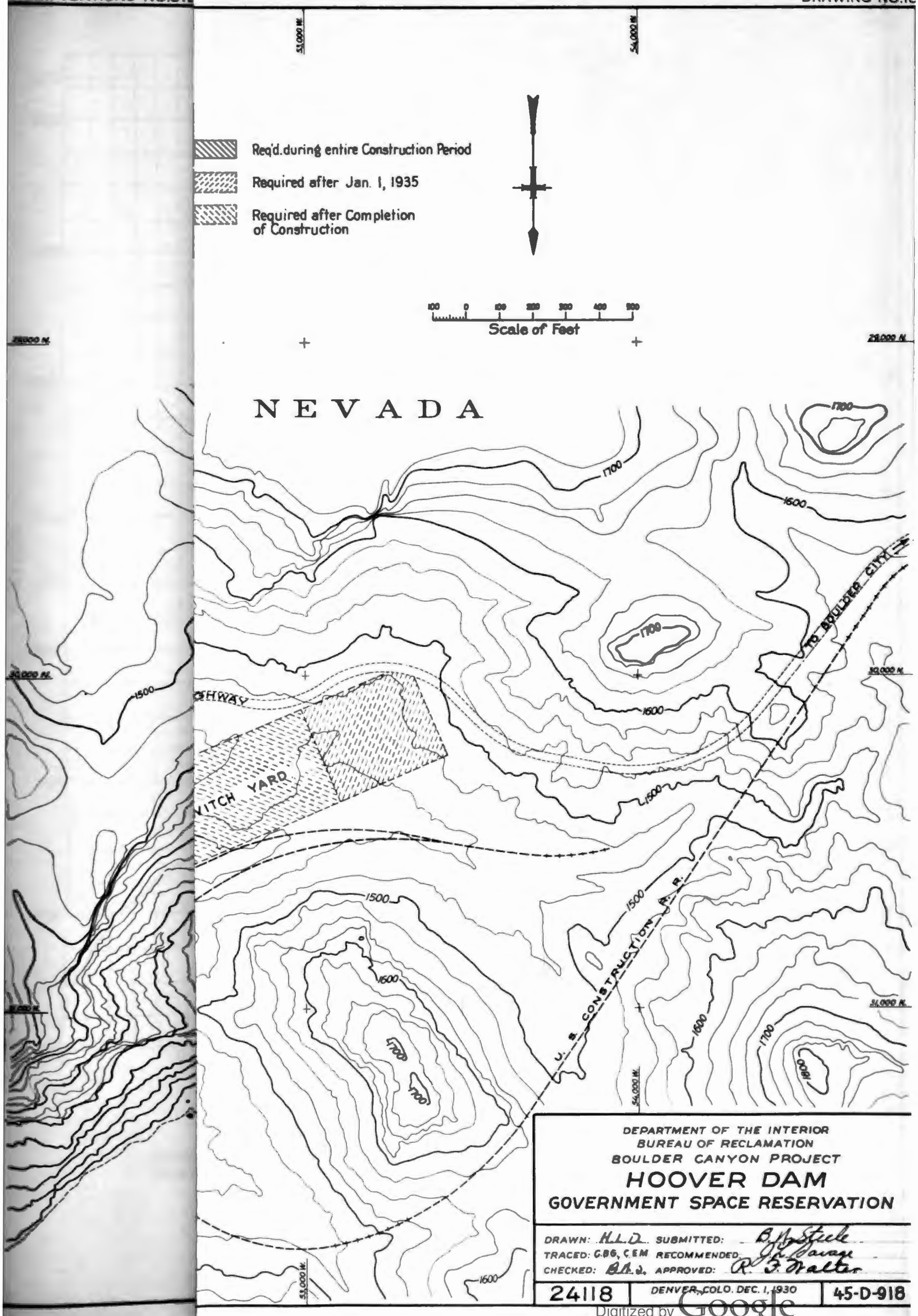
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
BOULDER CANYON PROJECT

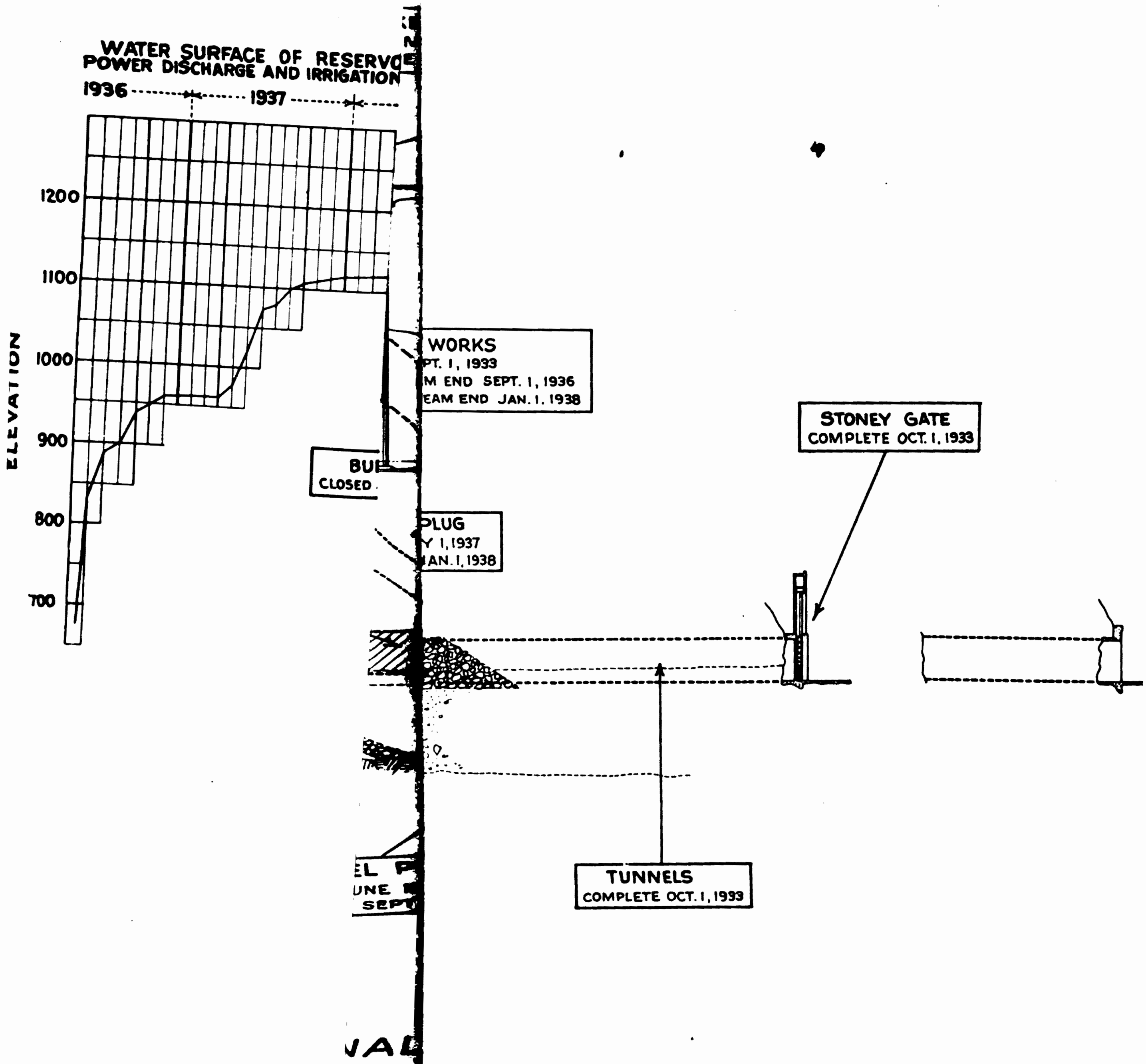
HOOVER DAM

PROFILE AND LOG OF DRILL HOLES
LINE "D" 1000

DRAWN: N.R.L. SUBMITTED: B. W. Steele
TRACED: C.B.6.-A.A.A RECOMMENDED: J. L. Savage
CHECKED: O.L.B. APPROVED: R. F. Walter

24116 DENVER, COLO. DEC 1, 1930 45-D-916


Req'd. during entire Construction Period
Required after Jan. 1, 1935
Required after Completion of Construction
Scale of Feet
NEVADA
TO BOULDER CITY
SHWAY
WITCH YARD
U. S. CONSTRUCTION R. R.
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
BOULDER CANYON PROJECT
HOOVER DAM
GOVERNMENT SPACE RESERVATION
DRAWN: H.L.D. SUBMITTED: B.W. Steele
TRACED: G.B.G, C.E.M RECOMMENDED: J.L. Savage
CHECKED: B.W.S. APPROVED: R. F. Walter
24118
DENVER, COLO. DEC. 1, 1930
45-D-918



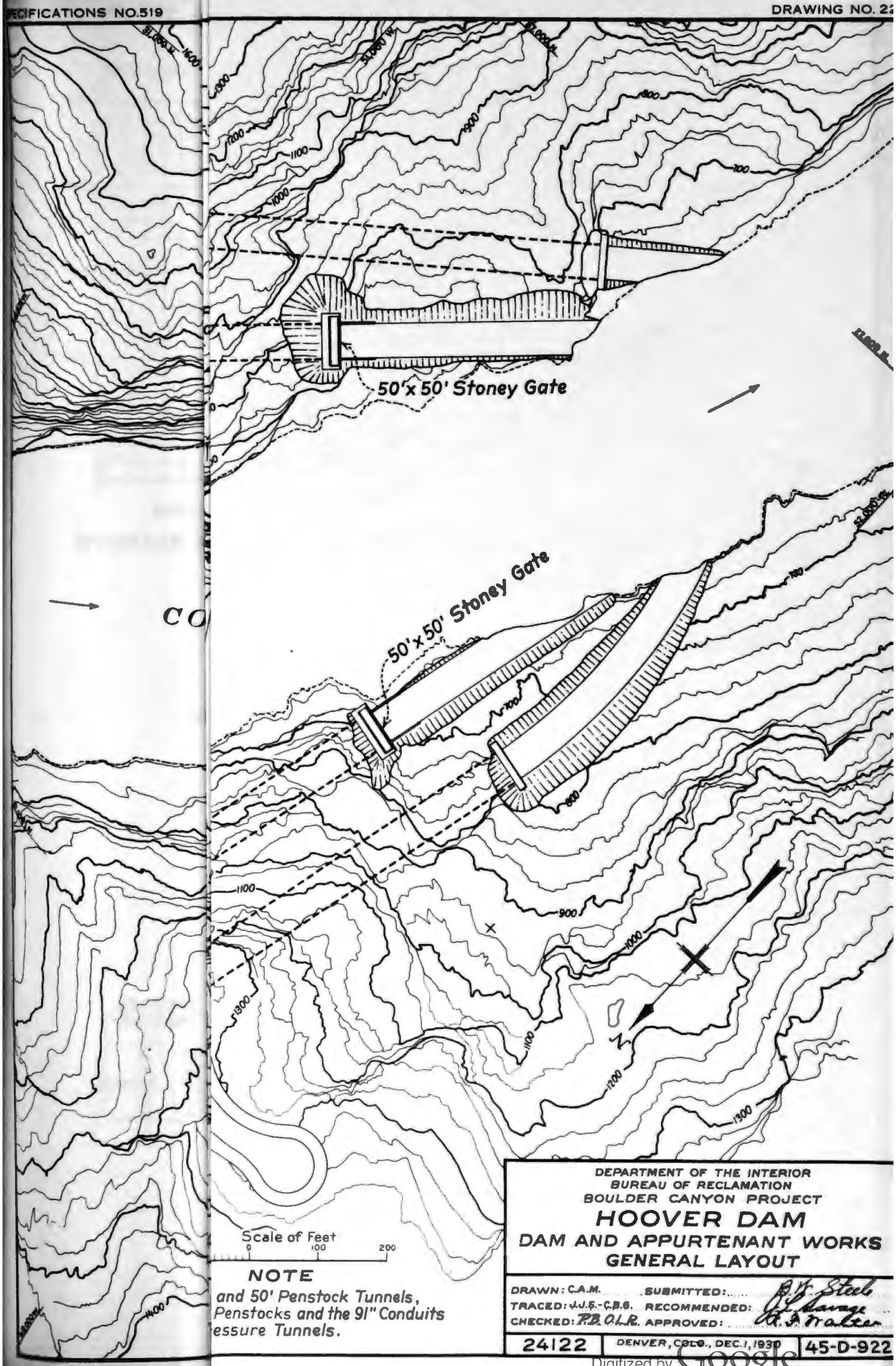
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
BOULDER CANYON PROJECT

HOOVER DAM

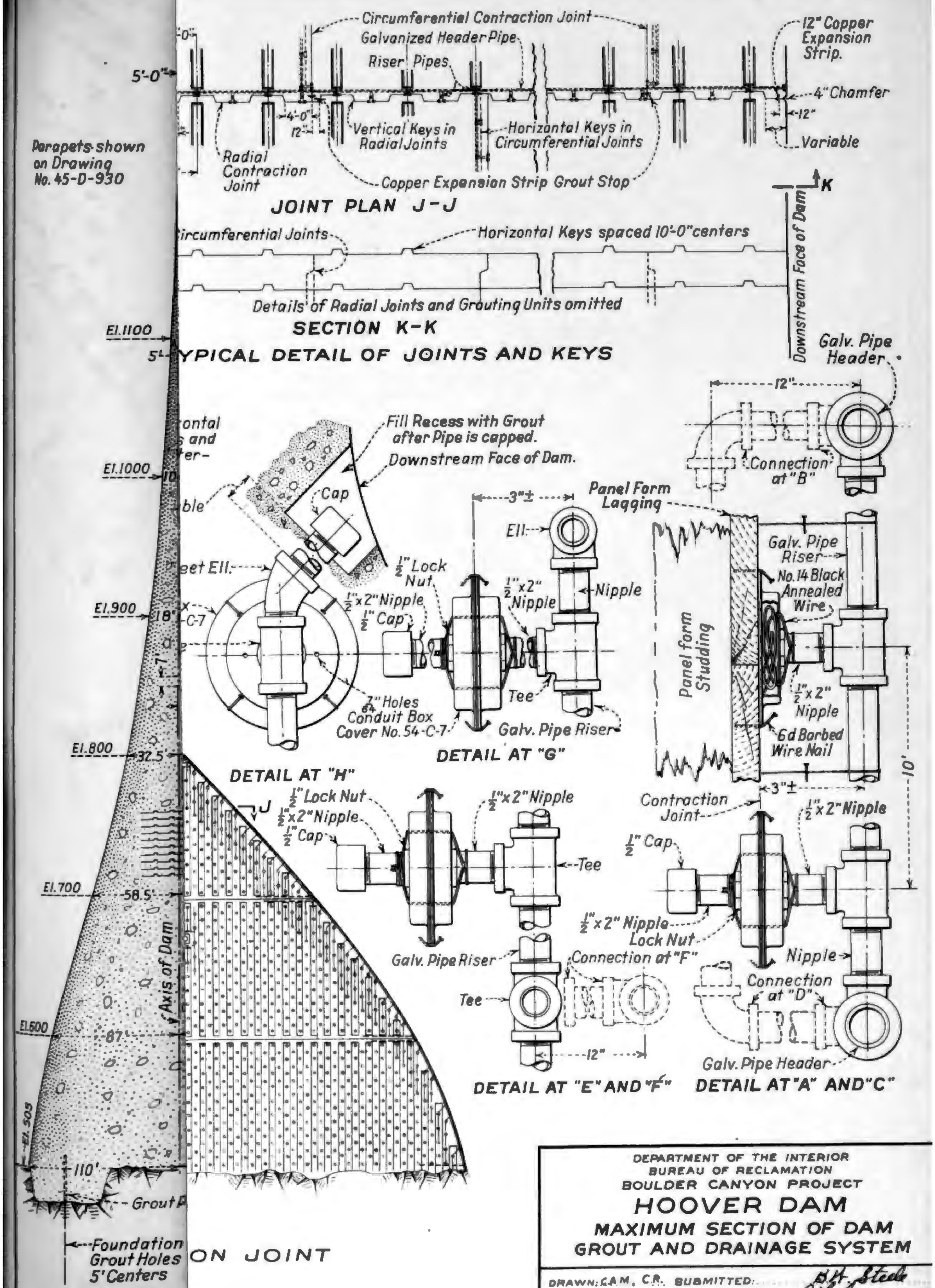
CONSTRUCTION PROGRESS DIAG
PICTORIAL

DRAWN: C.A.M.-H.W.T. SUBMITTED:
TRACED: H.G.K. RECOMMENDED:
CHECKED: A.H.S. APPROVED:

24121 DENVER, COLO. DEC. 1, 1930 45-



ECIFICATIONS NO.519
DRAWING NO. 22
50'x 50' Stoney Gate
50'x 50' Stoney Gate
CO
Scale of Feet
0
100
200
NOTE
and 50' Penstock Tunnels,
Penstocks and the 91" Conduits
essure Tunnels.
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
BOULDER CANYON PROJECT
HOOVER DAM
DAM AND APPURTENANT WORKS
GENERAL LAYOUT
DRAWN: C.A.M.
SUBMITTED:
TRACED: J.J.S.-C.B.G.
RECOMMENDED:
CHECKED: P.B. O.L.R.
APPROVED:
24122
DENVER, COLO., DEC. 1, 1930
45-D-922



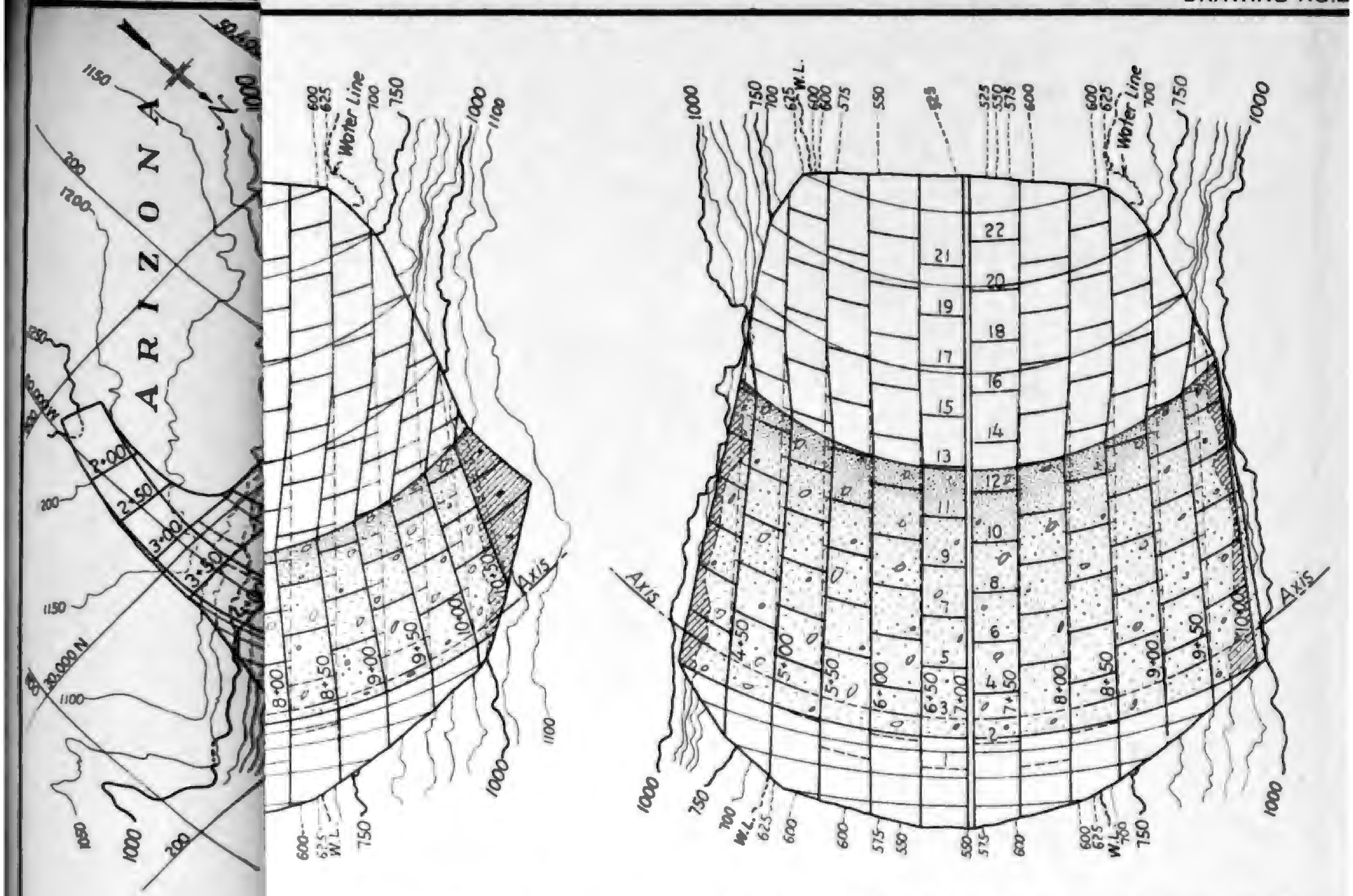
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
BOULDER CANYON PROJECT

HOOVER DAM

MAXIMUM SECTION OF DAM GROUT AND DRAINAGE SYSTEM

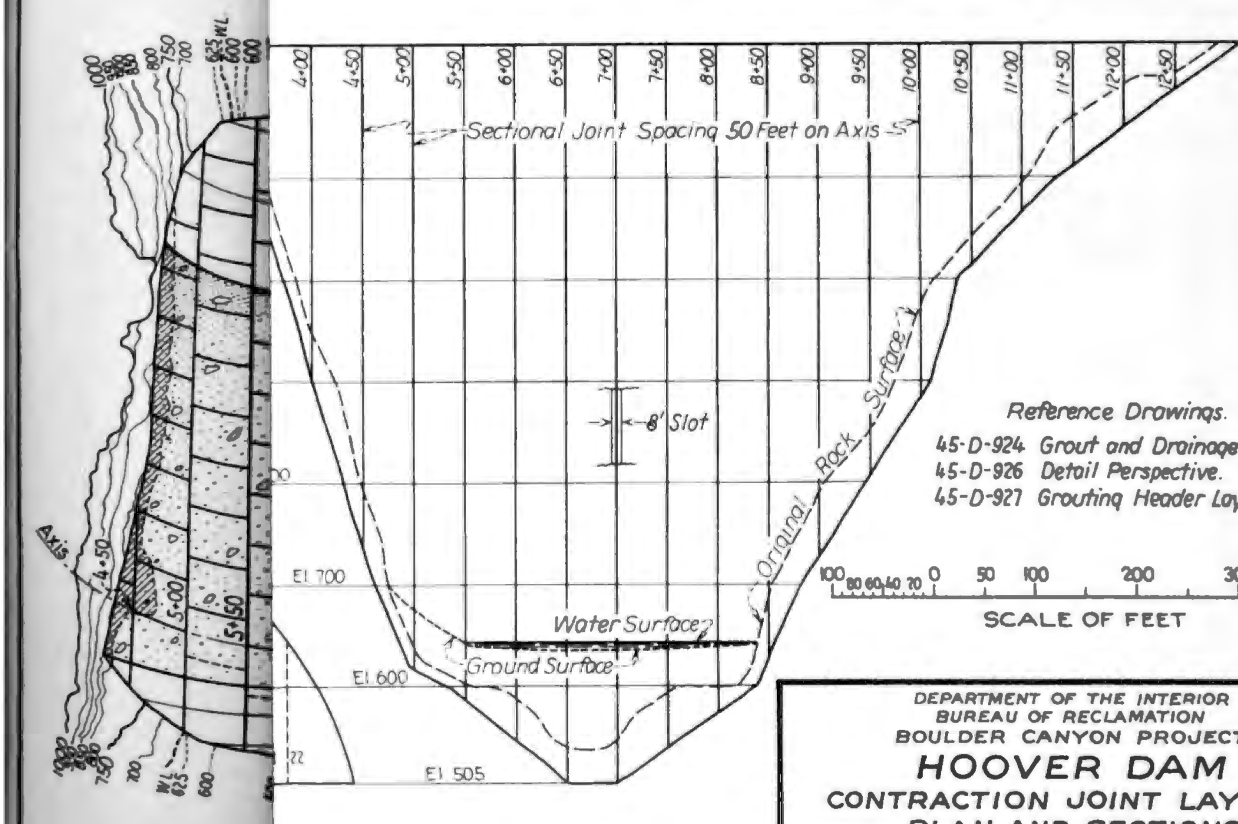
DRAWN: C.A.M., C.R. SUBMITTED: S.H. Steele
TRACED: A.A.A. RECOMMENDED: J.L. Savage
CHECKED: R.B.O.L.B. APPROVED: R.F. Walter

24124 DENVER, COLO., DEC. 1, 1930 45-D-924



AT ELEVATION 1000

SECTIONAL PLAN OF DAM AT ELEVATION 900



Reference Drawings.
45-D-924 Grout and Drainage System.
45-D-926 Detail Perspective.
45-D-927 Grouting Header Layout.

100 80 60 40 20 0 50 100 200 300 400
SCALE OF FEET

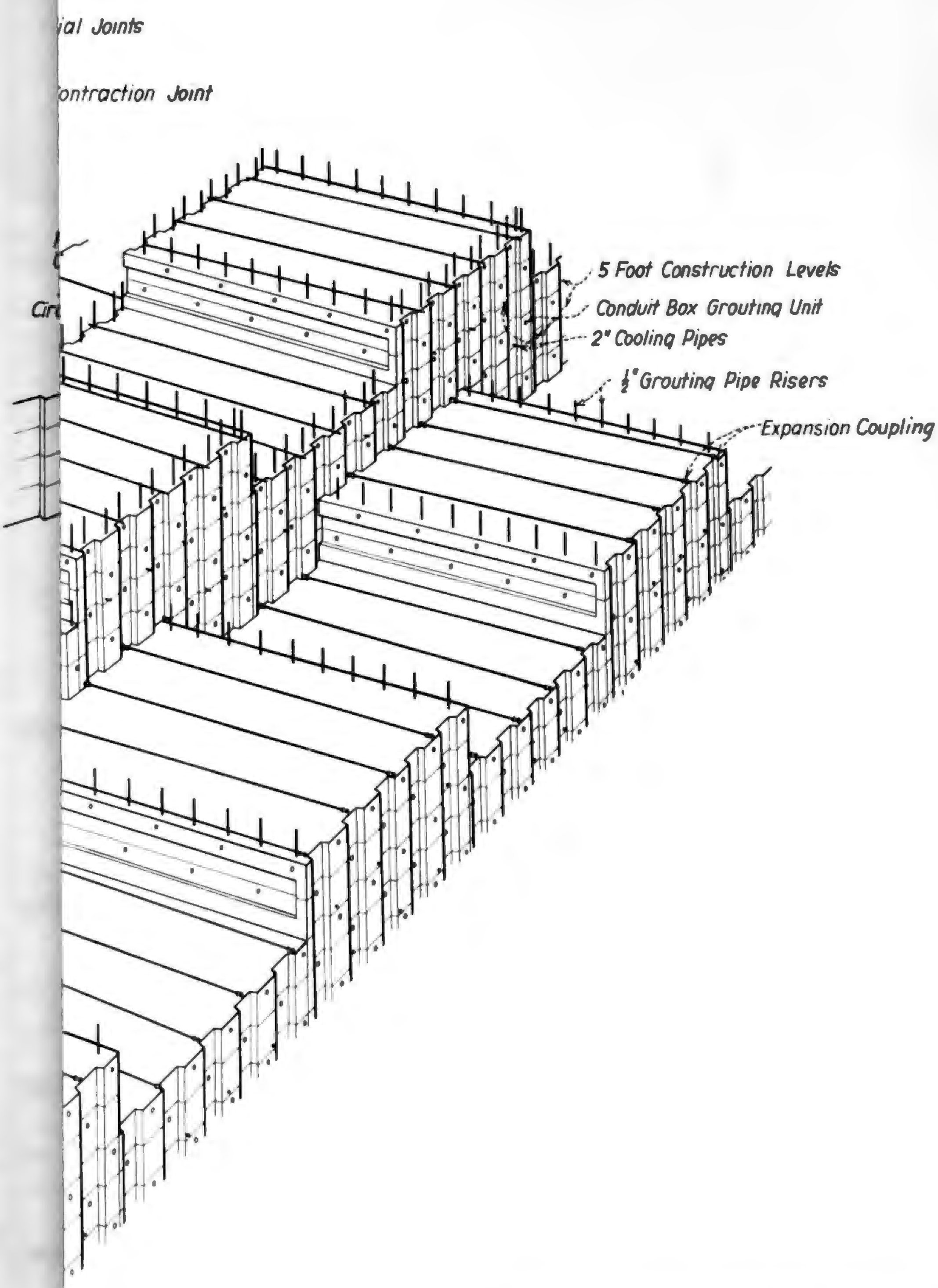
SECTIO[N]...[CE]NTERS
AT ...[JOI]NTS

PROFILE
ON AXIS OF DAM

DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
BOULDER CANYON PROJECT
HOOVER DAM
CONTRACTION JOINT LAYOUT
PLAN AND SECTIONS

DRAWN: C.R.	SUBMITTED: B. W. Steele
TRACED: R.M.W.	RECOMMENDED: J. L. Savage
CHECKED: Q.L.B. P.B.	APPROVED: R. F. Walter

24125	DENVER, COLO. DEC. 1, 1930	45-D-925



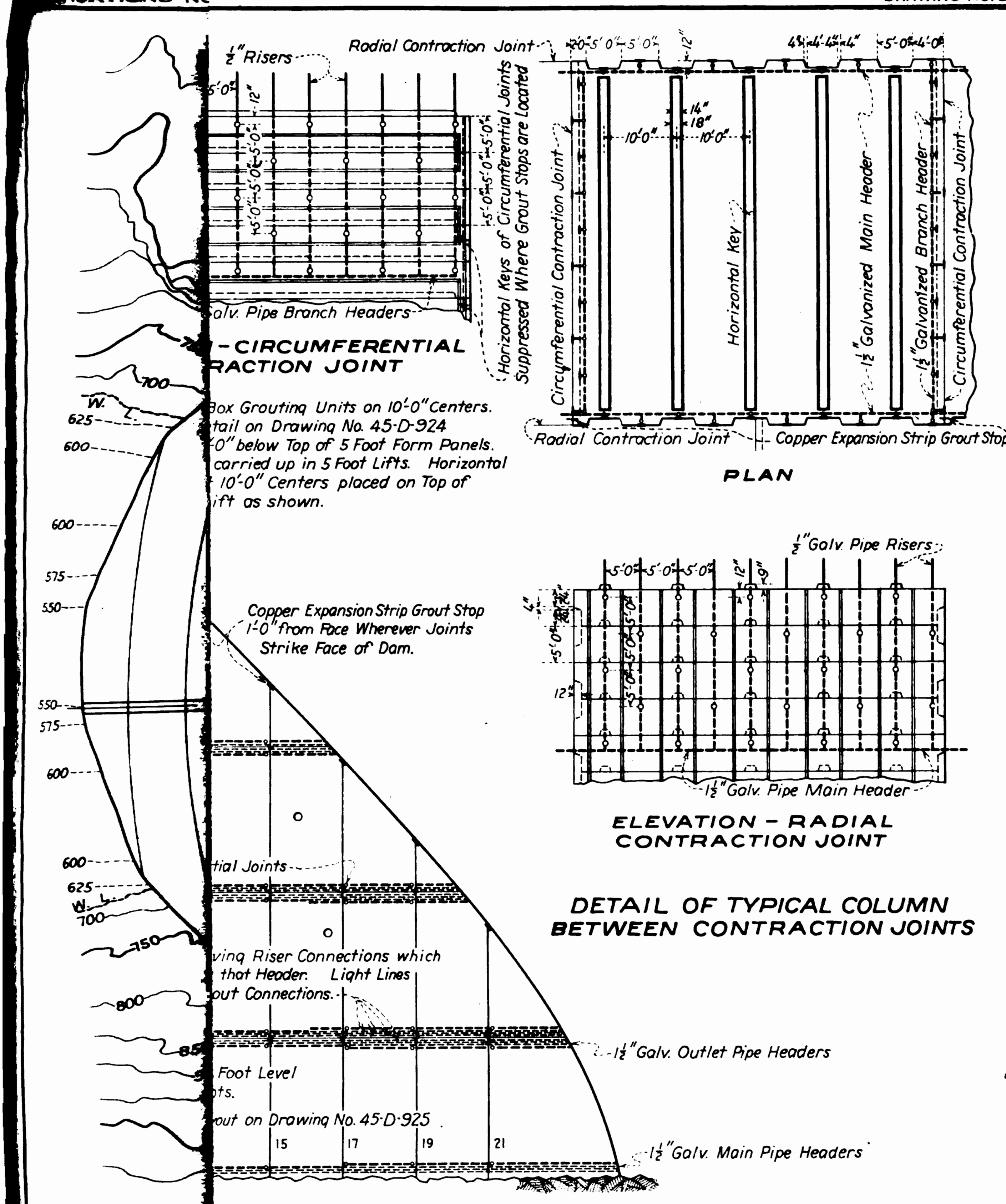
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
BOULDER CANYON PROJECT

HOOVER DAM

CONTRACTION JOINT LAYOUT
DETAIL PERSPECTIVE

DRAWN: C.R. SUBMITTED: R.B. Steele
TRACED: H.G.K.-W.H.K. RECOMMENDED: J.L. Savage
CHECKED: F.R.O.L.R. APPROVED: R. F. Walter.

24126 | DENVER, COLO. DEC. 1, 1930 | 45-D-926



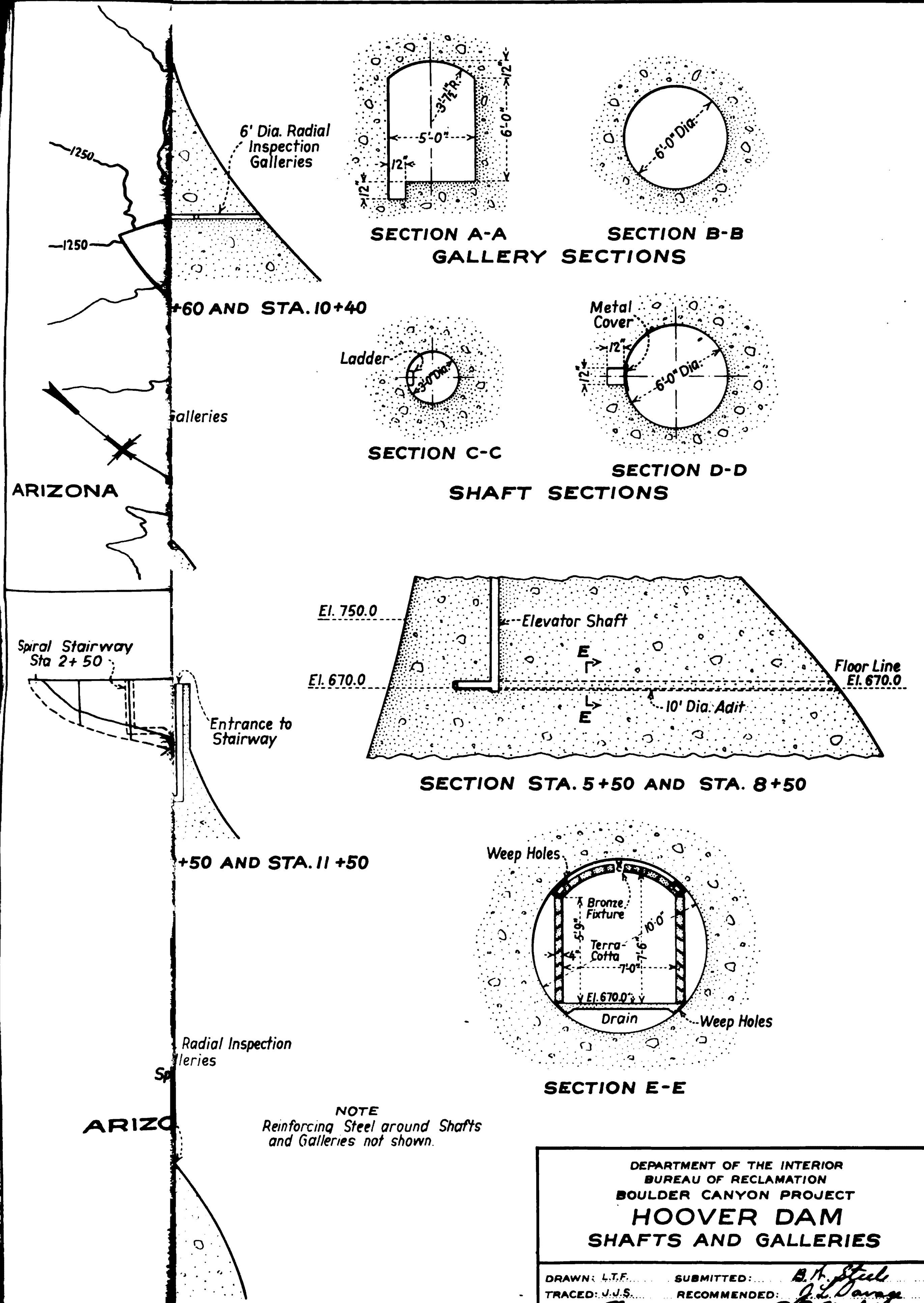
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
BOULDER CANYON PROJECT

HOOVER DAM

GROUTING SYSTEM LAYOUT

DRAWN C.R. SUBMITTED: B. W. Steele
TRACED: P.M.W. RECOMMENDED: J. L. Savage
CHECKED: O.L.R. P.B. APPROVED: R. F. Walter

24127 | DENVER, COLORADO - DEC. 1, 1930 | 45-D-927



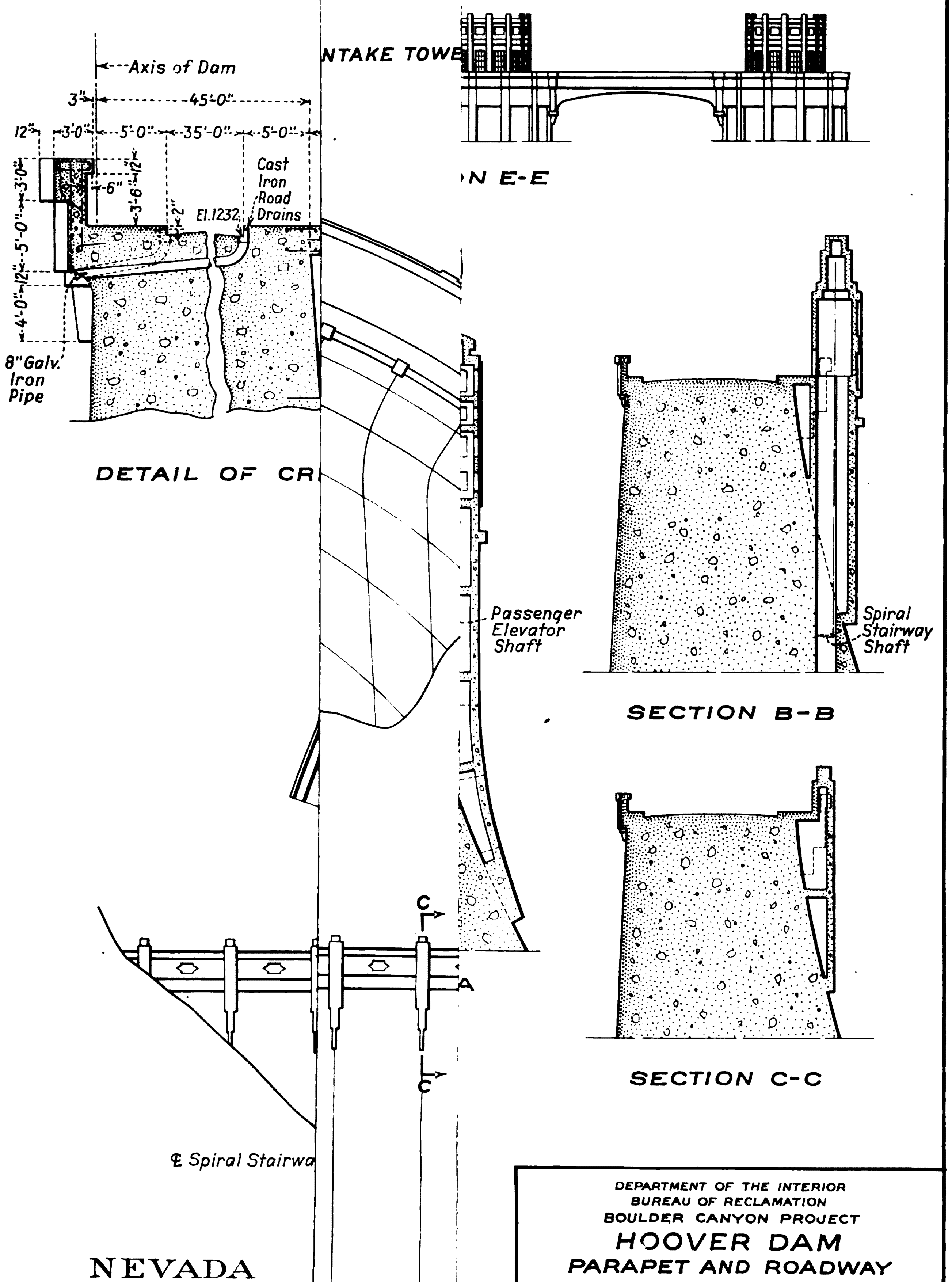
NOTE
Reinforcing Steel around Shafts and Galleries not shown.

DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
BOULDER CANYON PROJECT

HOOVER DAM

SHAFTS AND GALLERIES

DRAWN: L.T.F.	SUBMITTED: B. W. Steele
TRACED: J.J.S.	RECOMMENDED: J. L. Savage
CHECKED: O.L.B.	APPROVED: R. F. Walter
24129	DENVER, COLO., DEC. 1, 1930
	45-D-929



DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
BOULDER CANYON PROJECT

HOOVER DAM
PARAPET AND ROADWAY

DRAWN: E.B.H. SUBMITTED: B. W. Steele
TRACED: H.G.K.-A.A.A. RECOMMENDED: J. L. Savage
CHECKED: O.L.B. P.B. APPROVED: R. F. Walter

24130 | DENVER, COLO., DEC. 1, 1930 | 45-D-930

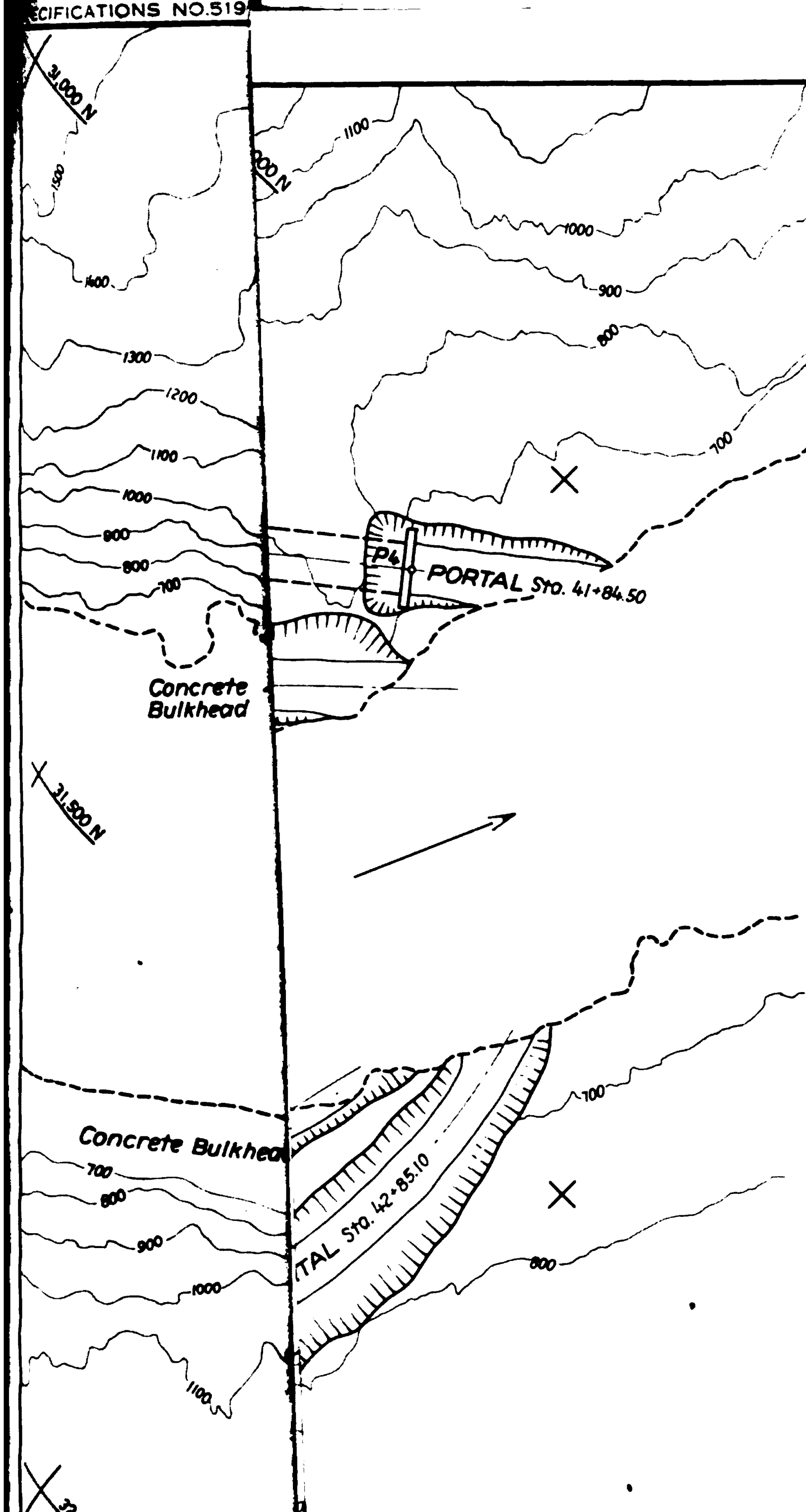


TABLE OF COORDINATES

Pt.	NORTH	WEST		Pt.	NORTH	WEST
A_1	31,591.39	49,063.07		A_2	31,475.28	49,109.37
B_1	31,702.04	49,340.54		B_2	31,569.74	49,346.23
C_1	31,545.19	49,594.75		C_2	31,411.84	49,546.47
D_1	31,157.14	50,380.48		D_2	30,737.33	50,401.84
E_1	30,896.43	50,646.24		E_2	30,029.89	51,298.98
F_1	30,889.34	50,657.74		F_2	29,925.00	51,432.00
G_1	30,879.95	50,667.45		G_2	29,793.18	51,463.03
H_1	30,177.59	51,394.58		H_2	29,760.45	51,472.24
J_1	30,013.08	51,564.89		P_2	28,893.40	51,684.29
K_1	29,783.07	51,621.14		L_2	30,381.58	50,852.99
P_1	28,816.35	51,857.56		T_2	30,716.71	50,126.44
A_4	31,059.66	48,605.79		A_3	31,036.61	48,728.81
B_4	30,922.85	48,572.85		B_3	30,943.27	48,706.35
C_4	30,812.02	48,659.55		C_3	30,877.15	48,775.95
D_4	29,677.25	49,547.14		D_3	29,974.66	49,725.92
E_4	29,665.38	49,556.42		E_3	28,974.95	50,774.65
F_4	29,656.06	49,568.26		F_3	28,953.93	50,754.69
G_4	29,905.44	49,251.57		L_3	29,572.50	50,149.23
P_4	28,168.00	51,458.00		P_3	28,518.20	51,258.99
				T_3	30,238.80	49,721.88
A_5	30,619.34	50,369.28		A_7	30,055.58	49,640.73
B_5	30,622.70	50,414.17		B_7	30,090.00*	49,673.00*
C_5	30,597.94	50,451.77		C_7	30,203.00*	50,013.00*
D_5	30,140.93	51,145.80		A_8	30,810.09	50,309.57
E_5	30,100.30	51,207.51		B_8	30,782.00*	50,283.00*
F_5	30,034.97	51,242.03		C_8	30,437.00*	50,197.00*
G_5	29,830.77	51,349.69		A_9	29,521.56	50,741.81
L_5	30,381.21	50,780.90		B_9	29,451.77	50,652.92
T_5	30,610.62	50,252.81		C_9	29,272.59	50,684.76
				D_9	28,932.79	51,017.69
A_6	30,059.24	49,871.49		E_9	28,833.59	50,923.45
B_6	30,014.01	49,886.51		A_{10}	29,780.28	50,950.34
C_6	29,976.43	49,916.02		B_{10}	29,891.93	51,023.87
D_6	29,138.21	50,574.11		C_{10}	29,739.05	51,209.92
L_6	29,660.26	50,164.24		D_{10}	29,522.34	51,362.60
T_6	30,131.68	49,847.38		E_{10}	29,561.08	51,521.00

* Approximate

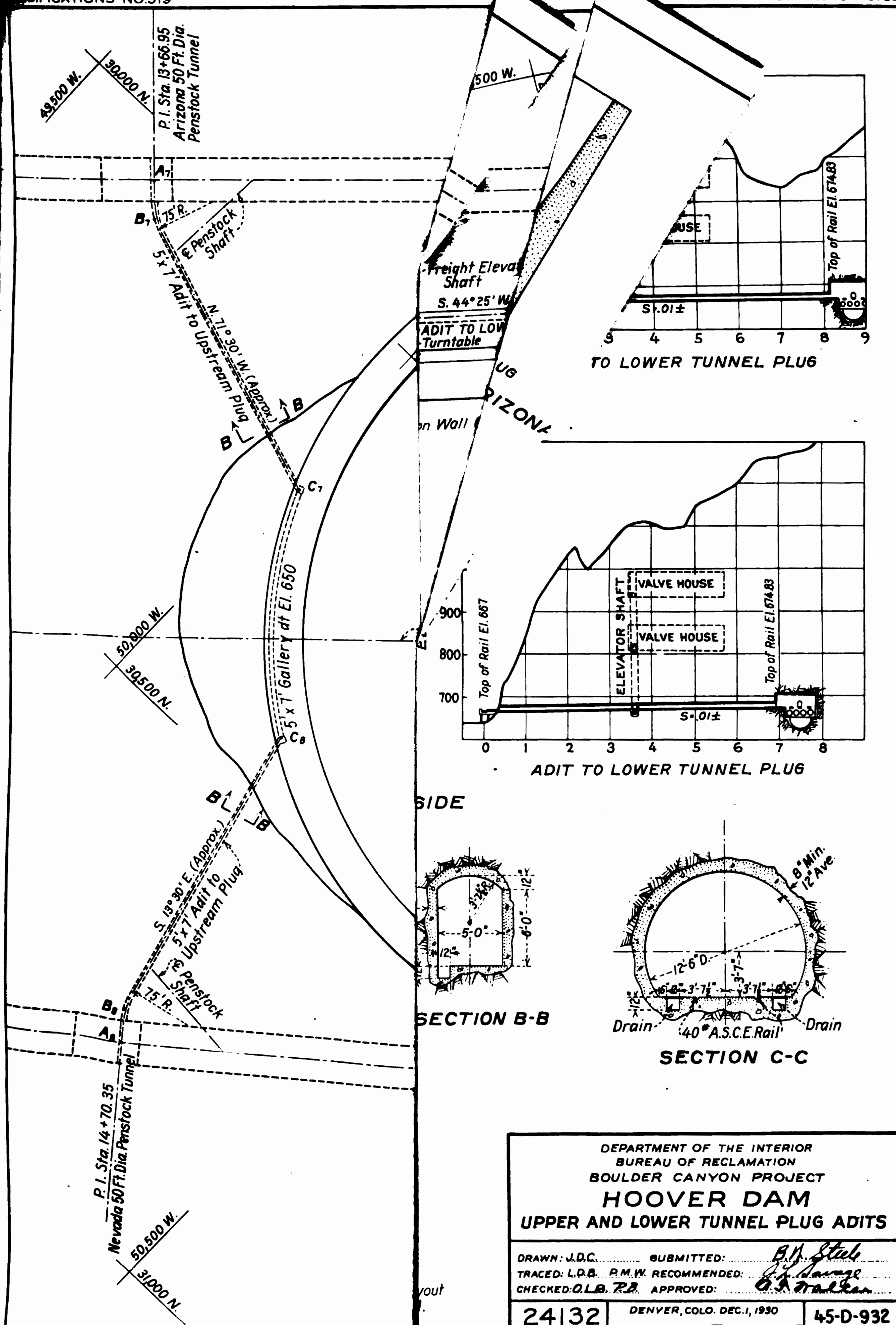
REFERENCE DRAWINGS

- General Layout 45-D-922
- hafts and Galleries 45-D-929
- unnel Plug Adits 45-D-932
- pillway Tunnels 45-D-933
- 0' Penstock Tunnels 45-D-934
- 0' Penstock Tunnels 45-D-935
- let Structure - Outer Tunnels 45-D-936
- rash Rack Structure - Inner Tunnels ... 45-D-938
- pillway Tunnel Plug 45-D-941
- pillway Tunnel Outlet 45-D-942
- pstream Tunnel Plug - Nevada 45-D-943
- pstream Tunnel Plug - Arizona 45-D-944
- nyon Wall Outlet Works - Arizona ... 45-D-949
- nyon Wall Outlet Works - Nevada ... 45-D-950
- wnstream Tunnel Plug 45-D-954
- 'x 50' Stoney Gate 45-D-956
- ake Towers 45-D-960
- wer Plant - General Plan 45-D-965
- wer Plant - Penstock Tunnels 45-D-972

DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
BOULDER CANYON PROJECT

HOOVER DAM
TUNNEL ALIGNMENT LAYOUT

DRAWN: W.F.B. SUBMITTED: [signature]
TRACED: P.M.W. RECOMMENDED: [signature]
CHECKED: W.F.R. APPROVED: [signature]



DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
BOULDER CANYON PROJECT

HOOVER DAM

UPPER AND LOWER TUNNEL PLUG ADITS

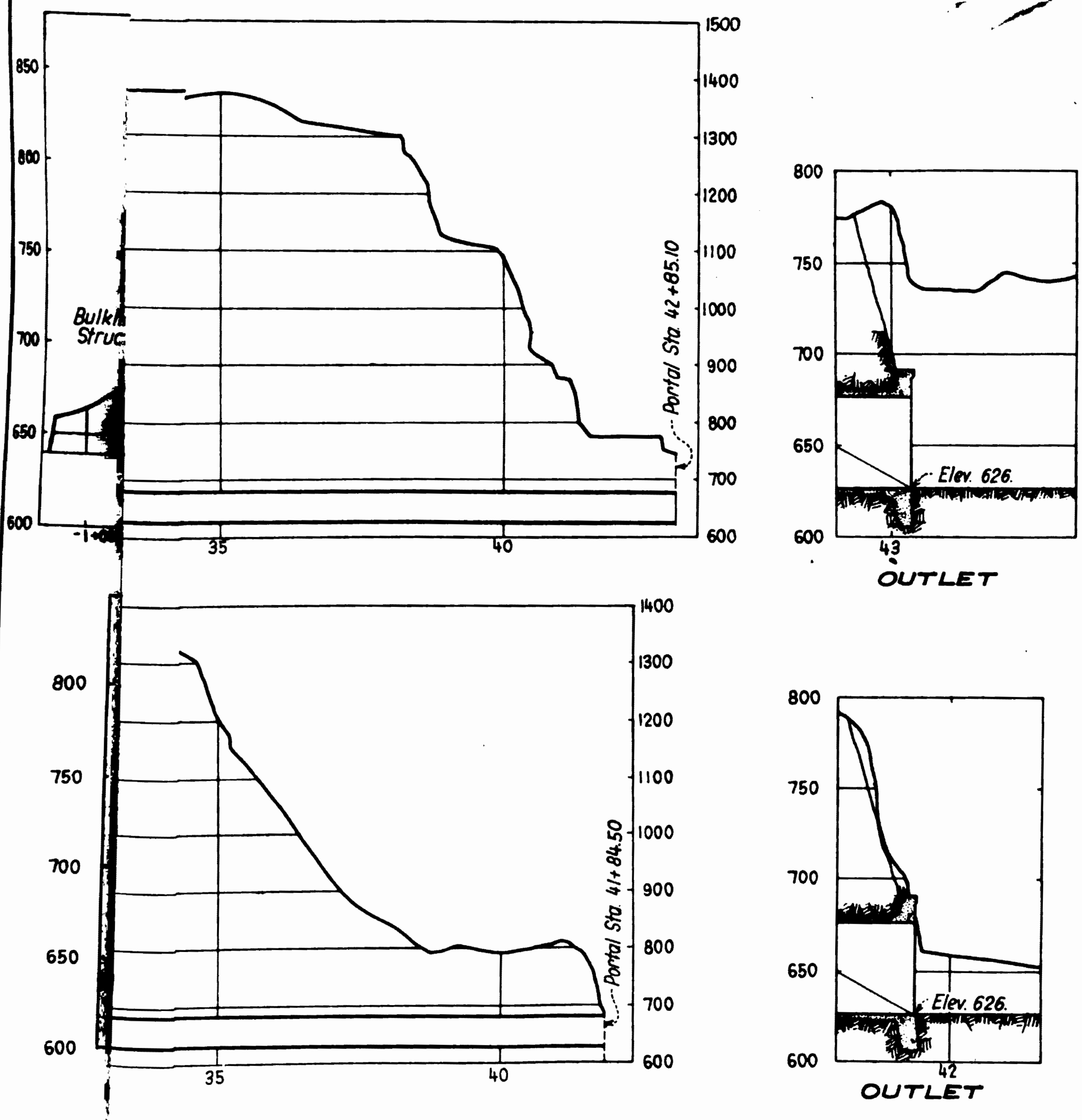
DRAWN: J.D.C. SUBMITTED: B.W. Steele
TRACED: L.D.B. P.M.W. RECOMMENDED: J.L. Savage
CHECKED: O.L.B. P.B. APPROVED: R.F. Walter

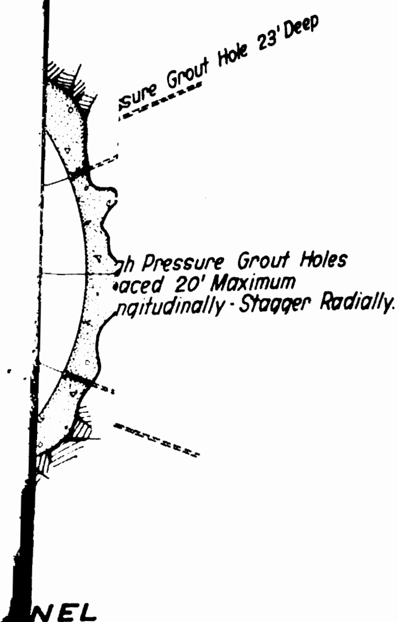
24132 DENVER, COLO. DEC. 1, 1930 45-D-932

PECIFICATI

DRAW

NO.34





DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
BOULDER CANYON PROJECT

HOOVER DAM

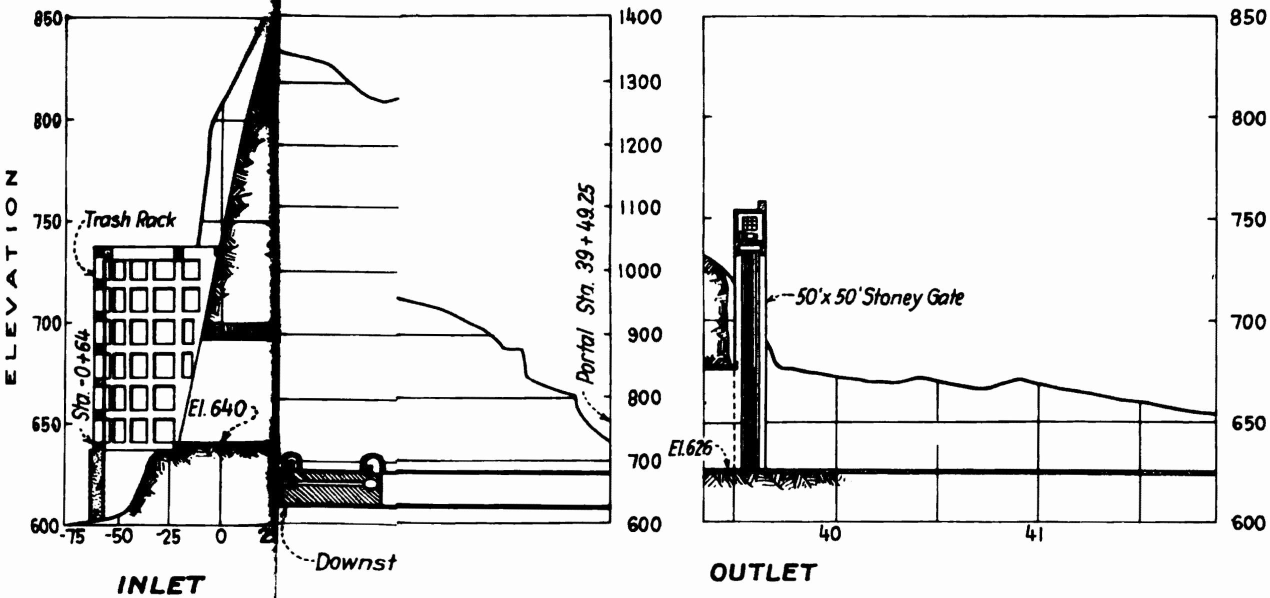
PROFILES AND SECTIONS
SPILLWAY TUNNELS

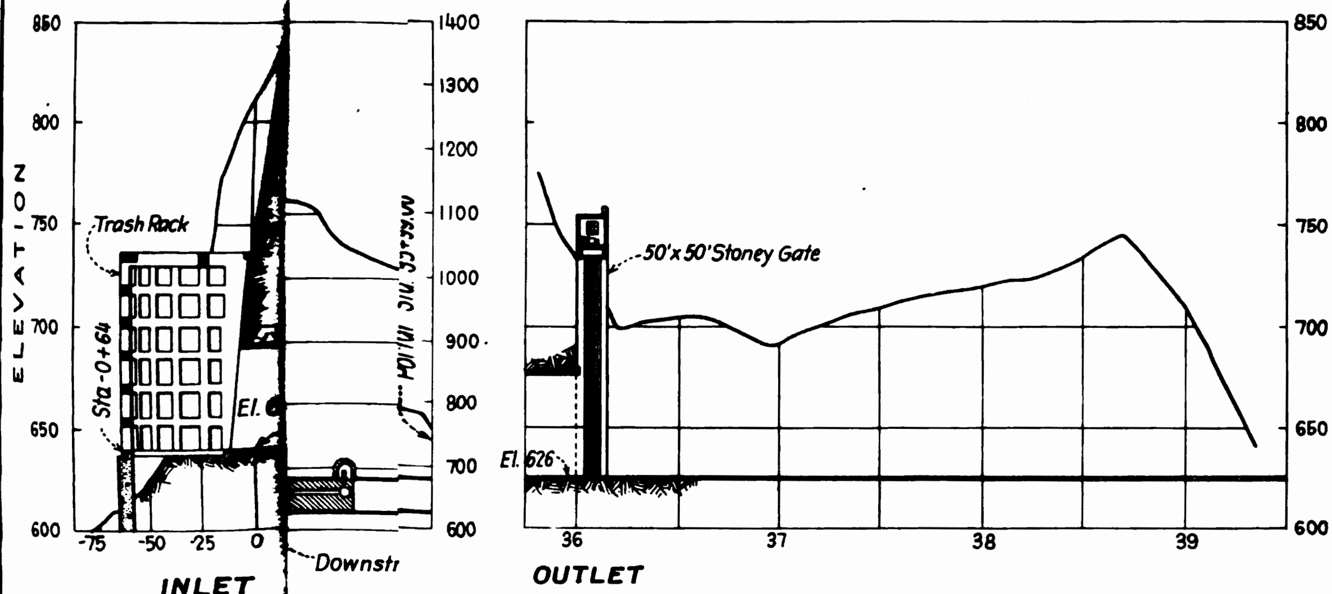
DRAWN: E.R.S. SUBMITTED: R.F. Steele

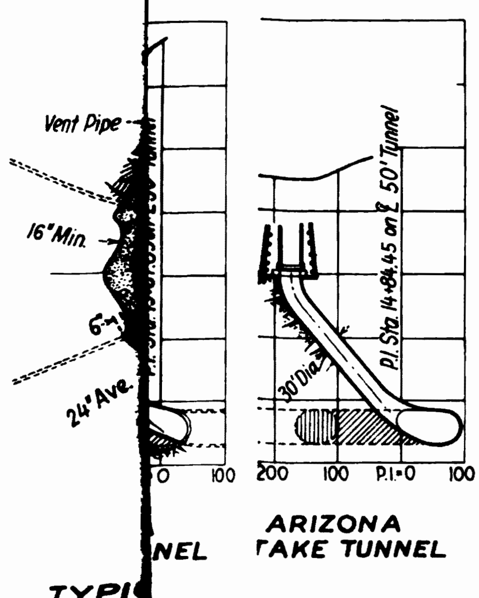
TRACED: W.H.K. RECOMMENDED: J.L. Savage

CHECKED: P.B. O.L.R. APPROVED: R.F. Walter

24133 | DENVER, COLO., DEC. 1, 1930 | 45-D-93







NOTE

All Tunnels and Riser Shafts will carry full Hydrostatic load and are considered Pressure Tunnels and Shafts.

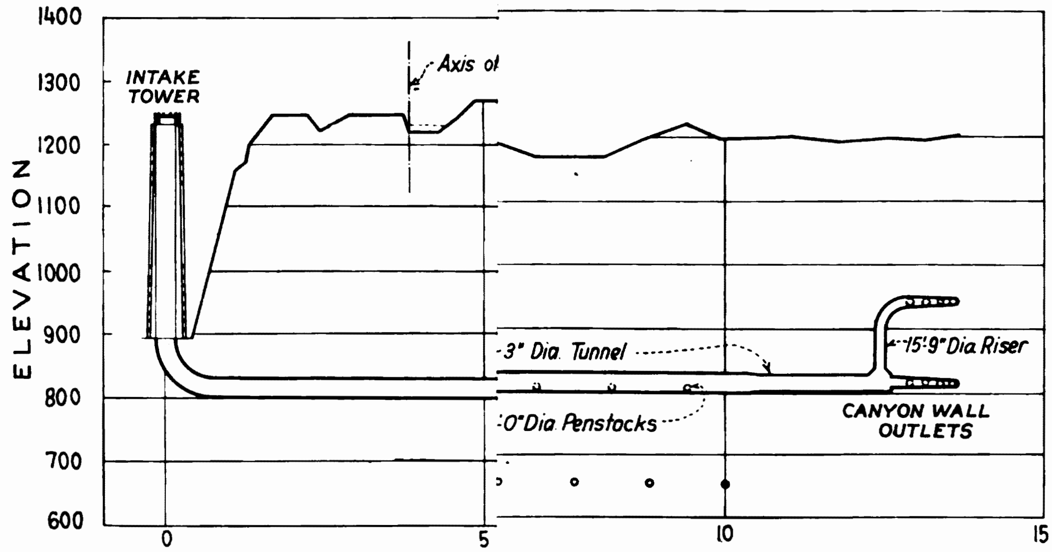
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
BOULDER CANYON PROJECT

HOOVER DAM

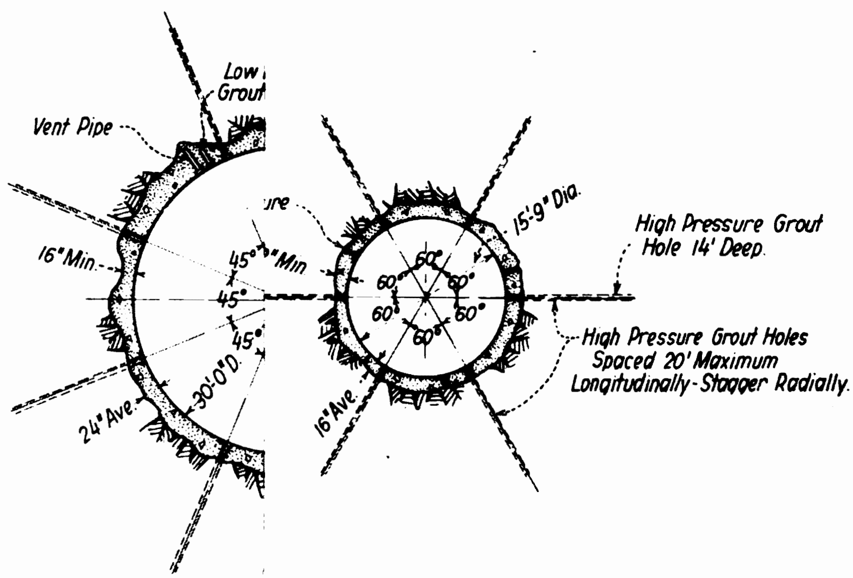
PROFILES AND SECTIONS
50' PENSTOCK TUNNELS

DRAWN: J.D.C. SUBMITTED: B.W. Steele
TRACED: J.S.-L.D.B.-W.H.K. RECOMMENDED: J.L. Savage
CHECKED: O.L.R. P.B. APPROVED: R.F. Walter

24134 DENVER, COLO. DEC. 1, 1930 45-D-934



NEVADA' PENSTOCK TUNNEL



TYPICAL SECICAL SECTION 15'-9" RISER

DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
BOULDER CANYON PROJECT

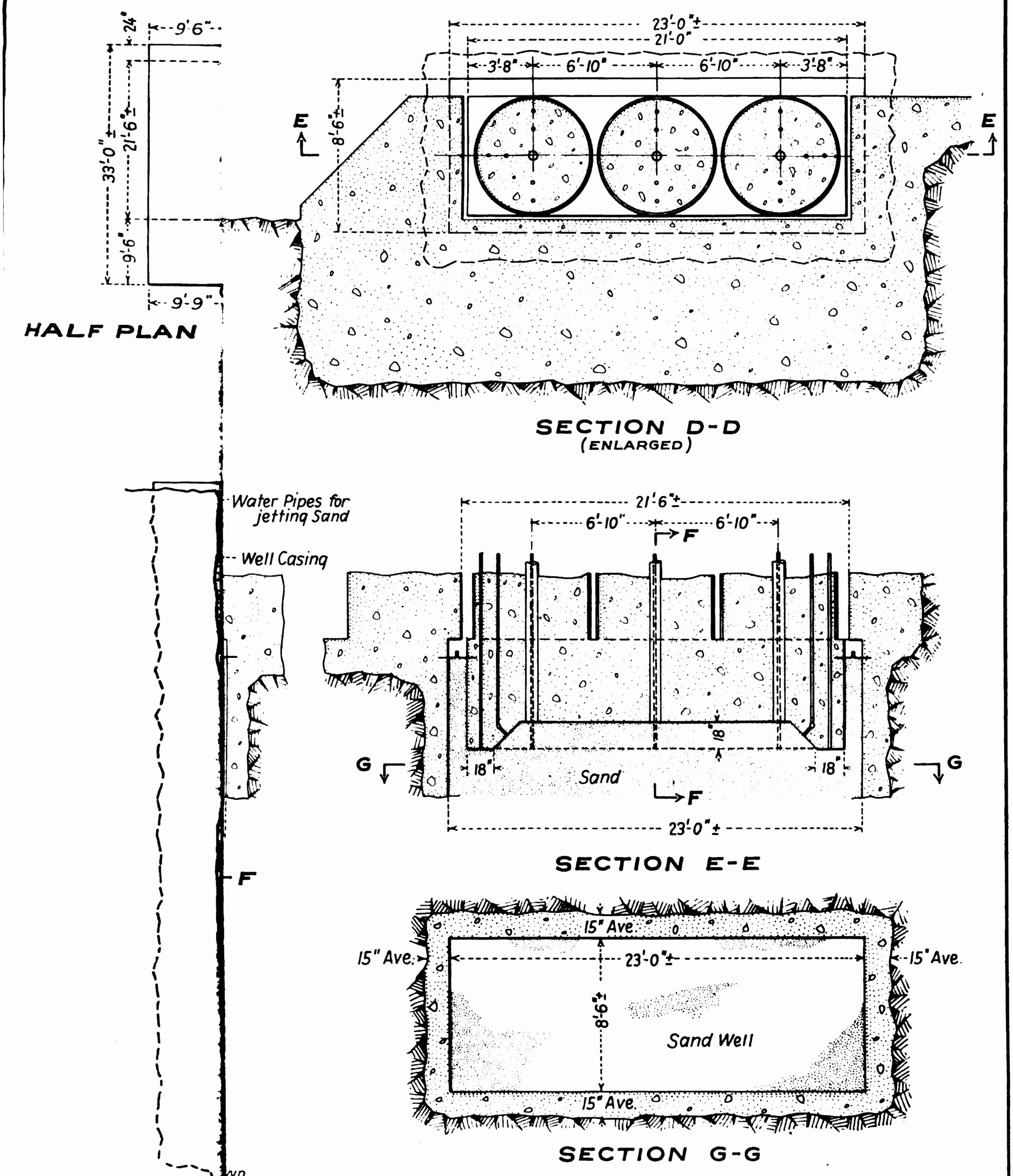
HOOVER DAM

PROFILES AND SECTIONS

30' PENSTOCK TUNNELS

DRAWN: J.B.	SUBMITTED: B. W. Steele
TRACED: W.H.K.	RECOMMENDED: J. L. Savage
CHECKED: T.B. O.L.R.	APPROVED: R. F. Walter

24135	DENVER, COLO. DEC. 1, 1930	45-D-935

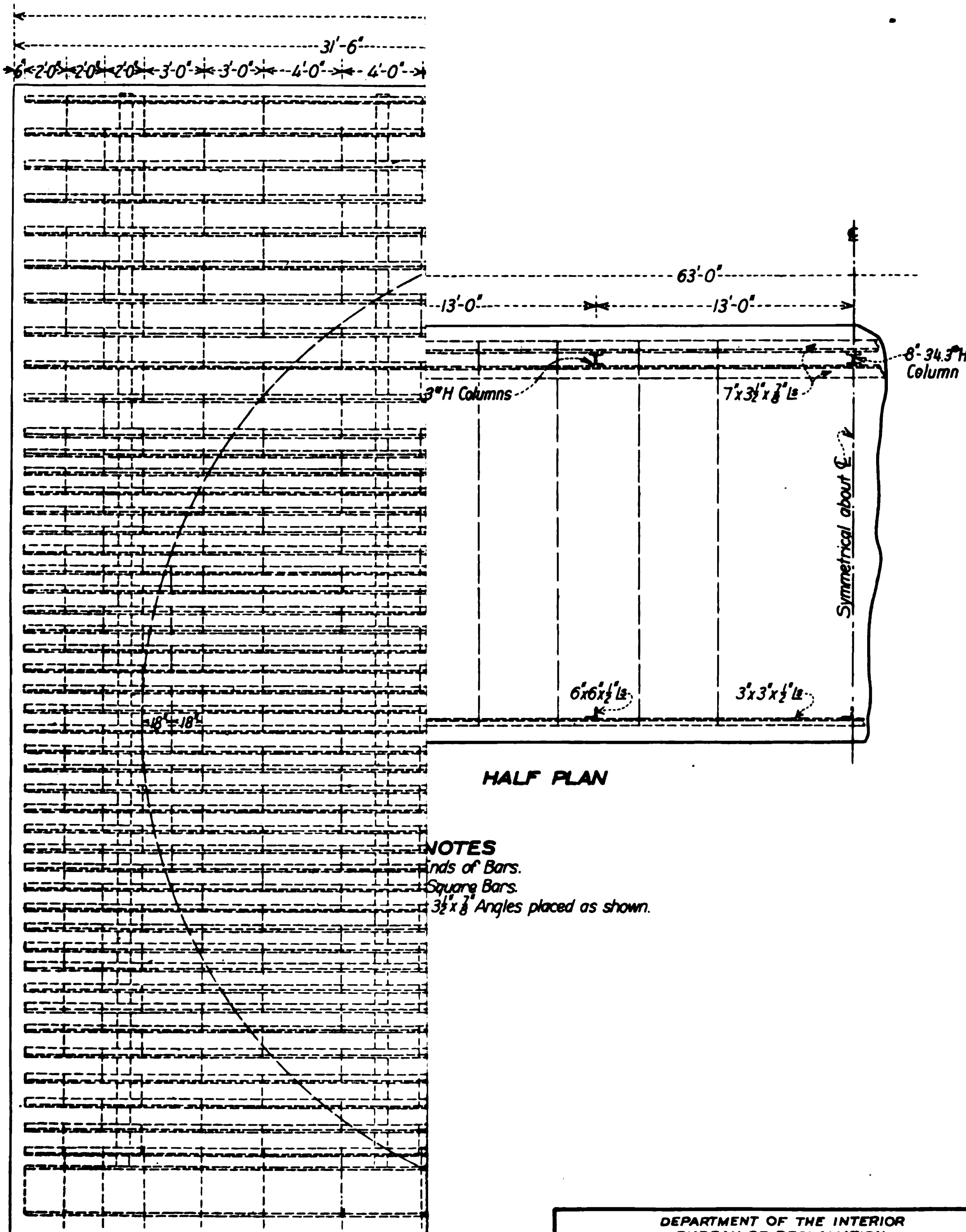


DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
BOULDER CANYON PROJECT

HOOVER DAM

OUTER DIVERSION TUNNEL PORTAL
INLET STRUCTURE

DRAWN: W.E.C.-P.A.K.	SUBMITTED:	B.K. Steele
TRACED: W.H.K.	RECOMMENDED:	J.L. Savage
CHECKED: P.B. O.L.R.	APPROVED:	R.F. Walter
24136	DENVER, COLO. DEC 1 1930	45-D-936



HALF PLAN

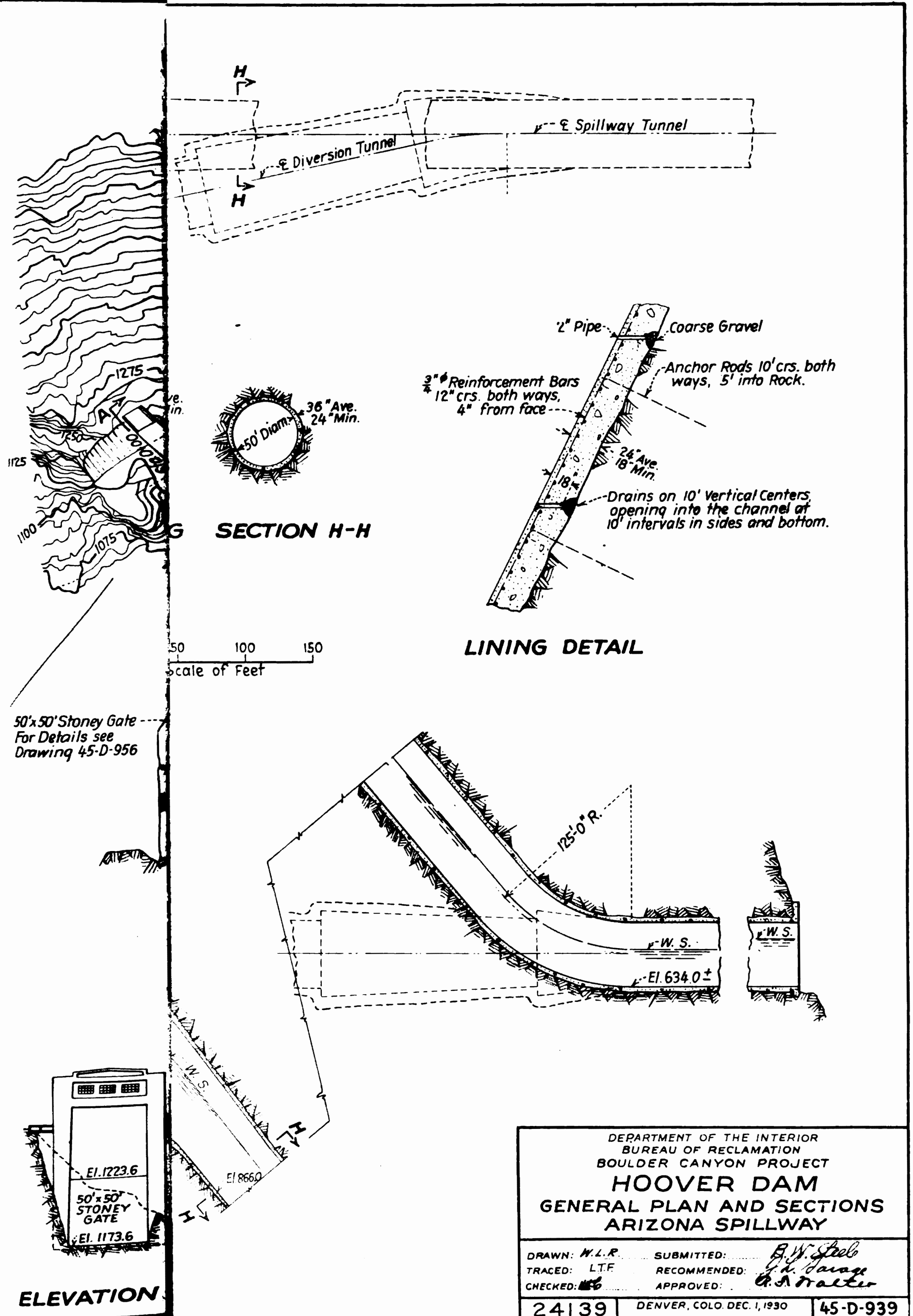
NOTES
...nds of Bars.
...Square Bars.
...3½"x⅞" Angles placed as shown.

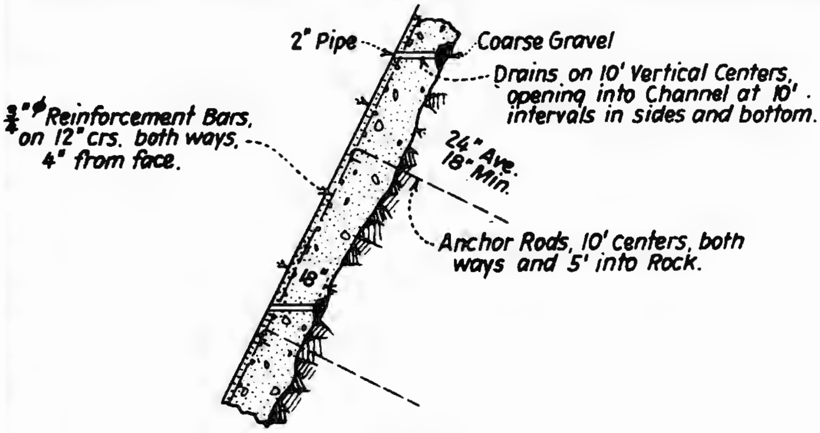
HALF ELEVATI...
(FRONT)

DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
BOULDER CANYON PROJECT
HOOVER DAM
OUTER DIVERSION TUNNEL PORTAL
CONCRETE BULKHEAD

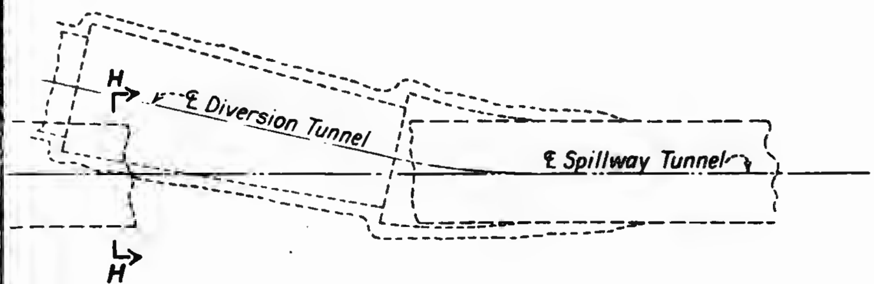
DRAWN: W.E.C. SUBMITTED: [signature]
TRACED: L.D.B.-C.E.M. RECOMMENDED: [signature]
CHECKED: P.E.O.-L.B. APPROVED: [signature]

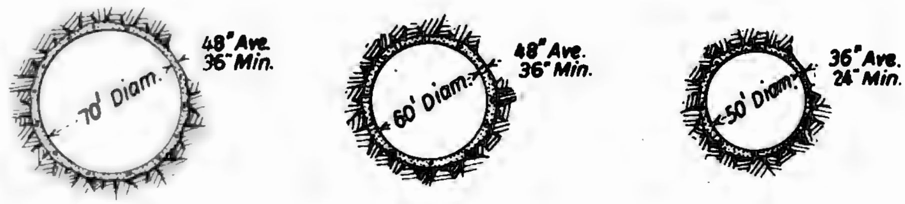
24137 DENVER, COLO. DEC. 1, 1930 45-D-937


H
H
℄ Spillway Tunnel
℄ Diversion Tunnel
1275
1250
1125
1100
1075
36" Ave.
24" Min.
50' Diam.
SECTION H-H
2" Pipe
Coarse Gravel
3/4" ϕ Reinforcement Bars
12" crs. both ways,
4" from face
Anchor Rods 10' crs. both
ways, 5' into Rock.
24" Ave.
18" Min.
18"
Drains on 10' Vertical Centers,
opening into the channel at
10' intervals in sides and bottom.
LINING DETAIL
50 100 150
Scale of Feet
50'x50' Stoney Gate
For Details see
Drawing 45-D-956
125'-0" R.
W. S.
El. 634.0±
W. S.
W. S.
El. 866.0
H
H
El. 1223.6
50'x50'
STONEY
GATE
El. 1173.6
ELEVATION
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
BOULDER CANYON PROJECT
HOOVER DAM
GENERAL PLAN AND SECTIONS
ARIZONA SPILLWAY
DRAWN: W.L.R.
TRACED: L.T.F.
CHECKED:
SUBMITTED:
RECOMMENDED:
APPROVED:
24139
DENVER, COLO. DEC. 1, 1930
45-D-939

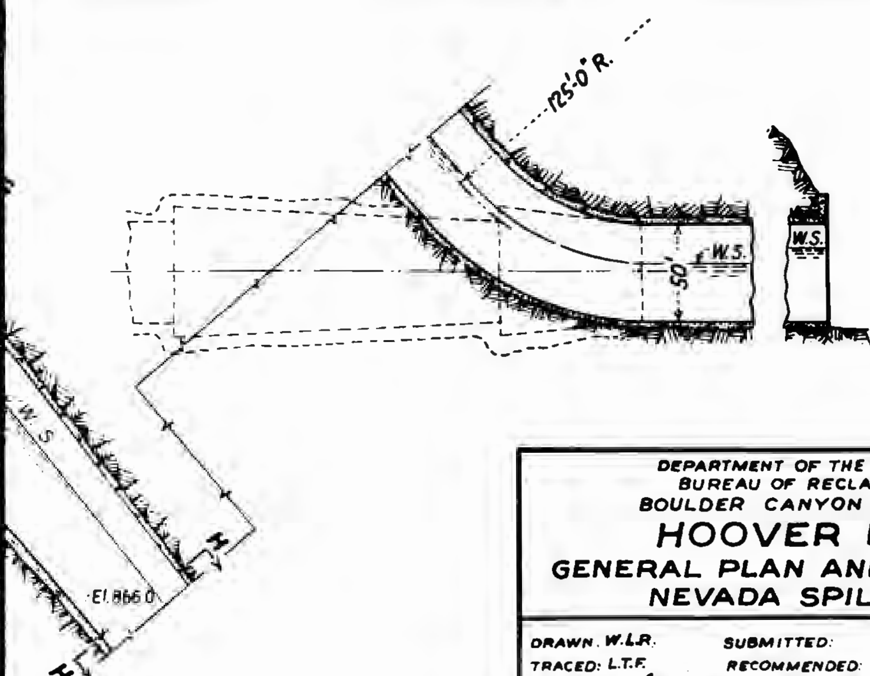


LINING DETAIL





SECTION F-F SECTION G-G SECTION H-H

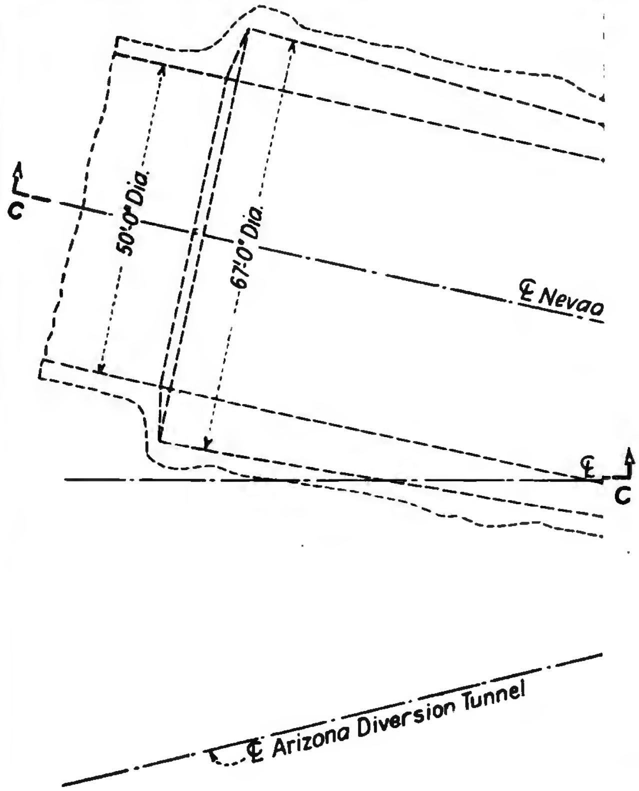


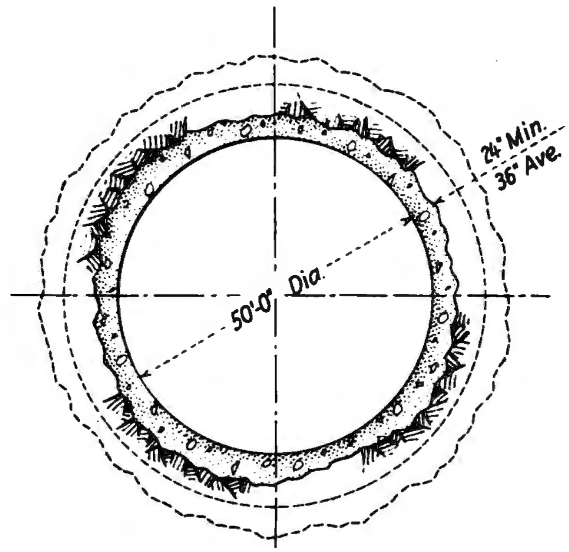
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
BOULDER CANYON PROJECT

HOOVER DAM
GENERAL PLAN AND SECTIONS
NEVADA SPILLWAY

DRAWN: W.L.R. SUBMITTED:
TRACED: L.T.F. RECOMMENDED:
CHECKED: APPROVED:

24140 DENVER, COLO. DEC 1, 1930 45-D-940



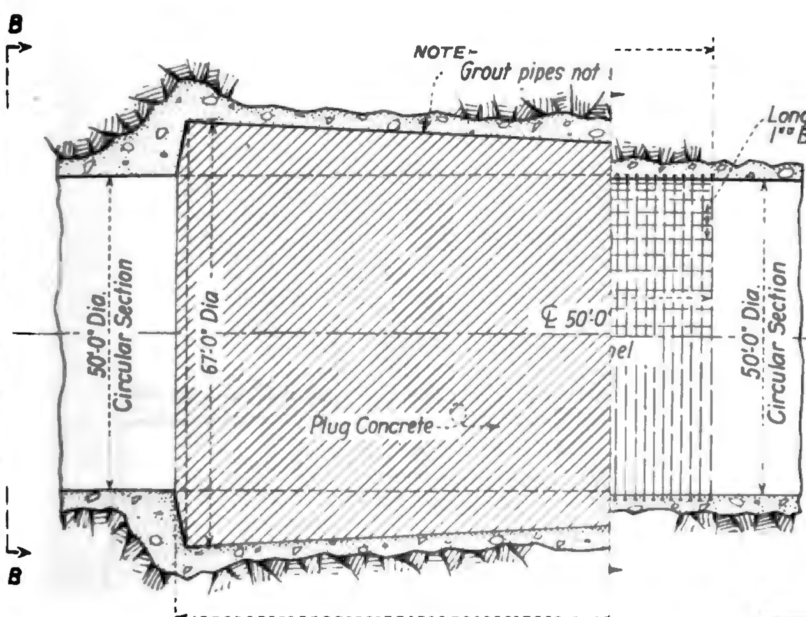


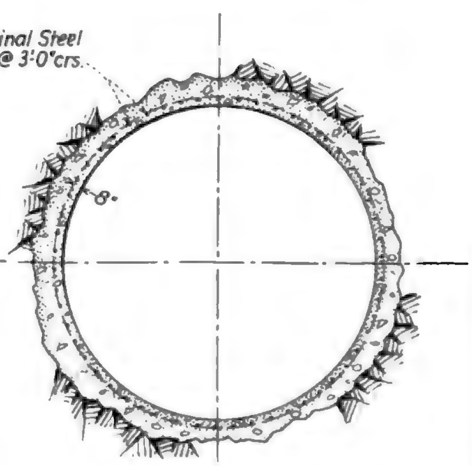
SECTIONAL ELEVATION B-B

'onform to
e during

'nel Section
'nform with

Lining
g as noted





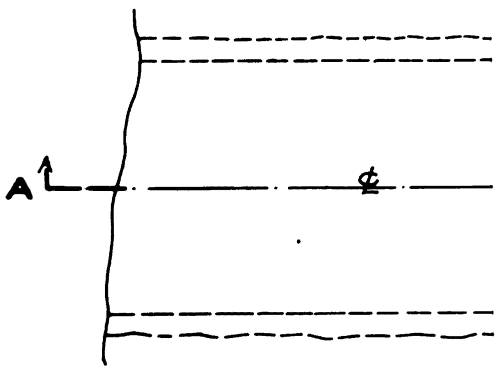
SECTIONAL ELEV. A-A

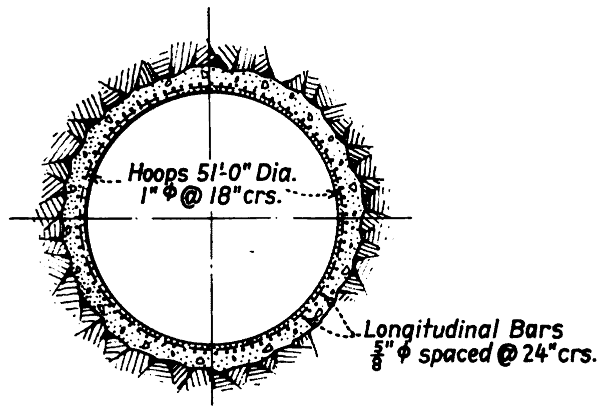
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
BOULDER CANYON PROJECT

HOOVER DAM
SPILLWAY TUNNEL PLUG
TYPICAL DESIGN

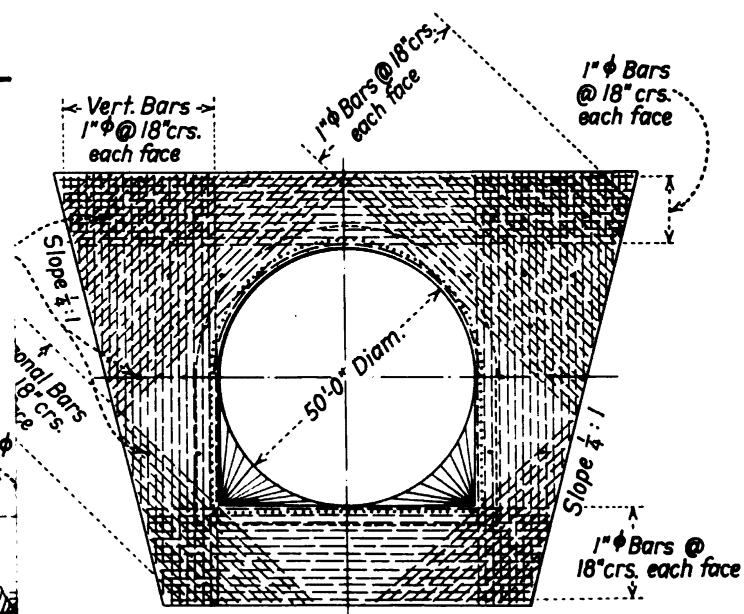
DRAWN: I.B.K. - J.D.C. SUBMITTED: B.W. Steele
TRACED: L.D.B. - C.B.G. RECOMMENDED: J.L. Savage
CHECKED: O.L.R. P.B. APPROVED: R.F. Walter

24141	DENVER, COLO., DEC. 1, 1930	45-D-941

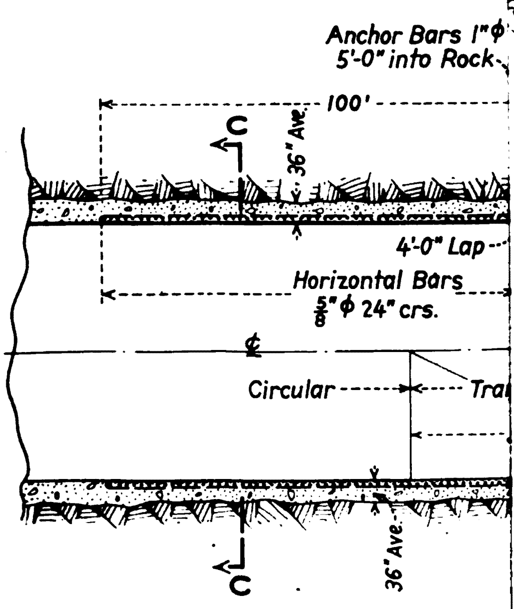




SECTION C-C



PORTAL REINFORCEMENT



SECTION A-A

DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
BOULDER CANYON PROJECT

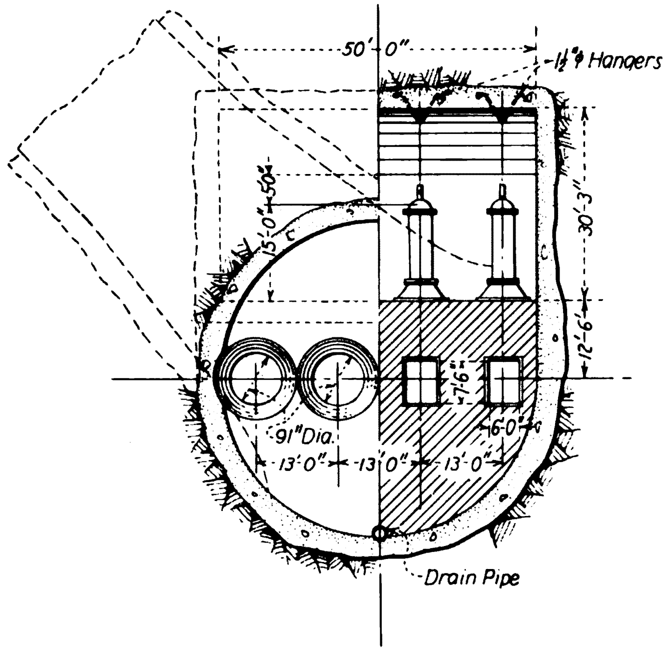
HOOVER DAM

SPILLWAY TUNNEL PORTAL OUTLET STRUCTURE

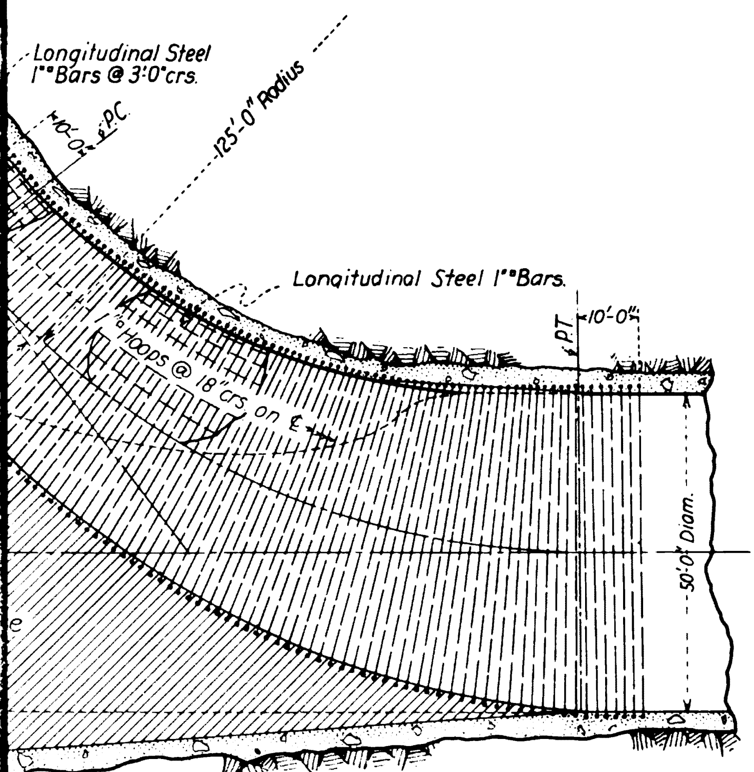
DRAWN: W.E.C. SUBMITTED:
TRACED: R.McC.-J.J.S. RECOMMENDED:
CHECKED: P.P. O.L.R. APPROVED:

24142 | DENVER, COLO., DEC. 1, 1930 | 45-D-942

NGS
45-D-945
45-D-946



SECTIONAL ELEV. A-A

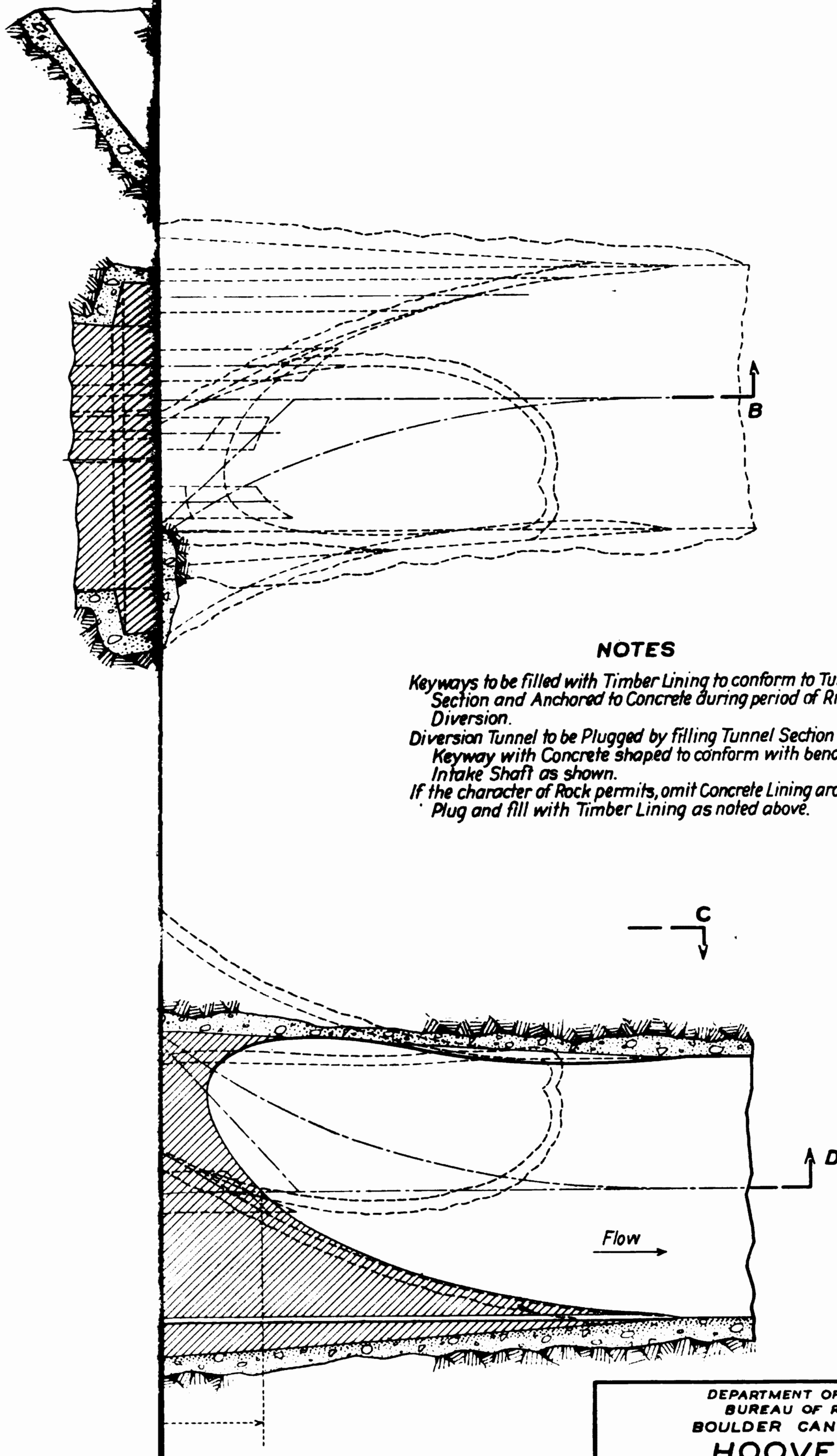


SECTION D-D

DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
BOULDER CANYON PROJECT
HOOVER DAM
UPSTREAM PLUG OUTLET WORKS
NEVADA SIDE

DRAWN: J.D.C.	SUBMITTED: B.W. Steele
TRACED: J.E.V.-P.M.W.	RECOMMENDED: J.L. Savage
CHECKED: O.L.R. P.B.	APPROVED: R.F. Walter

24143 DENVER, COLO. DEC. 1, 1930 45-D-943



NOTES

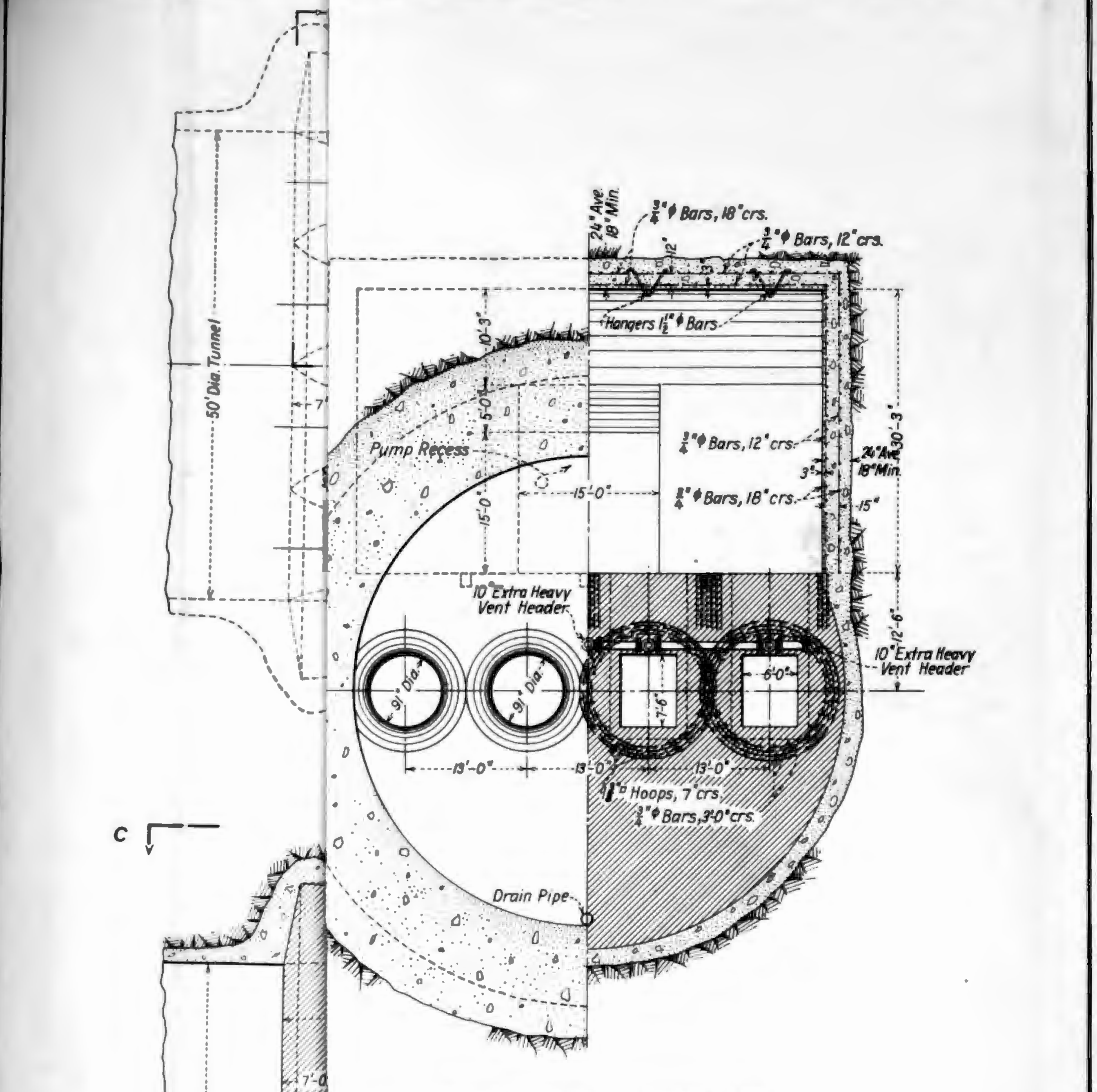
Keyways to be filled with Timber Lining to conform to Tunnel Section and Anchored to Concrete during period of River Diversion.
Diversion Tunnel to be Plugged by filling Tunnel Section and Keyway with Concrete shaped to conform with bend of Intake Shaft as shown.
If the character of Rock permits, omit Concrete Lining around Plug and fill with Timber Lining as noted above.

DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
BOULDER CANYON PROJECT

HOOVER DAM
UPSTREAM PLUG OUTLET WORKS ARIZONA SIDE

DRAWN: E.R.S. SUBMITTED: B. W. Steele
TRACED: C.B.B. RECOMMENDED: J. L. Savage
CHECKED: P.P.O.L.P. APPROVED: R. F. Walter

24144 | DENVER, COLO. DEC. 1, 1930 | 45-D-944



SECTIONAL ELEVATION A-A

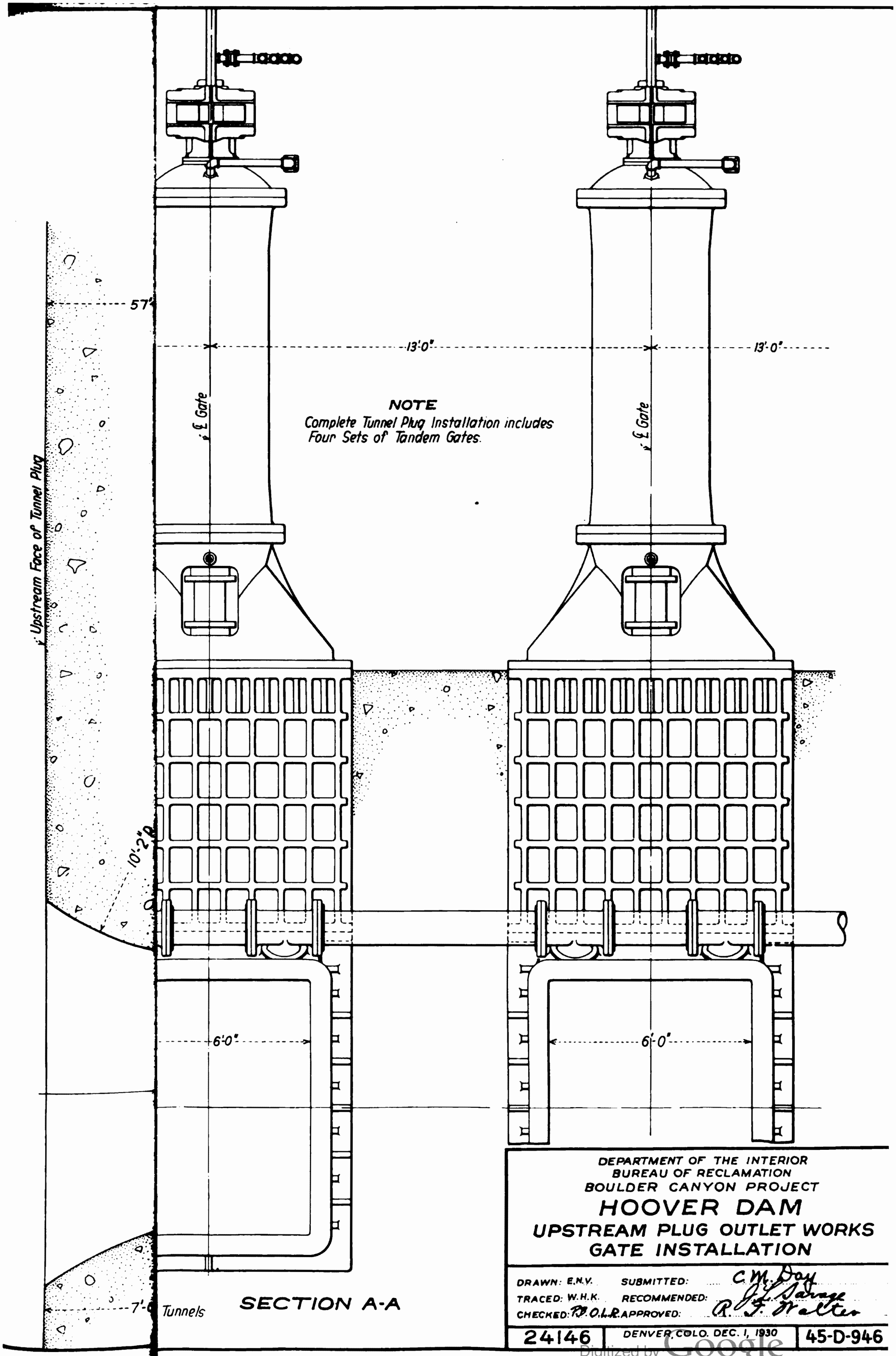
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
BOULDER CANYON PROJECT

HOOVER DAM

UPSTREAM PLUG OUTLET WORKS
REINFORCING DETAILS

DRAWN: F.J.T. SUBMITTED: B.W. Steele
TRACED: J.E.V. RECOMMENDED: J.L. Savage
CHECKED: O.L.B. P.B. APPROVED: R. F. Walter

24145 DENVER, COLO., DEC. 1, 1930 45-D-945



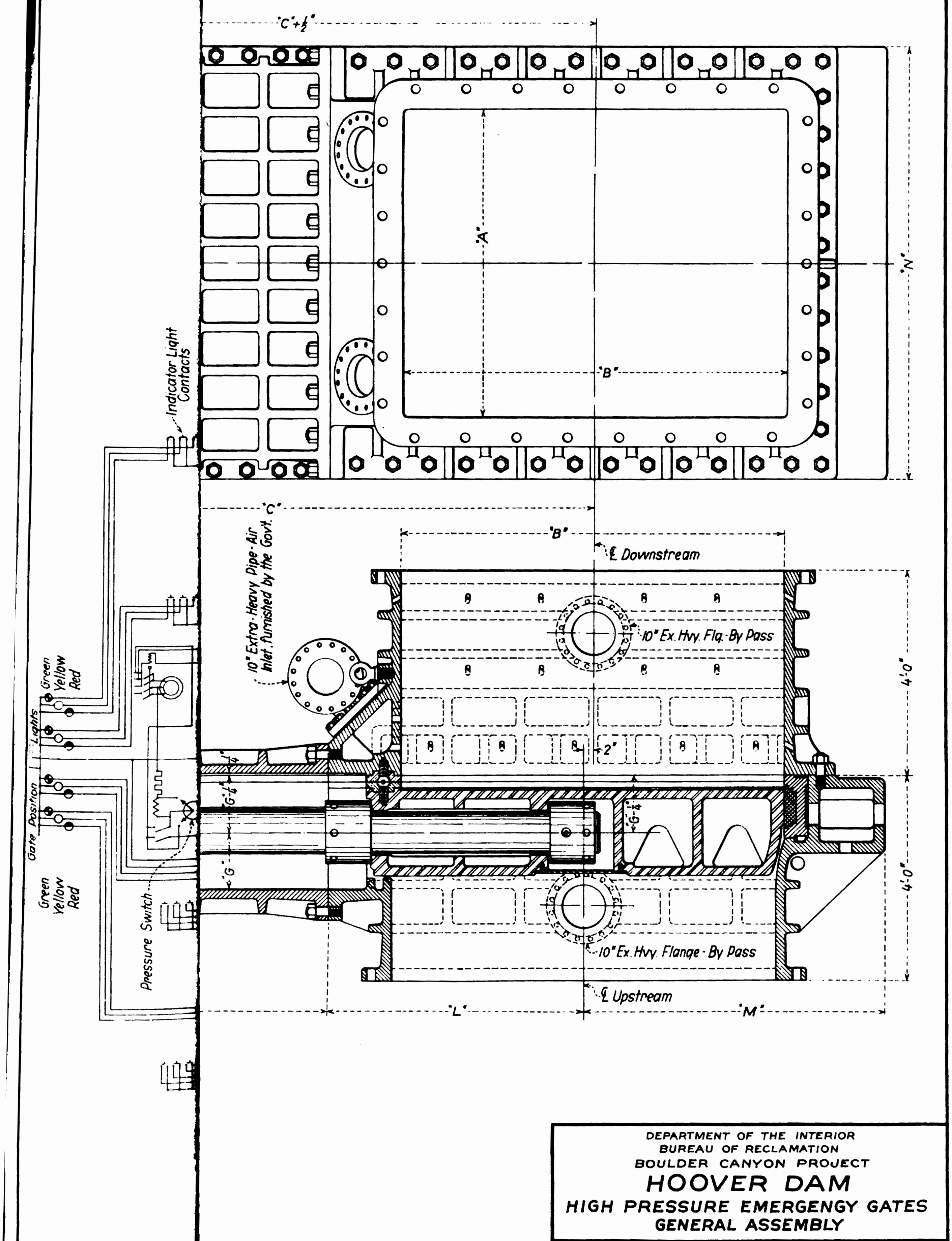
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
BOULDER CANYON PROJECT

HOOVER DAM

UPSTREAM PLUG OUTLET WORKS
GATE INSTALLATION

DRAWN: E.N.V. SUBMITTED: C. M. Day
TRACED: W.H.K. RECOMMENDED: J. L. Savage
CHECKED: P.B. O.L.R. APPROVED: R. F. Walter

24146 DENVER, COLO. DEC. 1, 1930 45-D-946



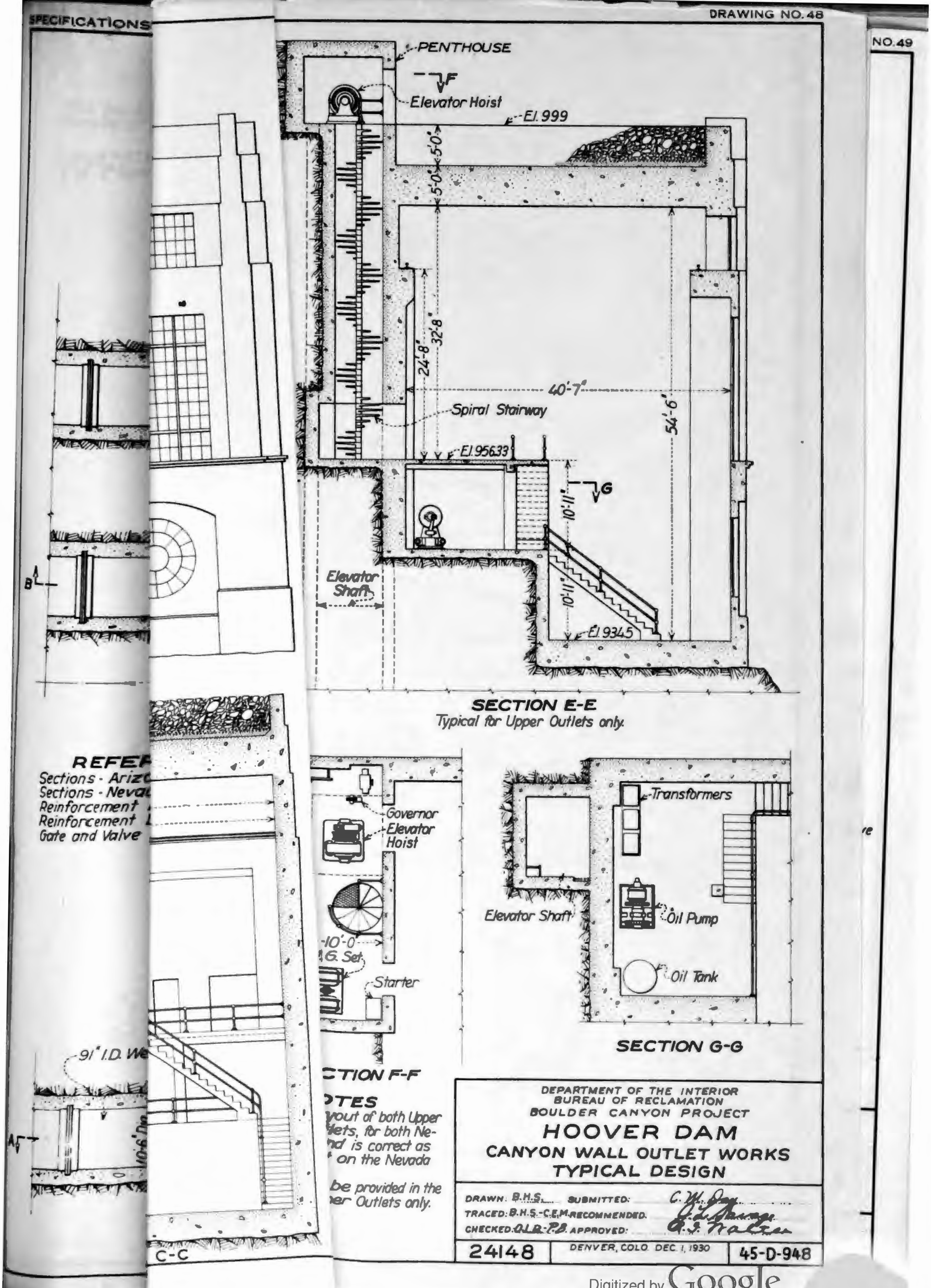
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
BOULDER CANYON PROJECT

HOOVER DAM

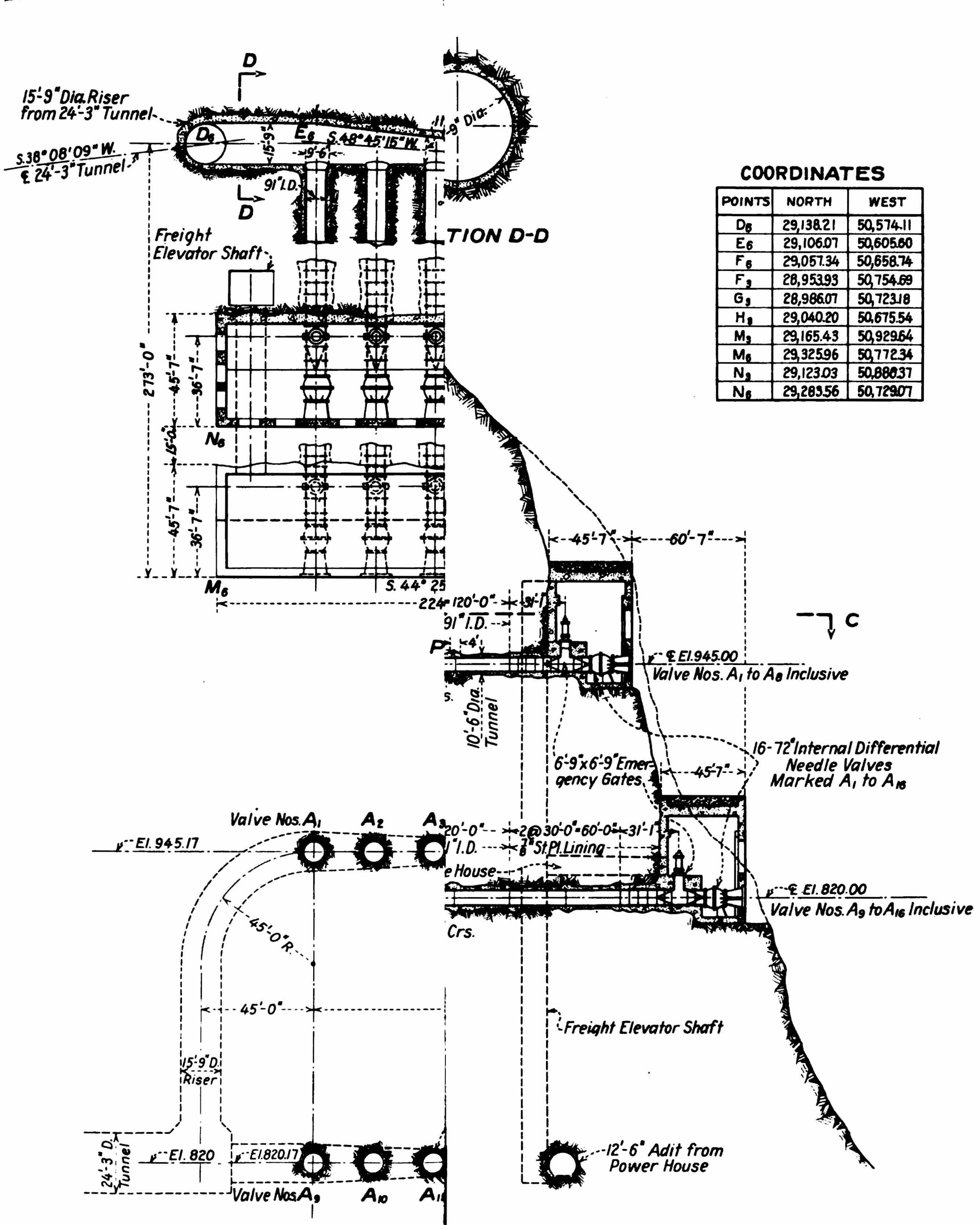
HIGH PRESSURE EMERGENCY GATES
GENERAL ASSEMBLY

DRAWN: E.B.H.	SUBMITTED: C. M. Day
TRACED: W.H.K.	RECOMMENDED: J. L. Savage
CHECKED: P.B. O.L.R.	APPROVED: R. F. Walter

24147 — DENVER, COLO., DEC. 1, 1930 — 45-D-947



SPECIFICATIONS
DRAWING NO. 48
NO. 49
PENTHOUSE
F
Elevator Hoist
El. 999
5'-0"
5'-0"
24'-8"
32'-8"
40'-7"
54'-6"
Spiral Stairway
El. 956.33
G
10'-11"
10'-11"
El. 934.5
Elevator Shaft
SECTION E-E
Typical for Upper Outlets only.
REFER
Sections - Ariz
Sections - Nevad
Reinforcement
Reinforcement
Gate and Valve
Governor
Elevator Hoist
10'-0"
G. Set
Starter
TION F-F
TES
yout of both Upper
lets, for both Ne-
nd is correct as
on the Nevada
be provided in the
er Outlets only.
Transformers
Elevator Shaft
Oil Pump
Oil Tank
SECTION G-G
91" I.D. We
10'-6" Dia
B
A
C-C
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
BOULDER CANYON PROJECT
HOOVER DAM
CANYON WALL OUTLET WORKS
TYPICAL DESIGN
DRAWN: B.H.S.
SUBMITTED:
TRACED: B.H.S.-C.E.M.
RECOMMENDED:
CHECKED: O.L.B.-P.B.
APPROVED:
24148
DENVER, COLO. DEC. 1, 1930
45-D-948



COORDINATES

POINTS	NORTH	WEST
D_6	29,138.21	50,574.11
E_6	29,106.07	50,605.60
F_6	29,057.34	50,658.74
F_3	28,953.93	50,754.69
G_3	28,986.07	50,723.18
H_3	29,040.20	50,675.54
M_3	29,165.43	50,929.64
M_6	29,325.96	50,772.34
N_3	29,123.03	50,888.37
N_6	29,283.56	50,729.07

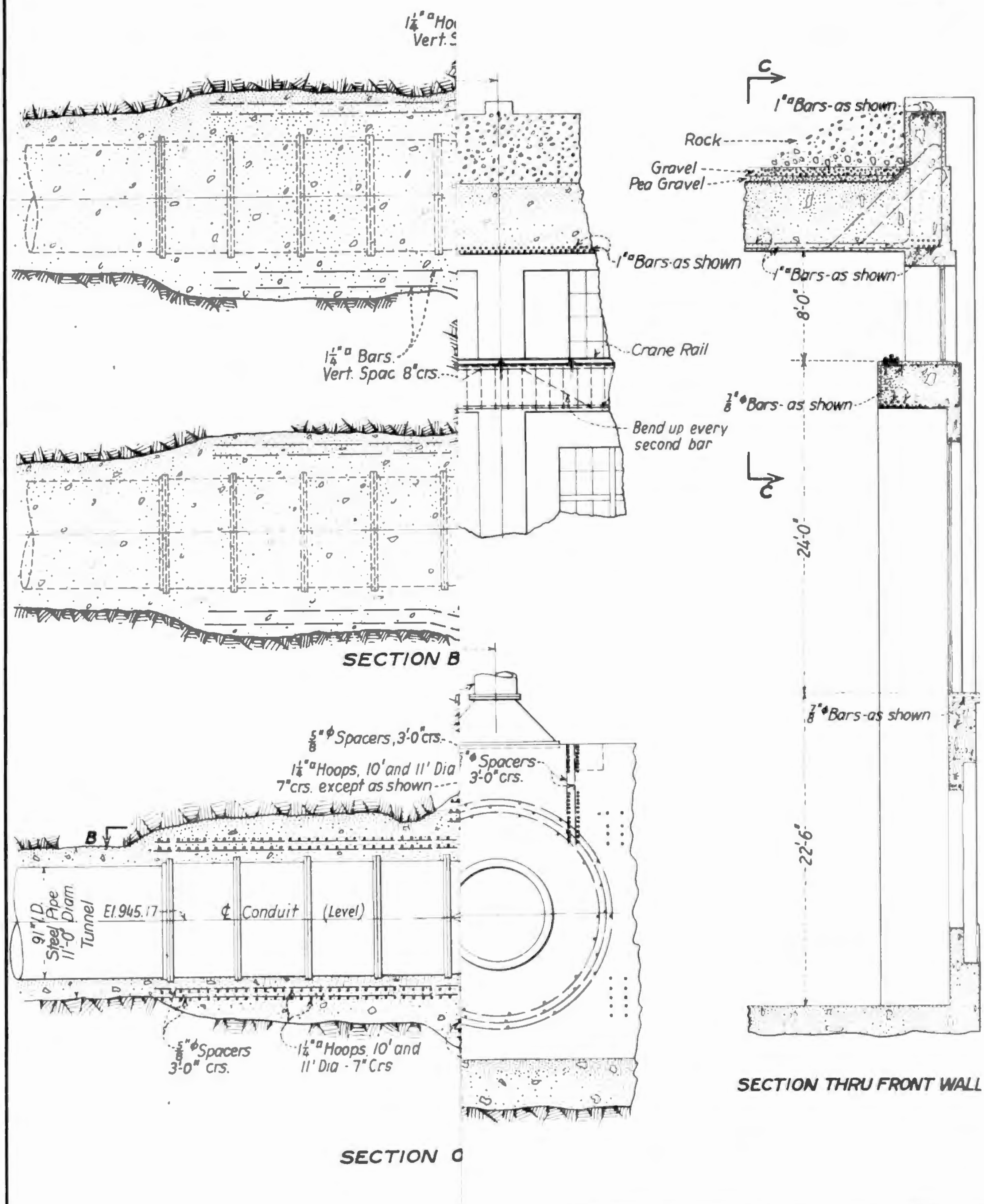
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
BOULDER CANYON PROJECT

HOOVER DAM

CANYON WALL OUTLET WORKS SECTIONS - ARIZONA SIDE

DRAWN: S.E.R.-J.D.C. SUBMITTED: B. H. [signature]
TRACED: L.D.B.-J.E.V. RECOMMENDED: J. L. Savage
CHECKED: P.B.Q.-L.R. APPROVED: [signature]

24149 | DENVER, COLO., DEC. 1, 1930 | 45-D-949



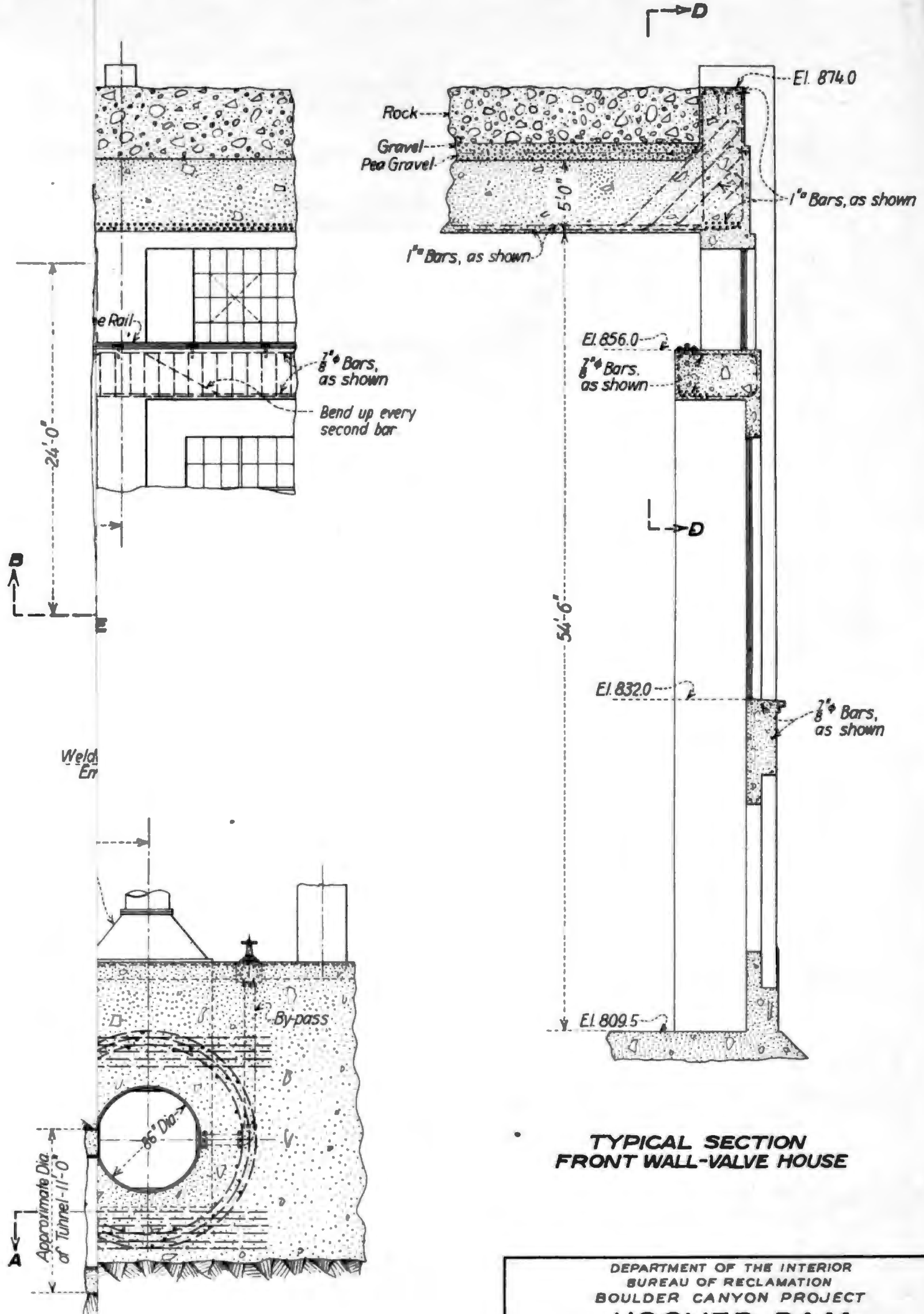
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
BOULDER CANYON PROJECT

HOOVER DAM

CANYON WALL OUTLET WORKS
REINFORCING DETAILS ELEVATION 945

DRAWN: H.S.M.	SUBMITTED: B.W. Steele
TRACED: W.H.S.-C.E.M.	RECOMMENDED: J.L. Savage
CHECKED: P.R.Q.L.R.	APPROVED: R.F. Walter

24151 DENVER, COLO. DEC. 1, 1930 45-D-951



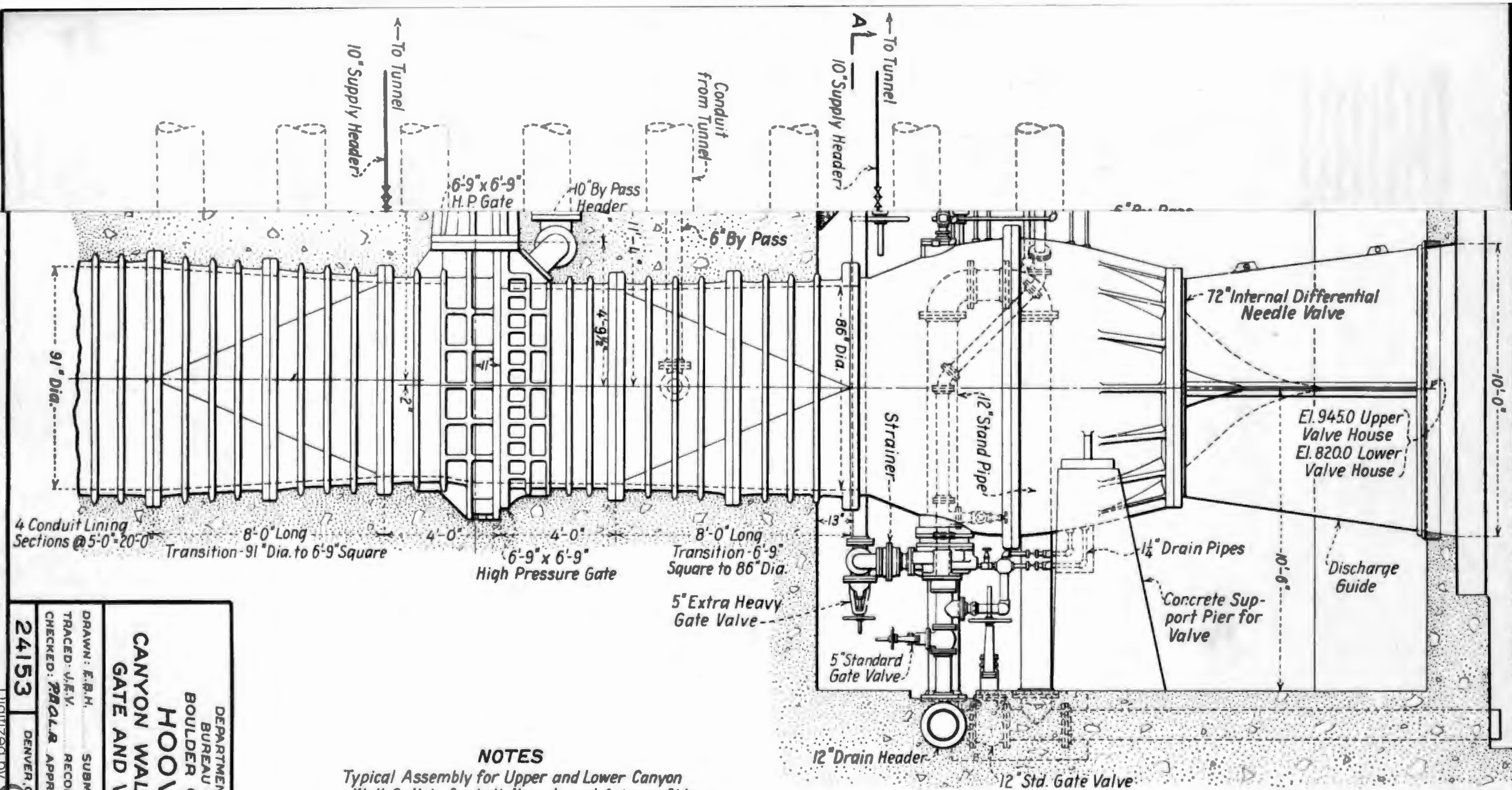
TYPICAL SECTION
FRONT WALL-VALVE HOUSE

NOTE
Reinforcing Details typical for both Lower Outlet Houses Nevada and Arizona sides
All Reinforcement Hoops to be welded in field.

DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
BOULDER CANYON PROJECT
HOOVER DAM
CANYON WALL OUTLET WORKS
REINFORCING DETAILS ELEVATION 820

DRAWN: L.T.W.	SUBMITTED:	B.H. Steele
TRACED: C.E.M.	RECOMMENDED:	J.L. Savage
CHECKED: P.B. O.L.R.	APPROVED:	R.F. Walter

24152 DENVER, COLO. DEC. 1, 1930 45-D-952



NOTES

Typical Assembly for Upper and Lower Canyon Wall Outlets, for both Nevada and Arizona Sides

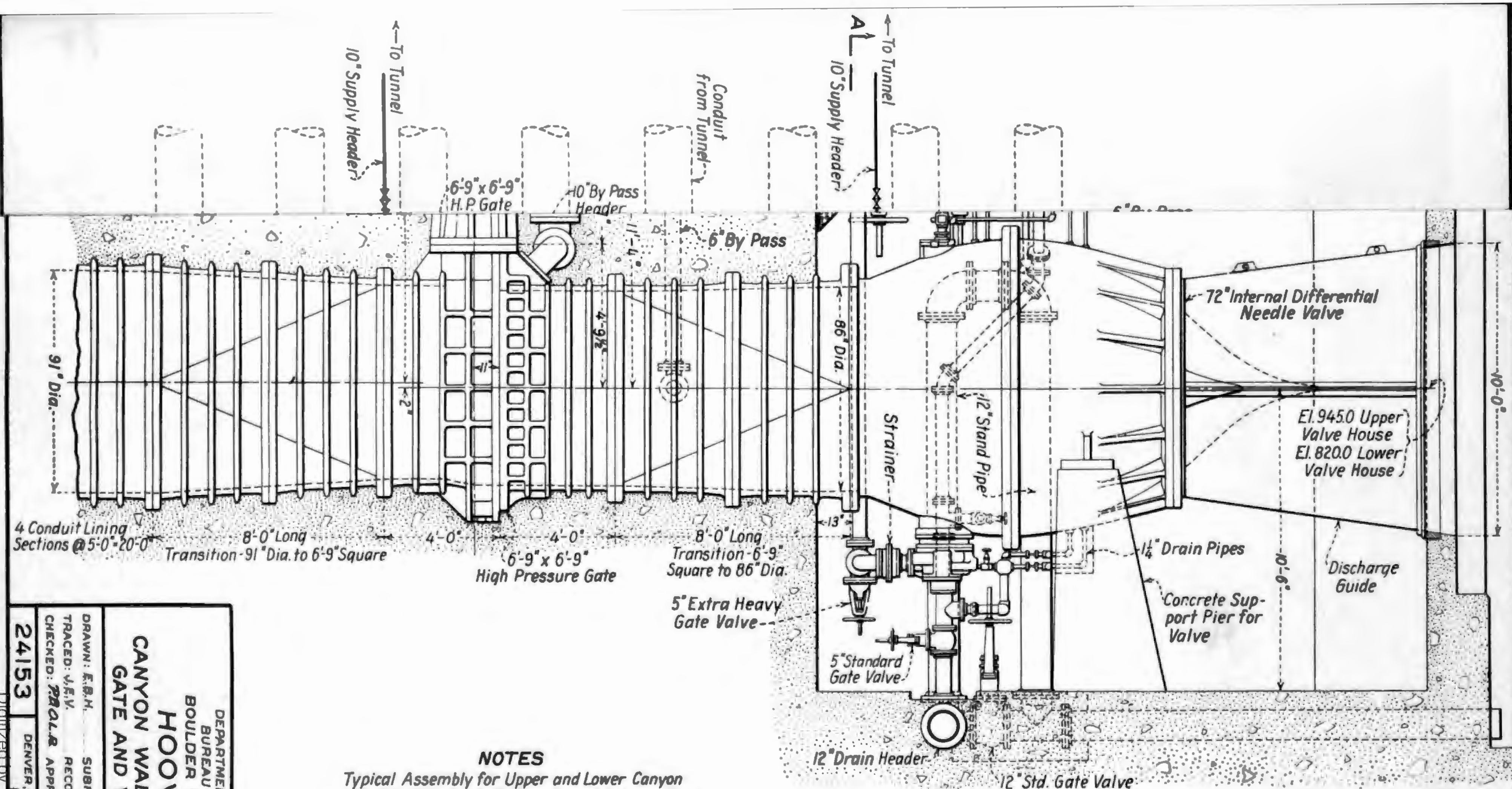
SECTION A-A

DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
BOULDER CANYON PROJECT

HOOVER DAM
CANYON WALL OUTLET WORKS
GATE AND VALVE ASSEMBLY

DRAWN: E.B.H. SUBMITTED: C. M. Day
TRACED: J.E.V. RECOMMENDED: [signature]
CHECKED: P.R.G.L.R. APPROVED: R. F. Walter
DENVER, COLO., DEC. 1, 1930

24153 | 45-D-9



NOTES

Typical Assembly for Upper and Lower Canyon Wall Outlets, for both Nevada and Arizona Sides

SECTION A-A

DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
BOULDER CANYON PROJECT

HOOVER DAM

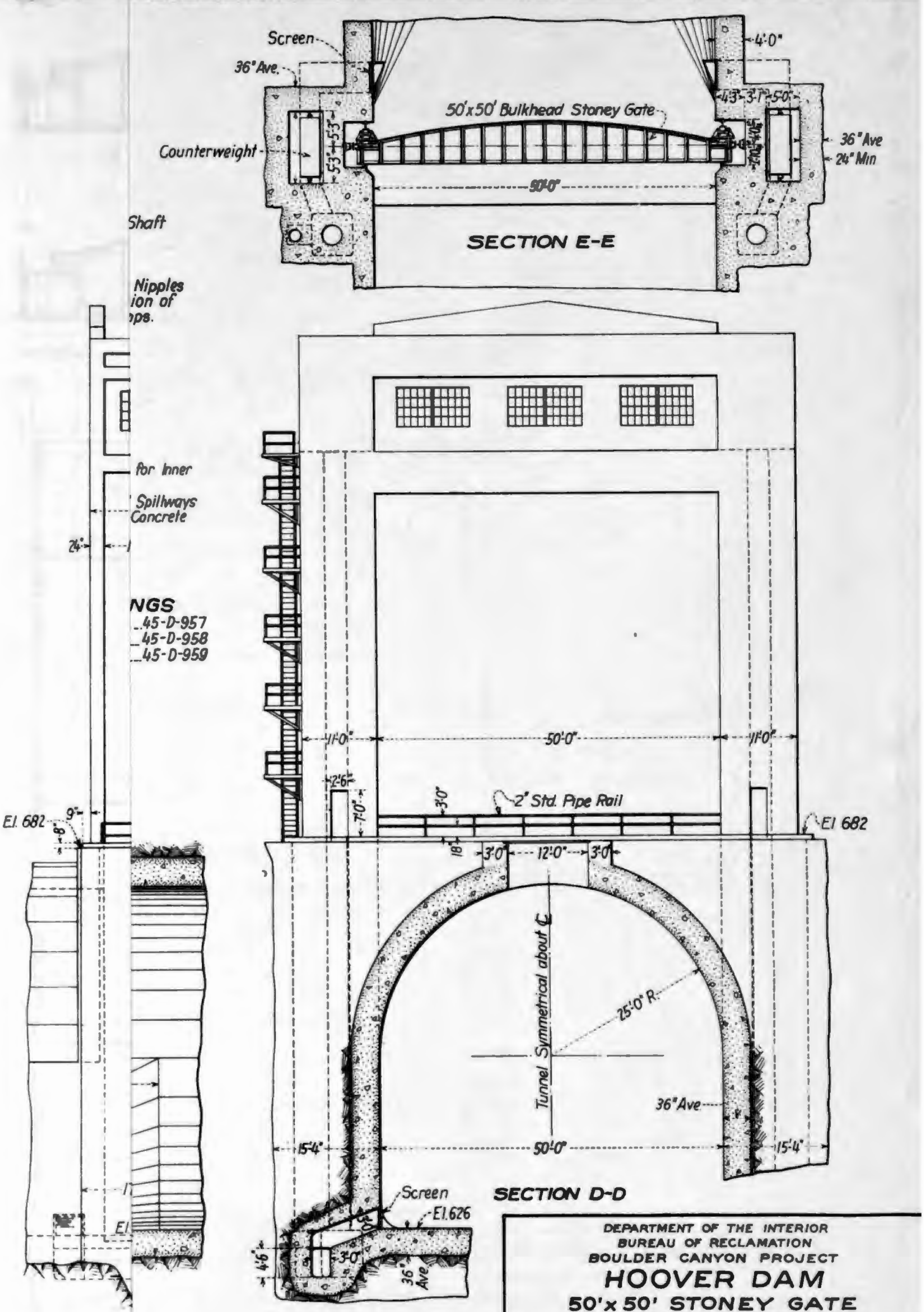
CANYON WALL OUTLET WORKS GATE AND VALVE ASSEMBLY

DRAWN: E.B.H. — SUBMITTED: C.W. [signature]
TRACED: J.E.V. — RECOMMENDED: [signature]
CHECKED: P.R.O.L.R. — APPROVED: R. F. Walter

DENVER, COLO., DEC. 1, 1930

24153 — 45-D-953

SPECIFICATIONS NO. 519 — DRAWING NO. 5

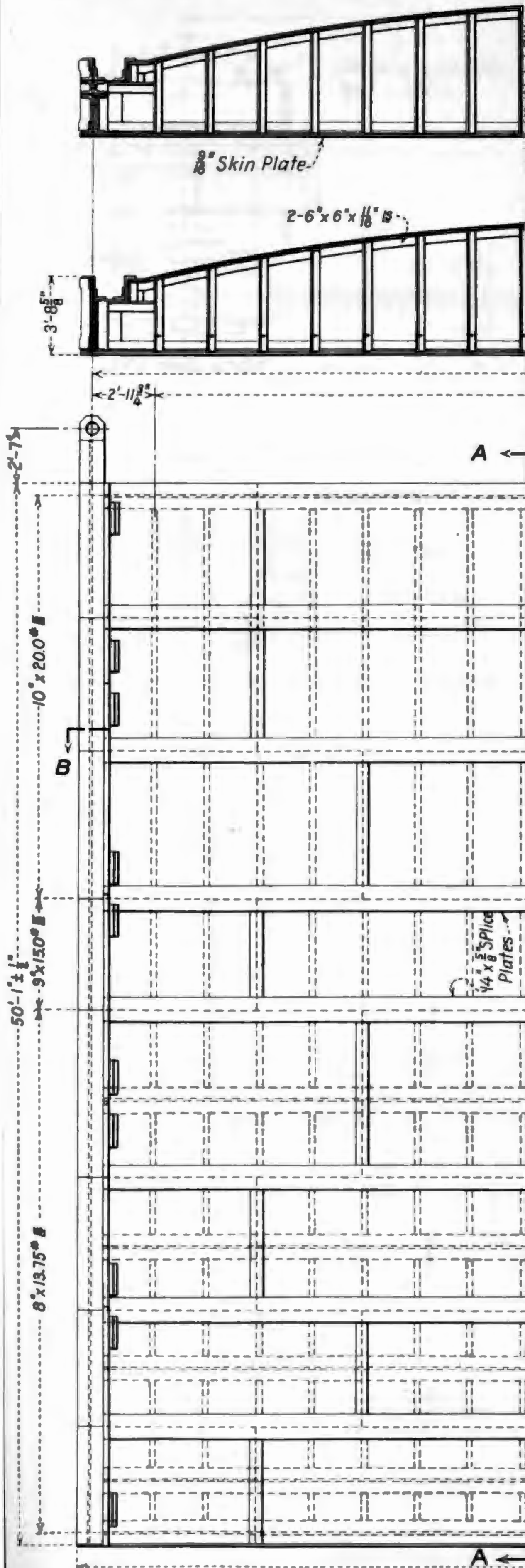


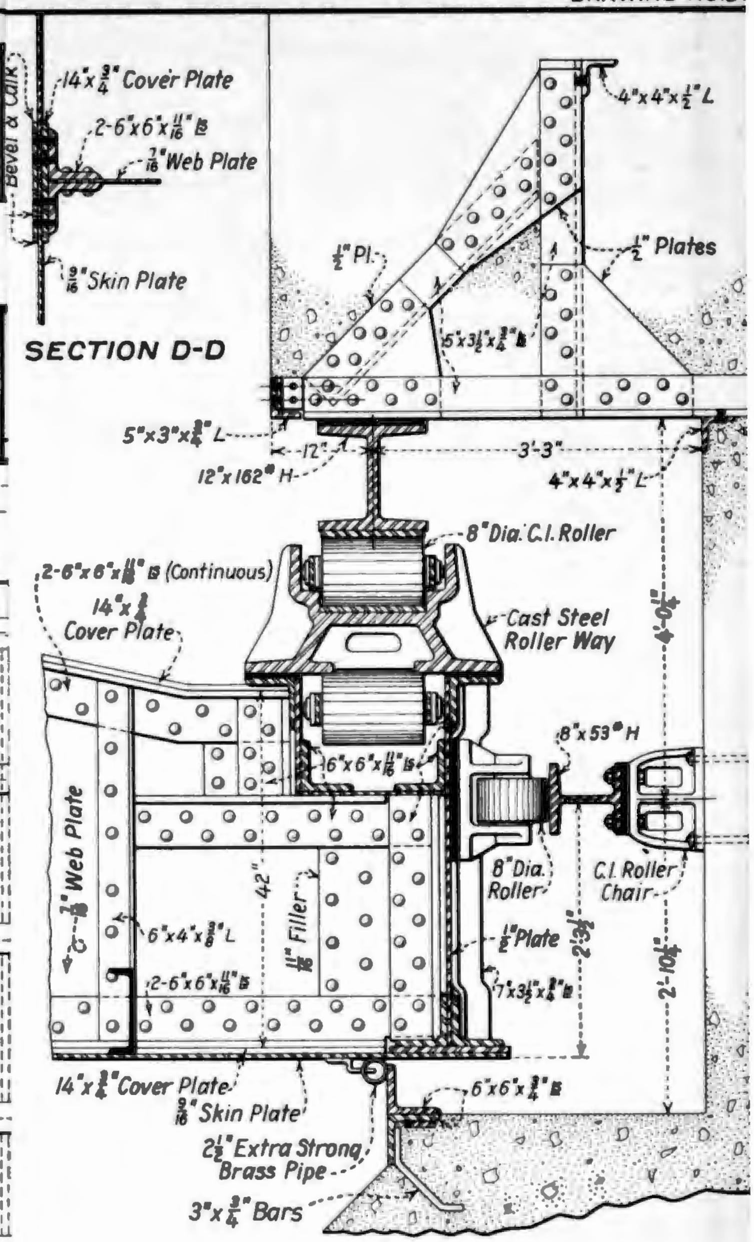
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
BOULDER CANYON PROJECT

HOOVER DAM
50'x 50' STONEY GATE
TYPICAL DESIGN

DRAWN: O.C.S. - E.H.V. SUBMITTED: ....
TRACED: C.B.G. - C.E.M. RECOMMENDED: ....
CHECKED: O.L.B. ..... APPROVED: R. F. Walter

24156	DENVER, COLO. DEC 1, 1930	45-D-956





SECTION D-D

HORIZONTAL END SECTION
OF GATE LEAF IN PLACE

NOTES

Skin Plate to be Field Riveted to Cross Girders with 7/8" Rivets. Joints on ℄ of Girders (except Joint "K").
All Splice plates to be bevel sheared for field calking.
Skin Plate and Splice Plates to be of Copper bearing Steel.

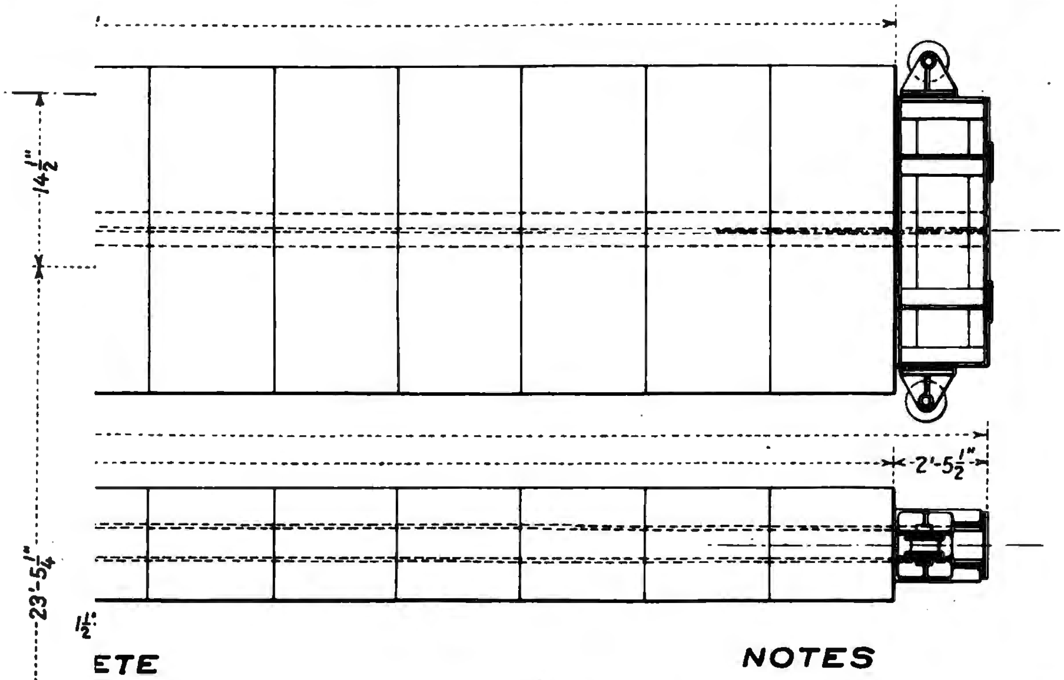
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
BOULDER CANYON PROJECT

HOOVER DAM
50'x 50' STONEY GATE LEAF ASSEMBLY

DRAWN: P.A.K.-E.N.V. SUBMITTED: C.W. Day
TRACED: J.E.V. RECOMMENDED: J.L. Savage
CHECKED: R.B. O.L.B. APPROVED: R.F. Walter

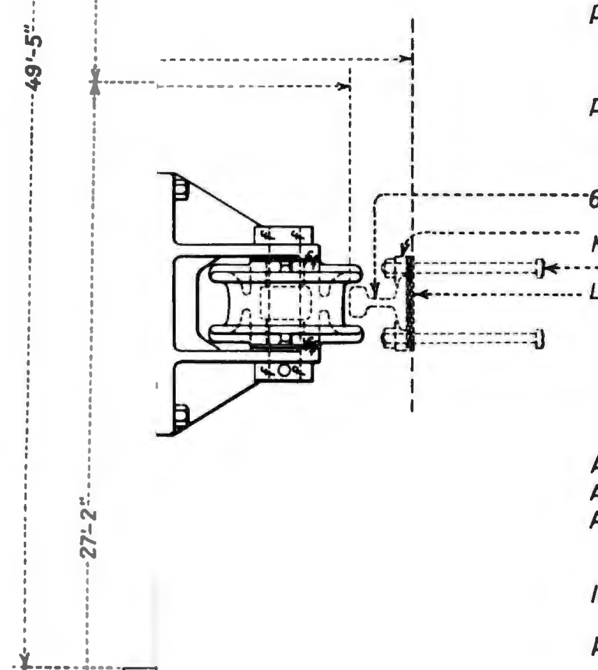
24157 | DENVER, COLO., DEC. 1, 1930 | 45-D-957

UN
GA



NOTES

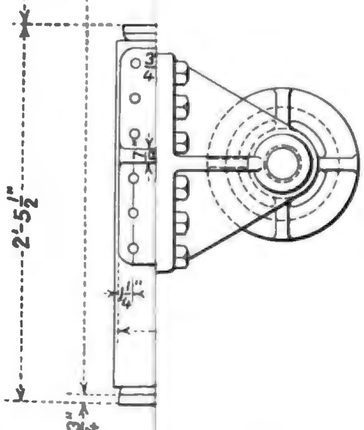
The required average weight for each counterweight block is 11,200 Pounds.
After counterweight blocks are placed in final position on hanger the stem hole should be filled with concrete of proportions 1 part of cement to 10 parts sand and gravel well rammed in place.
Provide 1"Φ grout holes leading to hoisting eye recesses. As each block is placed in final position on hanger pour thin grout of 1 part of cement and 5 parts sand thru grout holes to fill hoisting eye recesses.
Particular care shall be observed to make hole in top block around counterweight stem water tight.



60 Lb. Guide Rails. A.S.C.E. Std. No. 6040 C.S.Co. with No. 6040 Splice Bars and Splice Bolts.
No. 103 Carnegie Standard Rail Clips.
3/4"x12" Galvanized Bolts with Hex. Nuts.
Laminated Steel Shim 3/4" thick by 2" wide by 7 1/4" long.
} FURNISHED BY THE GOVERNMENT

SHOP NOTES

All Rivets shall be 7/8"
All Rivet Holes shall be 15/16"
All Stiffener Angles shall have milled ends and bear against the outstanding legs of the horizontal angles at top and bottom.
10" H Column members forming stems of hangers shall be straight and true within 1/4" in 20 Ft. of length.
Painting- Two Shop Coats of Red Lead.



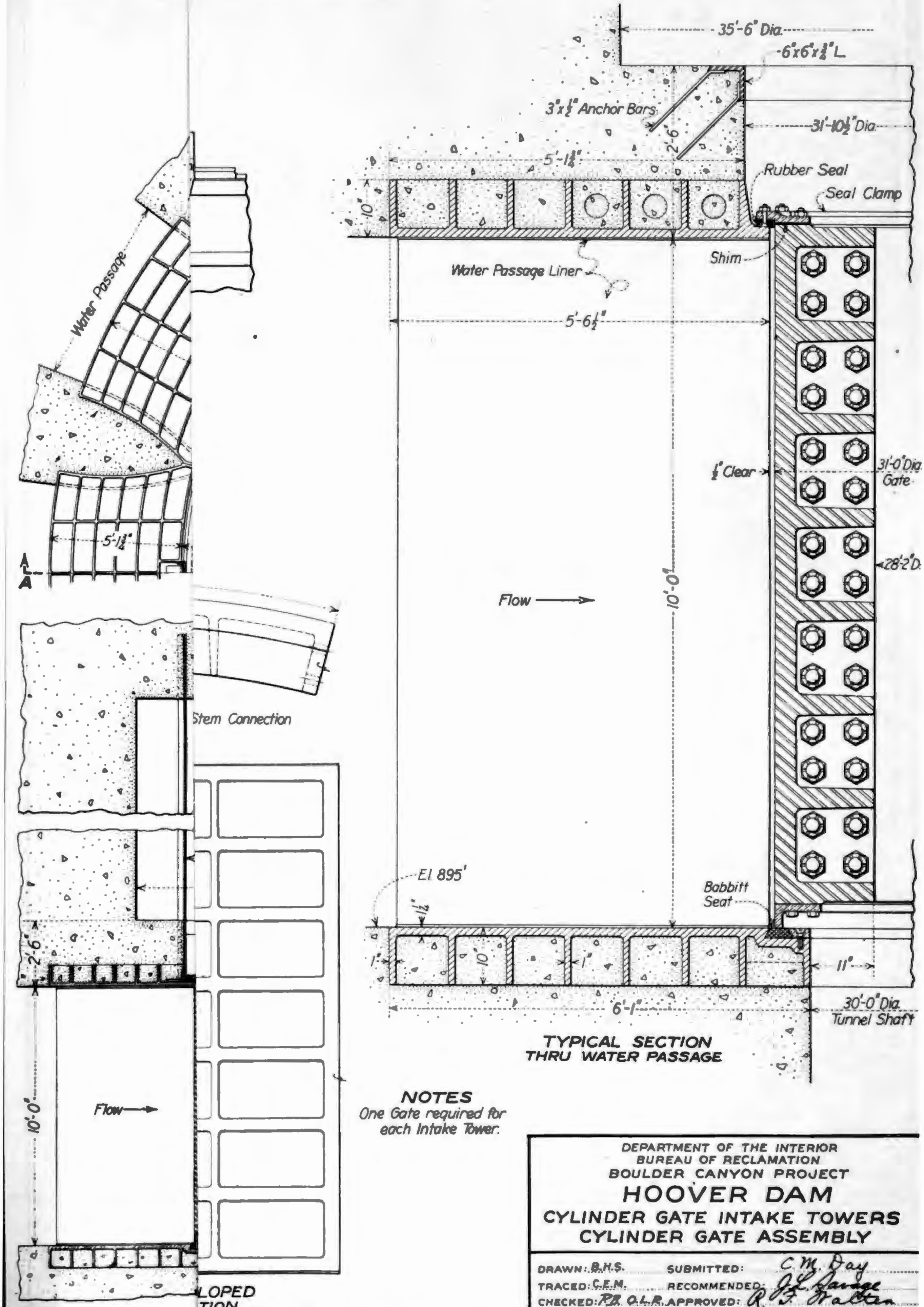
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
BOULDER CANYON PROJECT

HOOVER DAM

50'x50' STONEY GATE COUNTERWEIGHT ASSEMBLY

DRAWN: P.A.K.	SUBMITTED: C. M. Day
TRACED: L.D.B.-A.A.A.	RECOMMENDED: J. L. Savage
CHECKED: P.R.G.L.R.	APPROVED: R. F. Walter

24159	DENVER, COLO., DEC. 1, 1930	45-D-959



NOTES

One Gate required for each Intake Tower.

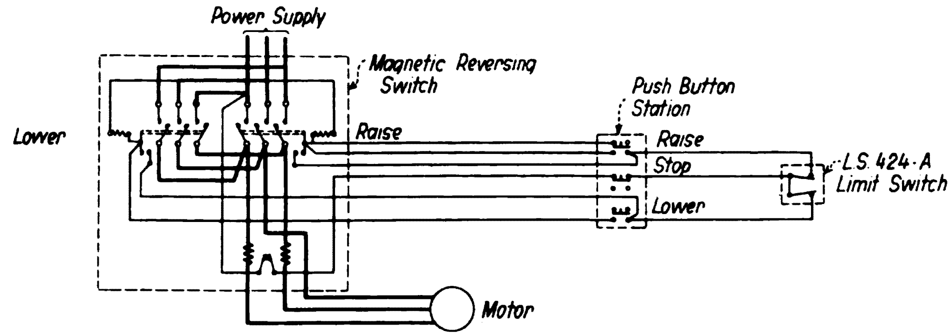
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
BOULDER CANYON PROJECT

HOOVER DAM

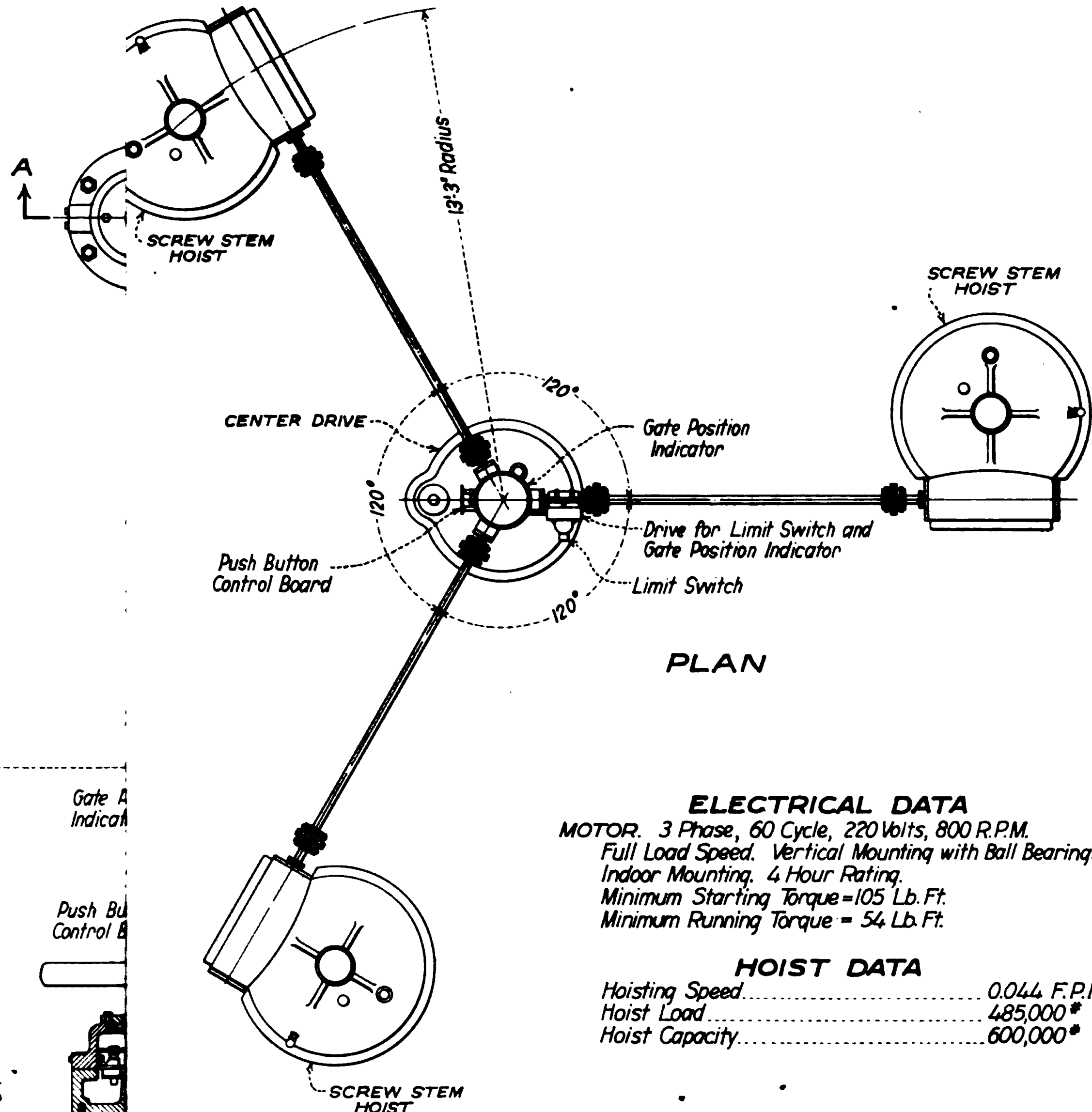
CYLINDER GATE INTAKE TOWERS
CYLINDER GATE ASSEMBLY

DRAWN: B.H.S. SUBMITTED: C. M. Day
TRACED: C.E.M. RECOMMENDED: J. L. Savage
CHECKED: P.B. O.L.R. APPROVED: R. F. Walter

24162 DENVER, COLO. DEC. 1, 1930 45-D-962



WIRING DIAGRAM



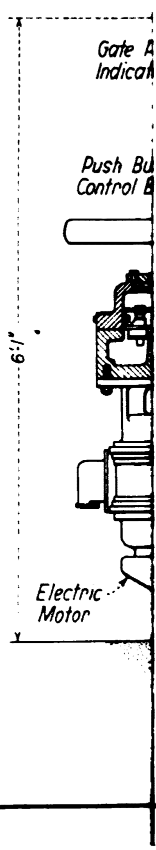
PLAN

ELECTRICAL DATA

MOTOR. 3 Phase, 60 Cycle, 220 Volts, 800 R.P.M.
Full Load Speed. Vertical Mounting with Ball Bearings.
Indoor Mounting. 4 Hour Rating.
Minimum Starting Torque = 105 Lb. Ft.
Minimum Running Torque = 54 Lb. Ft.

HOIST DATA

Hoisting Speed.............................. 0.044 F.P.M.
Hoist Load.................................... 485,000#
Hoist Capacity................................ 600,000#



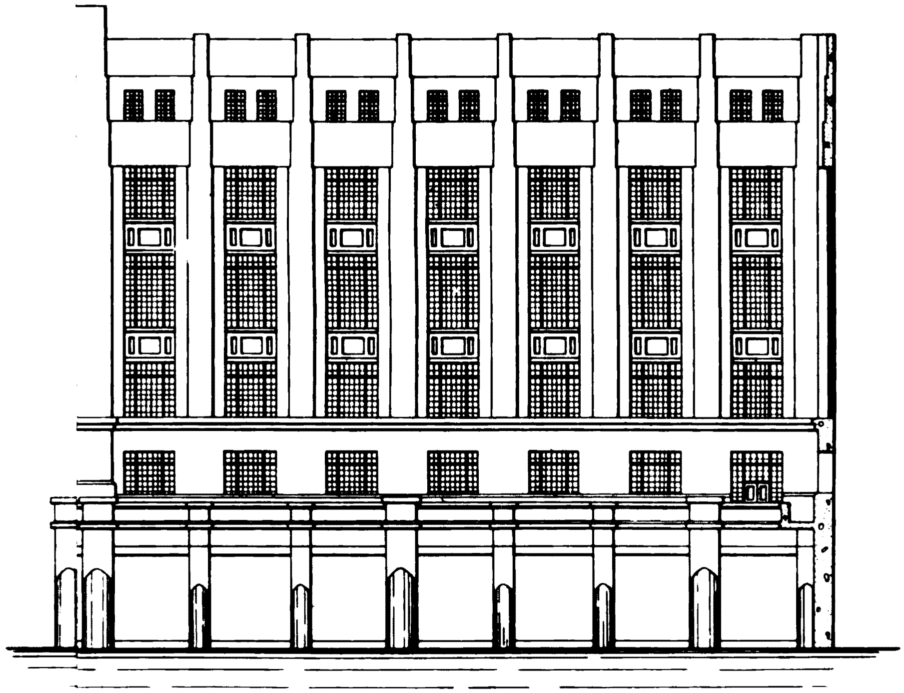
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
BOULDER CANYON PROJECT

HOOVER DAM

CYLINDER GATE INTAKE TOWERS
GATE HOIST ASSEMBLY

DRAWN: P.A.K.-E.B.H. SUBMITTED: C.M. Day
TRACED: W.H.K. RECOMMENDED: J. L. Savage
CHECKED: P.B. O.L.R. APPROVED: R. F. Walter

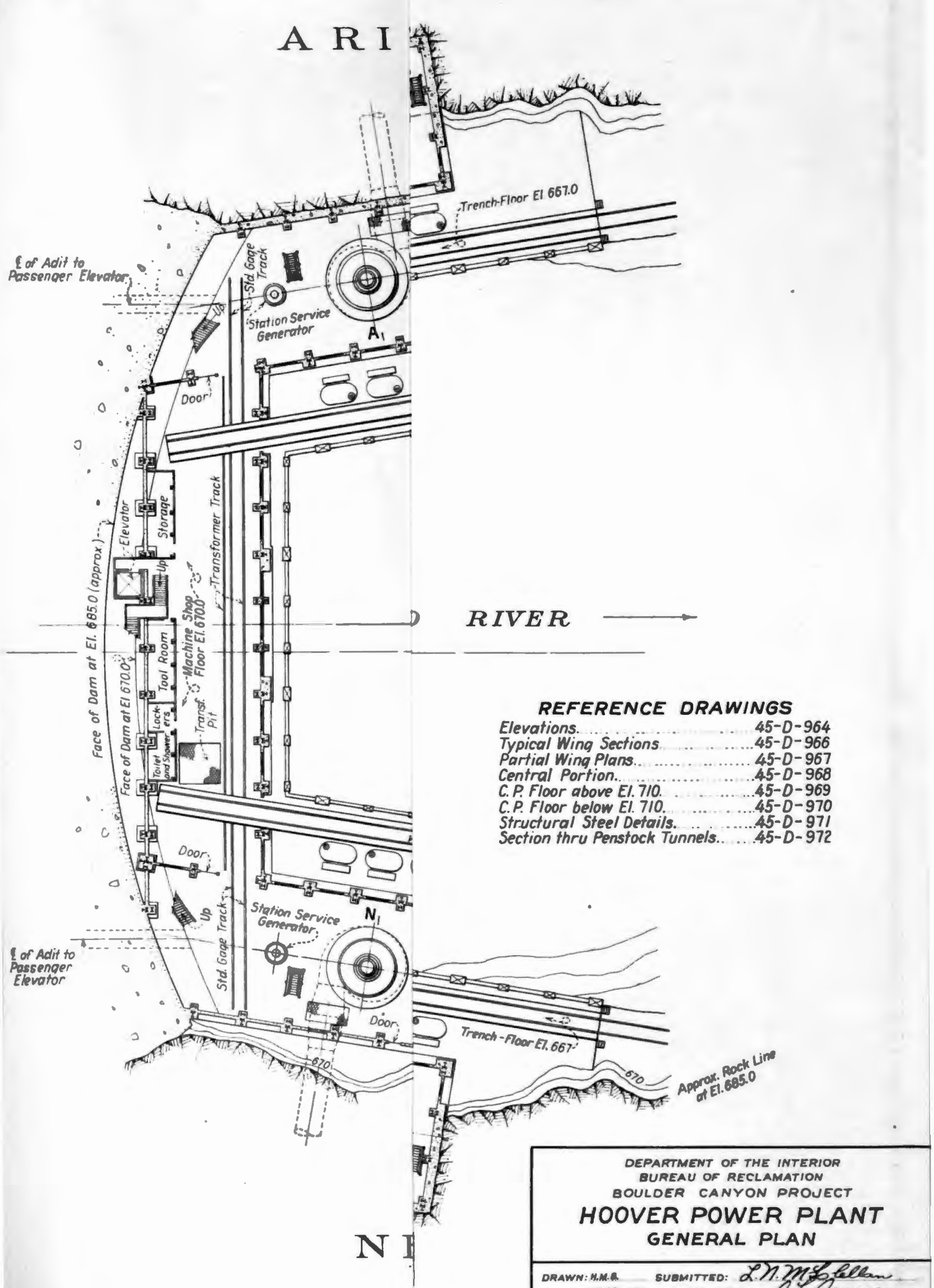
24163 | DENVER, COLO., DEC. 1, 1930 | 45-D-963



DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
BOULDER CANYON PROJECT

HOOVER POWER PLANT
ELEVATIONS

DRAWN: F.E.J.	SUBMITTED: L. N. McClellan
TRACED: W.H.K.	RECOMMENDED: J. L. Savage
CHECKED:	APPROVED: R. F. Walter
24164	DENVER COLO. DEC. 1, 1930 — 45-D-964



REFERENCE DRAWINGS

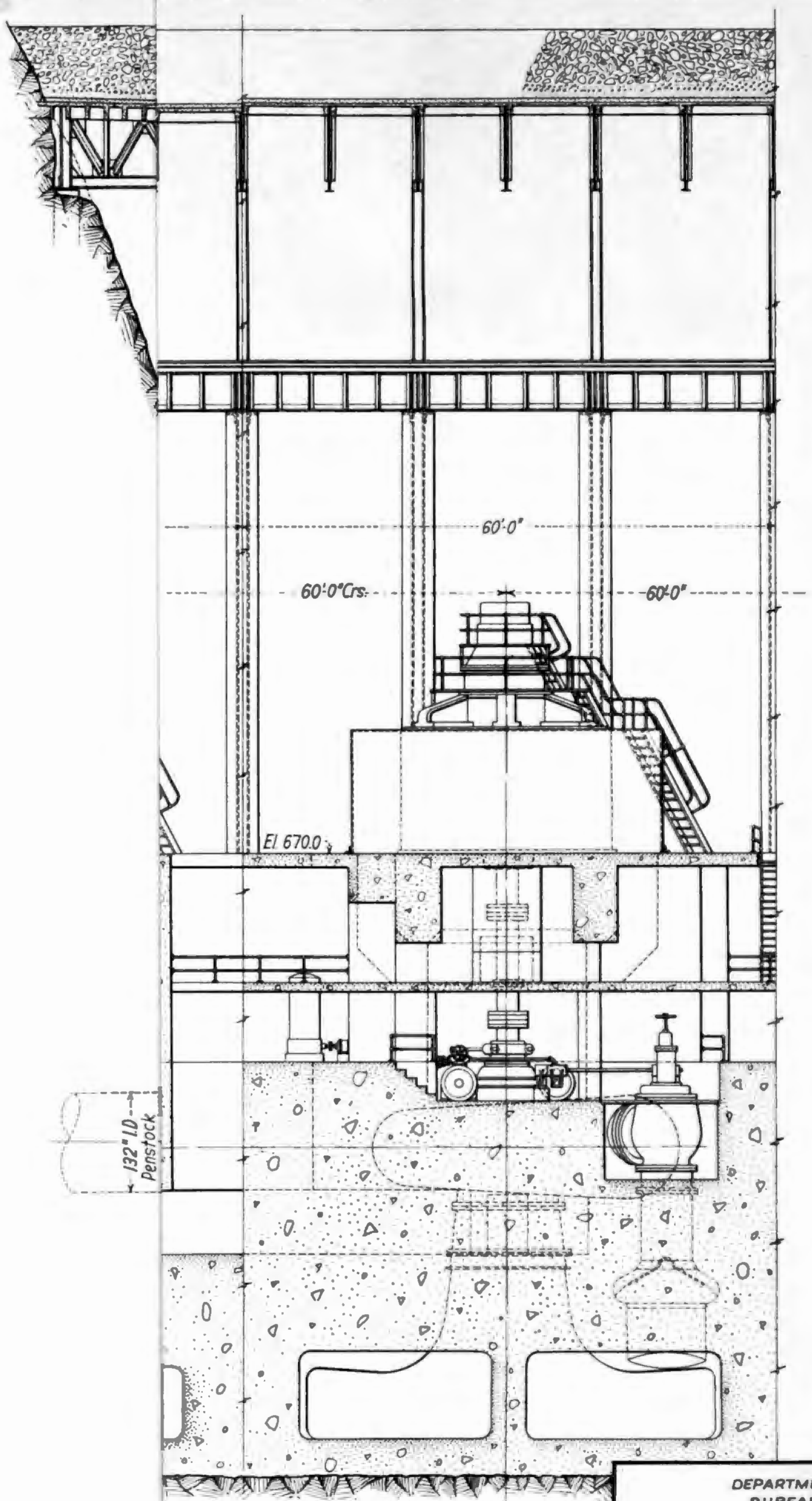
Elevations	45-D-964
Typical Wing Sections	45-D-966
Partial Wing Plans	45-D-967
Central Portion	45-D-968
C.P. Floor above El. 710	45-D-969
C.P. Floor below El. 710	45-D-970
Structural Steel Details	45-D-971
Section thru Penstock Tunnels	45-D-972

DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
BOULDER CANYON PROJECT

HOOVER POWER PLANT
GENERAL PLAN

DRAWN: H.M.B. SUBMITTED: L.N. McClellan
TRACED: H.M.B.-J.E.V. RECOMMENDED: J.L. Savage
CHECKED: APPROVED: R. F. Walter

24165 DENVER, COLO. DEC. 1, 1930 45-D-965



ECTION B-B

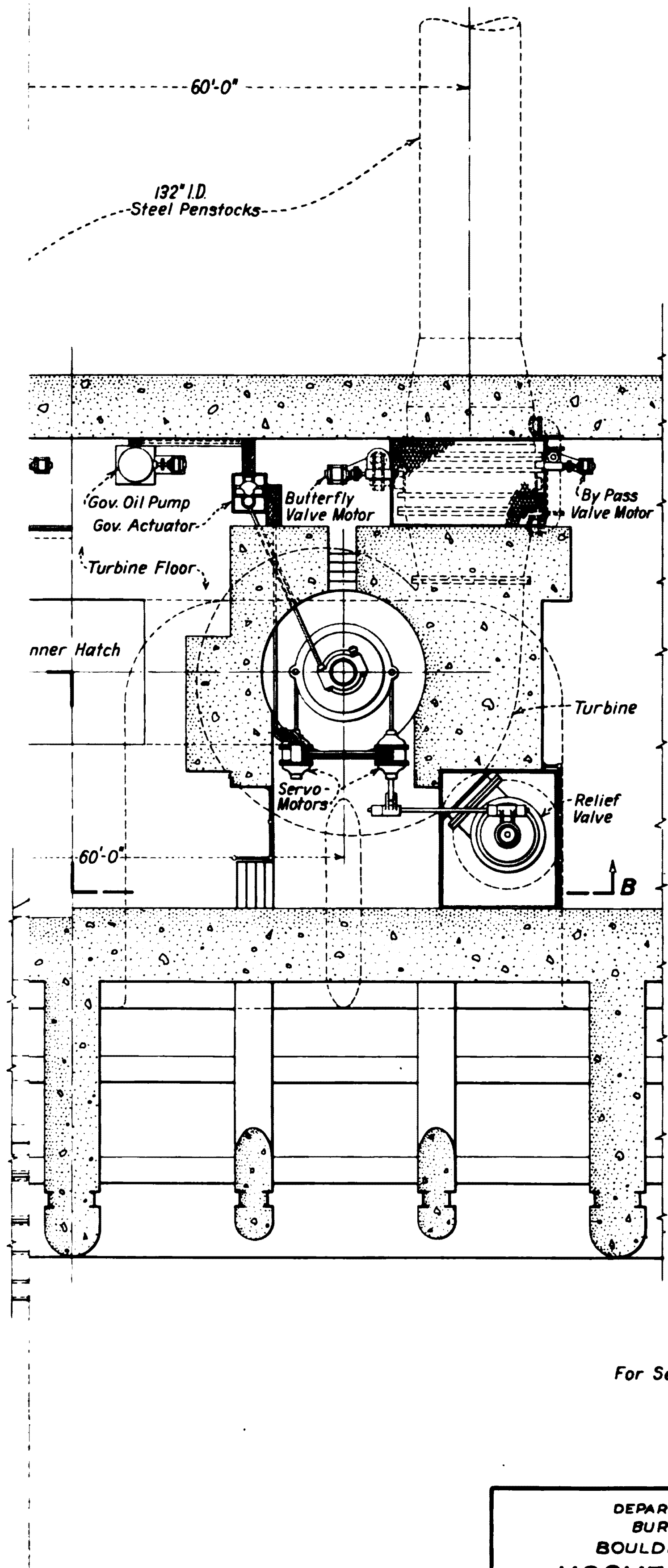
For Plan see Drawing No. 45-D-965
For Partial Wing Plans See Dwg No. 45-D-967

DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
BOULDER CANYON PROJECT

HOOVER POWER PLANT
TYPICAL WING SECTIONS

DRAWN: H.M.B. SUBMITTED: L. N. McClellan
TRACED: W.N.K. RECOMMENDED: J. L. Savage
CHECKED: APPROVED: R. F. Walter

24166 DENVER, COLO. DEC. 1, 1930 45-D-966



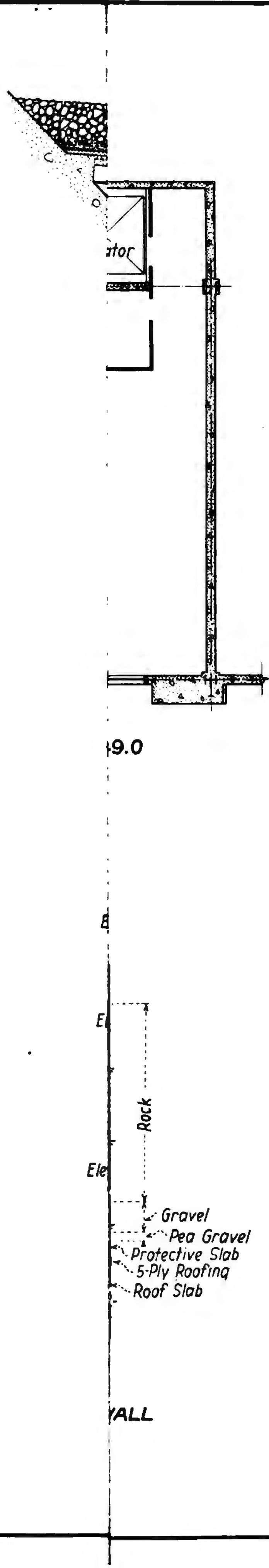
NOTE
For Sections See Drawing No. 45-D-966

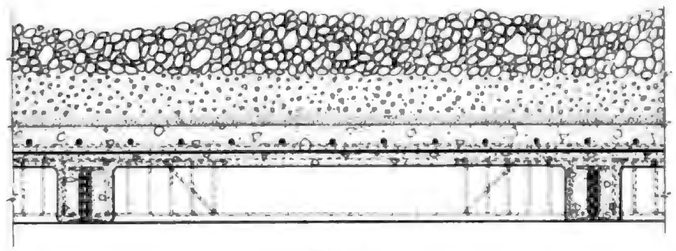
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
BOULDER CANYON PROJECT

HOOVER POWER PLANT
PARTIAL WING PLANS

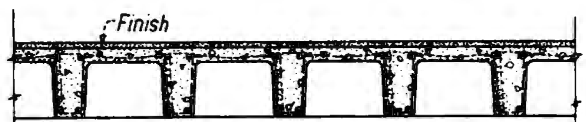
DRAWN: H.M.B. SUBMITTED: L. N. McClellan
TRACED: B.H.S.-J.E.V. RECOMMENDED: J. L. Savage
CHECKED: H.F.M. APPROVED: R. F. Walter

24167 DENVER, COLO. DEC. 1, 1930 45-D-967

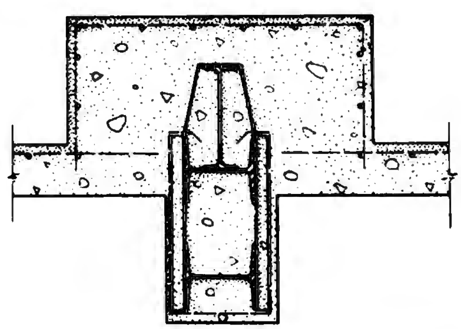




SECTION A-A



SECTION-TYPICAL FLOOR CONSTRUCTION



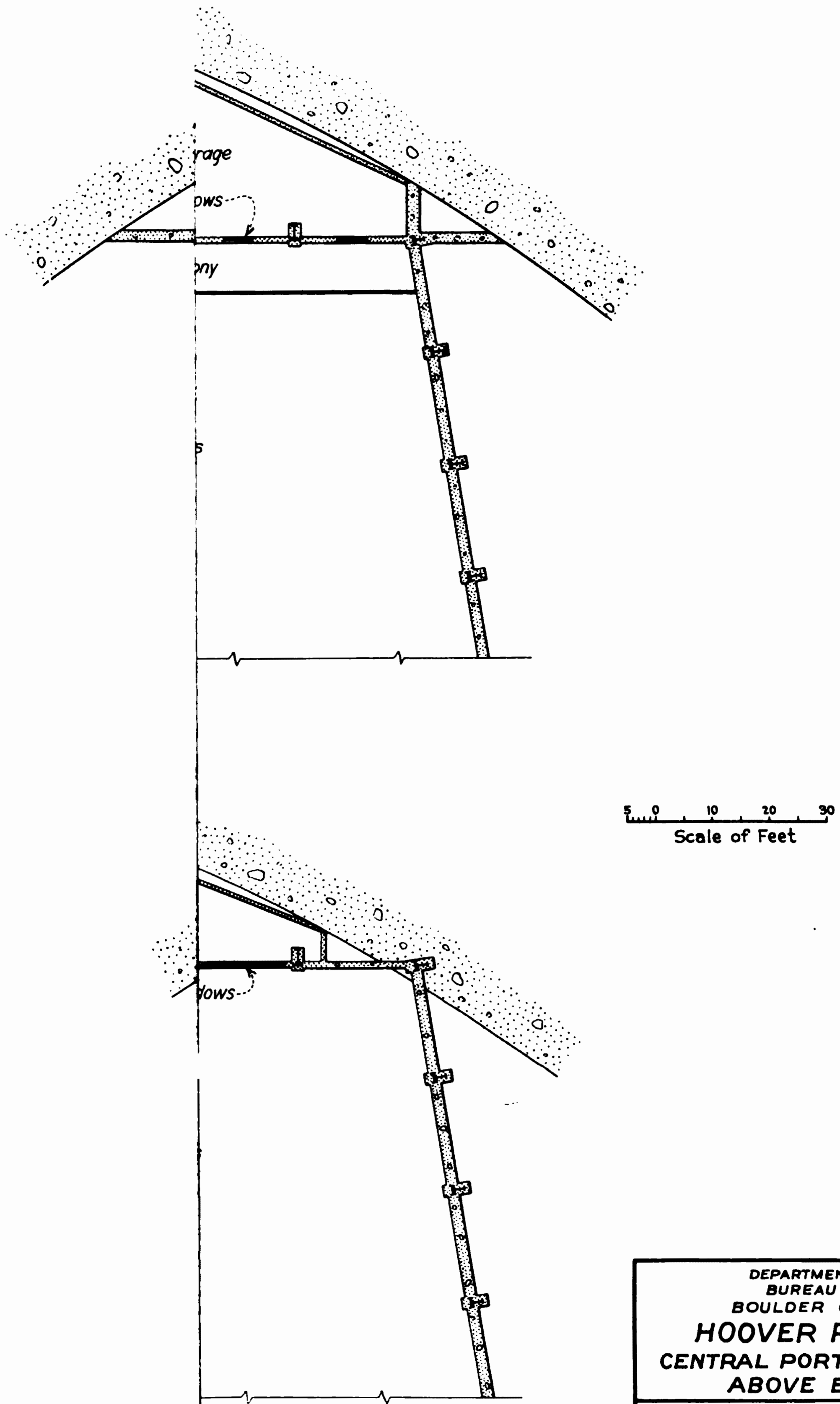
SECTION-TYPICAL COLUMN

DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
BOULDER CANYON PROJECT

HOOVER POWER PLANT
CENTRAL SECTION

DRAWN: F.E.W. SUBMITTED: L. N. McClellan
TRACED: H.G.K.-W.H.K. RECOMMENDED: J. L. Savage
CHECKED: H.F.M. P.B.O.L. APPROVED: R. F. Walter

24168	DENVER, COLO., DEC. 1, 1930	45-D-968



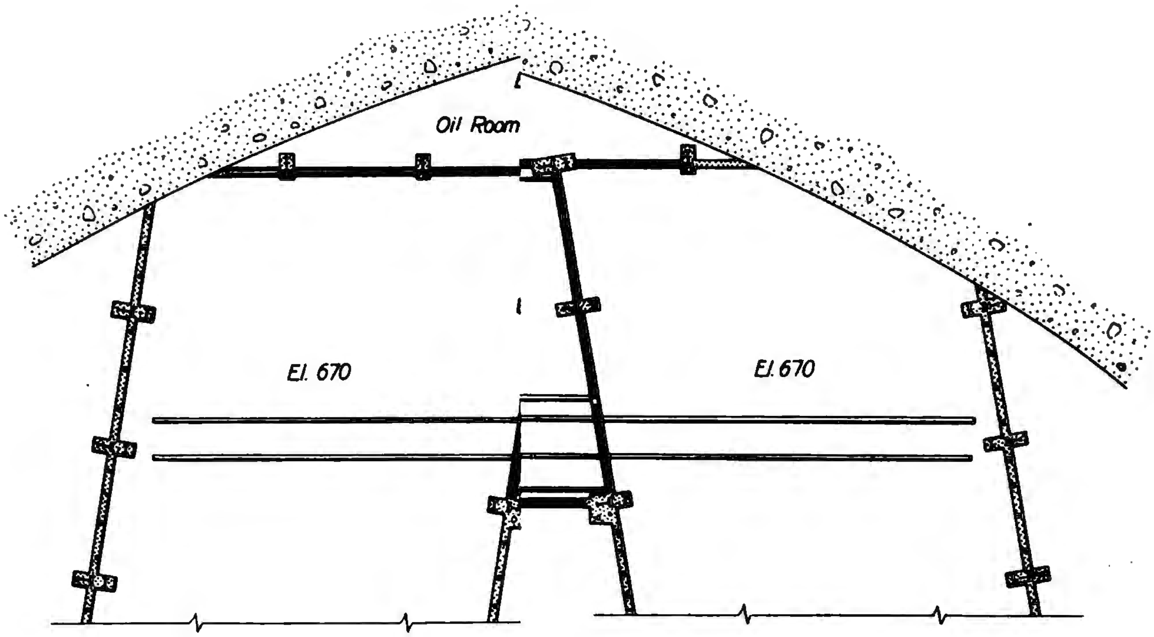
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
BOULDER CANYON PROJECT

HOOVER POWER PLANT

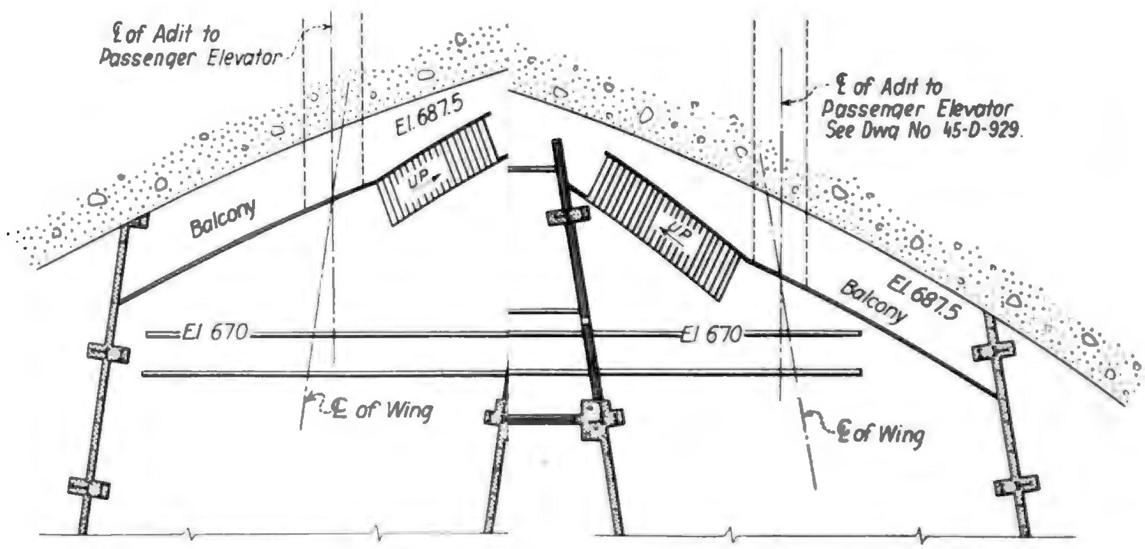
CENTRAL PORTION FLOOR PLANS ABOVE ELEVATION 710

DRAWN: F.E.W. - M.H.K. SUBMITTED: L. N. McClellan
TRACED: L.D.B. - C.E.M. RECOMMENDED: J. L. Savage
CHECKED: H.F.M. P.R. O.L.R. APPROVED: R. F. Walter

24169 DENVER, COLO. DEC. 1, 1930 45-D-969



5 0 10 20 30
Scale of Feet



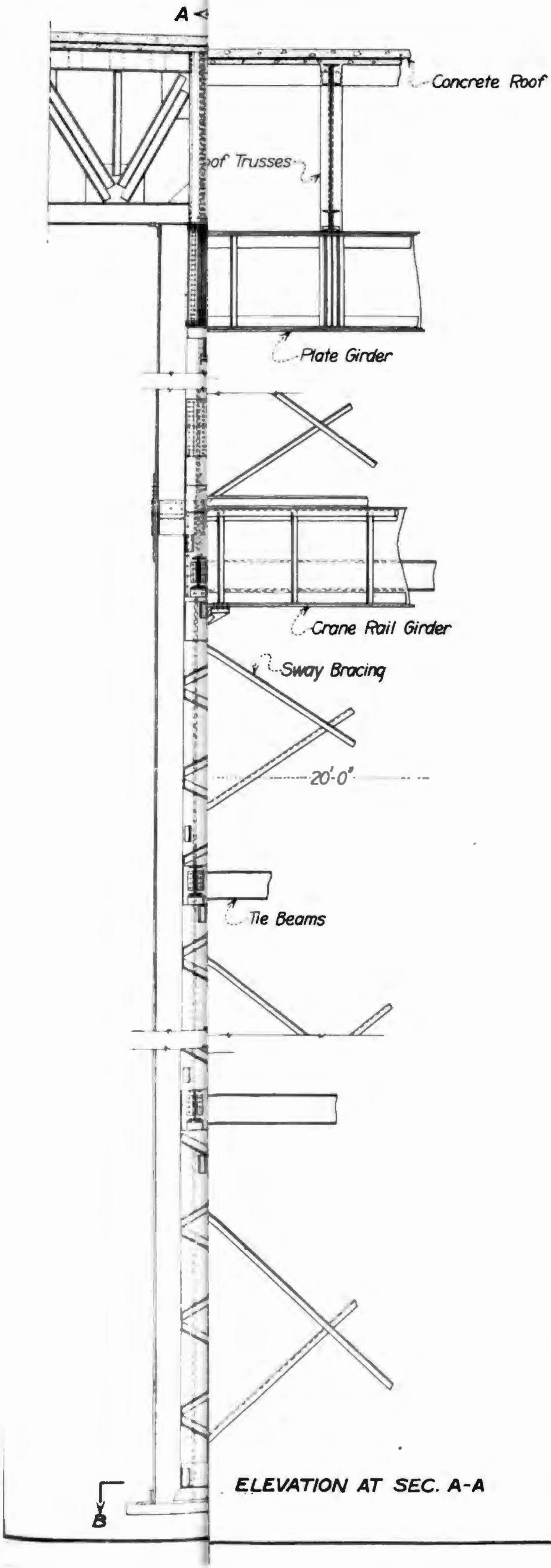
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
BOULDER CANYON PROJECT

HOOVER POWER PLANT

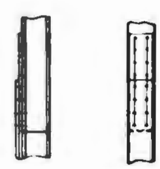
CENTRAL PORTION FLOOR PLANS BELOW ELEVATION 710

DRAWN: F.E.W.-K.T.D. SUBMITTED: L. N. McClellan
TRACED: T.A.C.-C.E.M. RECOMMENDED: J. L. Savage
CHECKED: H.F.M. T.D. O.L.B. APPROVED: R. F. Walter

24170	DENVER, COLO. DEC. 1, 1930	45-D-970



ELEVATION AT SEC. A-A



TYPICAL FIELD CONNECTIONS

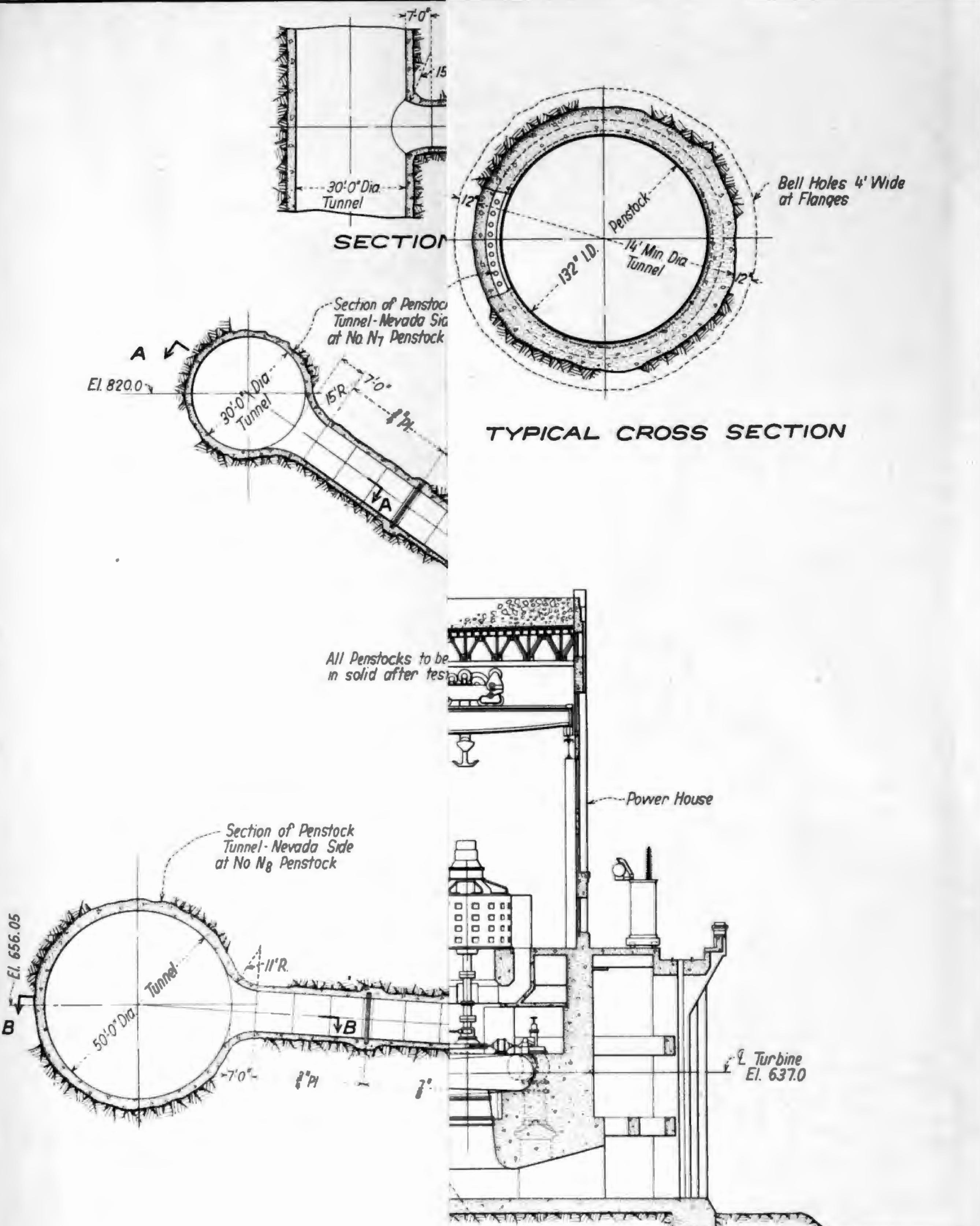
0 5 10
Scale of Feet

DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
BOULDER CANYON PROJECT

HOOVER POWER PLANT
STRUCTURAL STEEL DETAILS

DRAWN RWB SUBMITTED L. N. McClellan
TRACED HGK-CEM RECOMMENDED J. L. Savage
CHECKED SJ-PJOL APPROVED R. F. Walter

24171 | DENVER COLO. DEC. 1, 1930 | 45-D-971

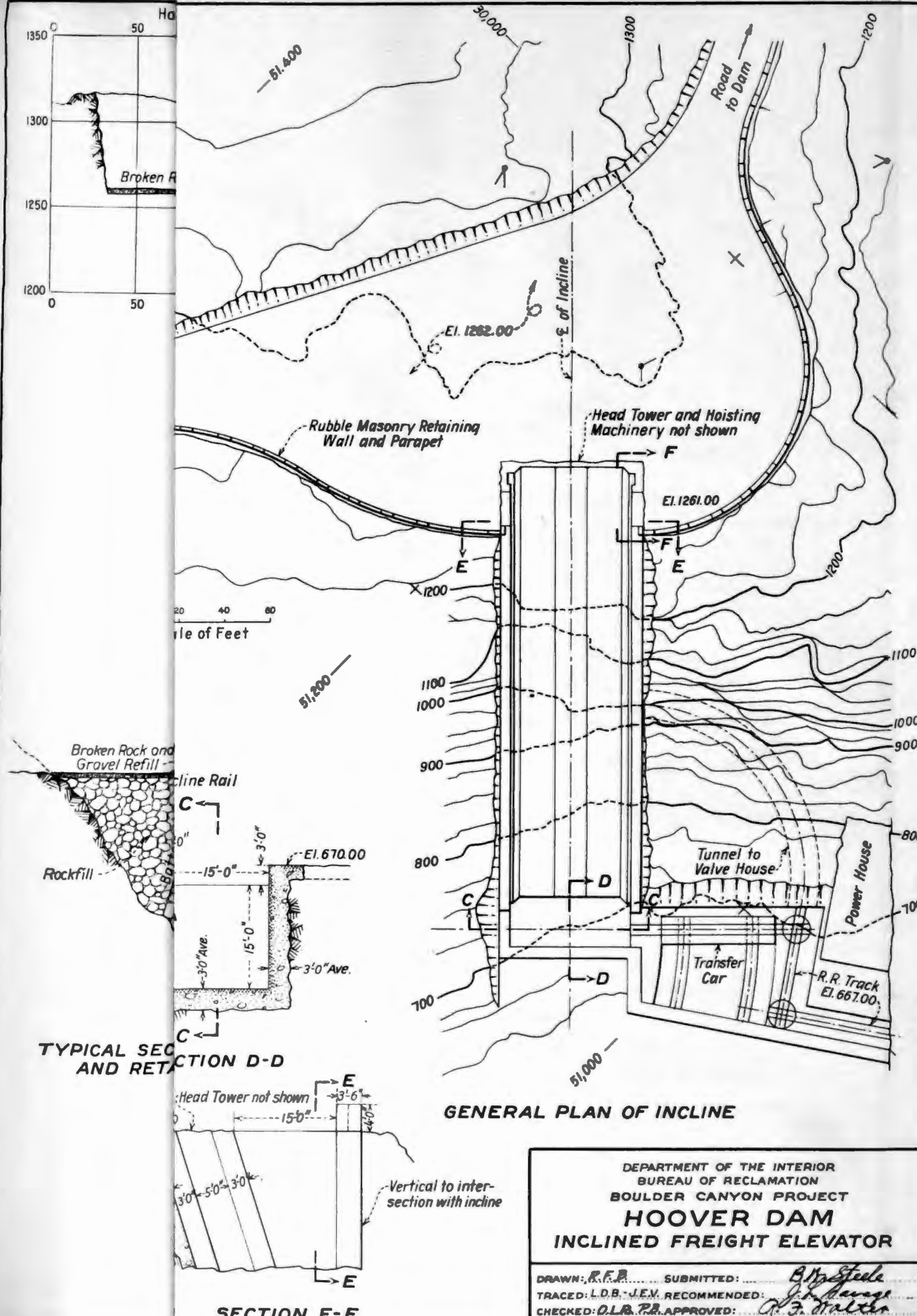


DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
BOULDER CANYON PROJECT

HOOVER POWER PLANT
SECTION THRU PENSTOCK TUNNELS

DRAWN: P.B. SUBMITTED: L. N. McClellan
TRACED: W.H.K. RECOMMENDED: J. L. Savage
CHECKED: P.B., O.L.R. APPROVED: R. F. Walter

24172 DENVER, COLO., DEC 1, 1930 45-D-972



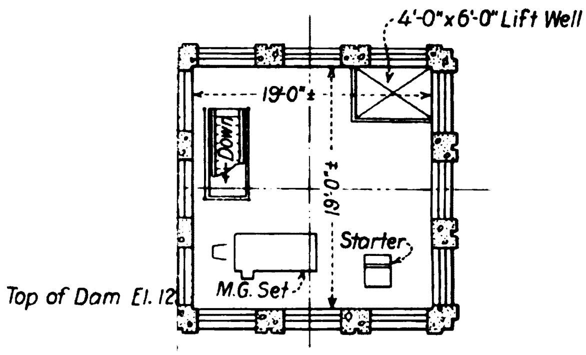
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
BOULDER CANYON PROJECT

HOOVER DAM

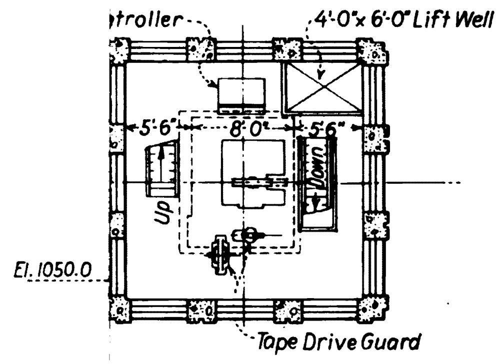
INCLINED FREIGHT ELEVATOR

DRAWN: R.F.B. SUBMITTED: B. W. Steele
TRACED: L.D.B.-J.E.V. RECOMMENDED: J. L. Savage
CHECKED: O.L.B. P.B. APPROVED: R. F. Walter

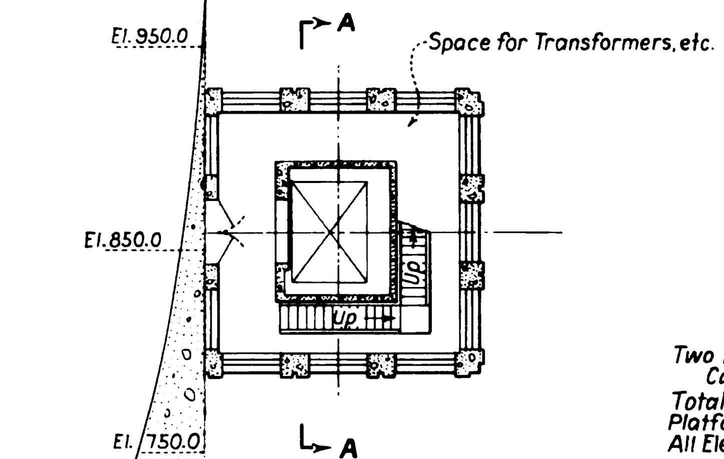
24173 | DENVER, COLO., DEC. 1, 1930 | 45-D-973



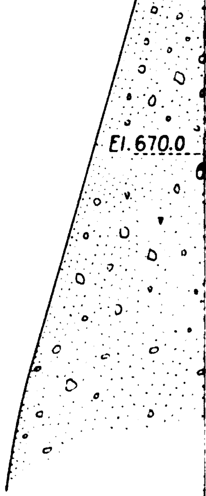
THIRD FLOOR PLAN

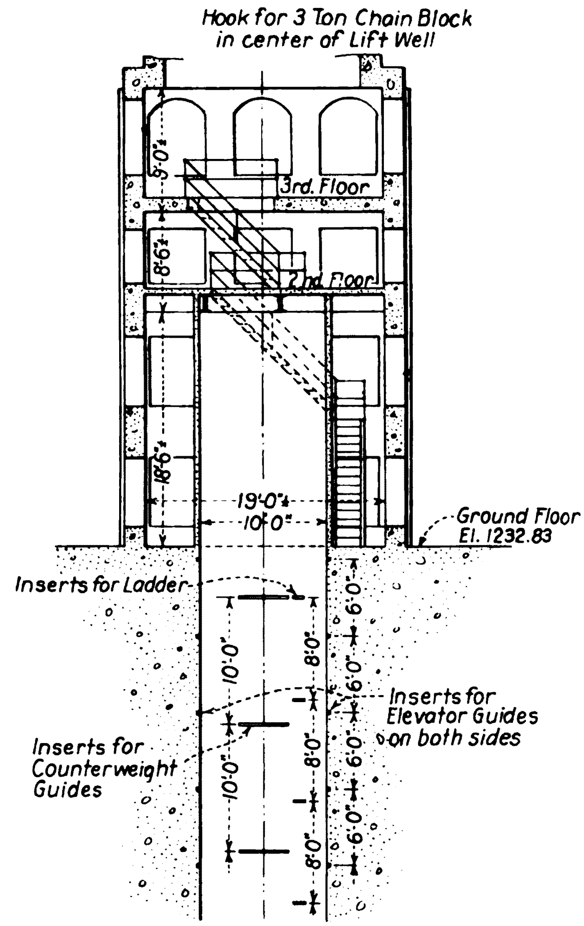


SECOND FLOOR PLAN



GROUND FLOOR PLAN





SECTION A-A

NOTES

Two Passenger Elevators required
Capacity 5000 Lbs. at 500 F.P.M.
Total Travel - 562 Ft. with 6 Landings at Elevations given
Platform and Enclosure approximately as shown.
All Elevators complete with Enclosure, Guides, Wiring and Bolts to be furnished and installed by the Government.
All Metal Inserts, Stairways and Ladders will be furnished by the Government and installed by the Contractor.

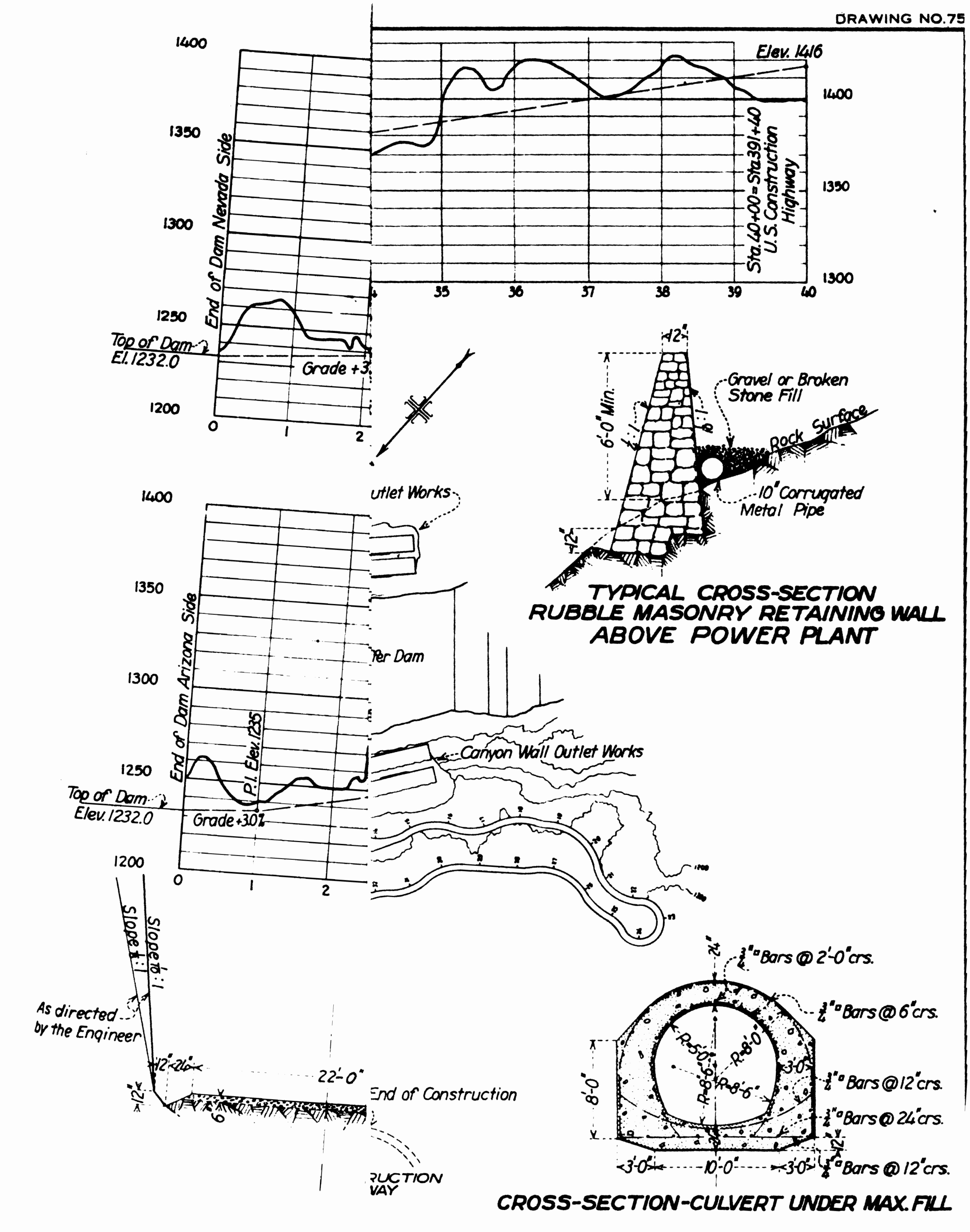
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
BOULDER CANYON PROJECT

HOOVER DAM
PASSENGER ELEVATOR LAYOUT

DRAWN: P.B.-L.T.F. SUBMITTED: B.R. Steele
TRACED: L.T.F. RECOMMENDED: J.L. Savage
CHECKED: P.B.O.L.B. APPROVED: R.F. Walter

24174 | DENVER, COLO., DEC. 1, 1930 | 45-D-974

DRAWING NO.75

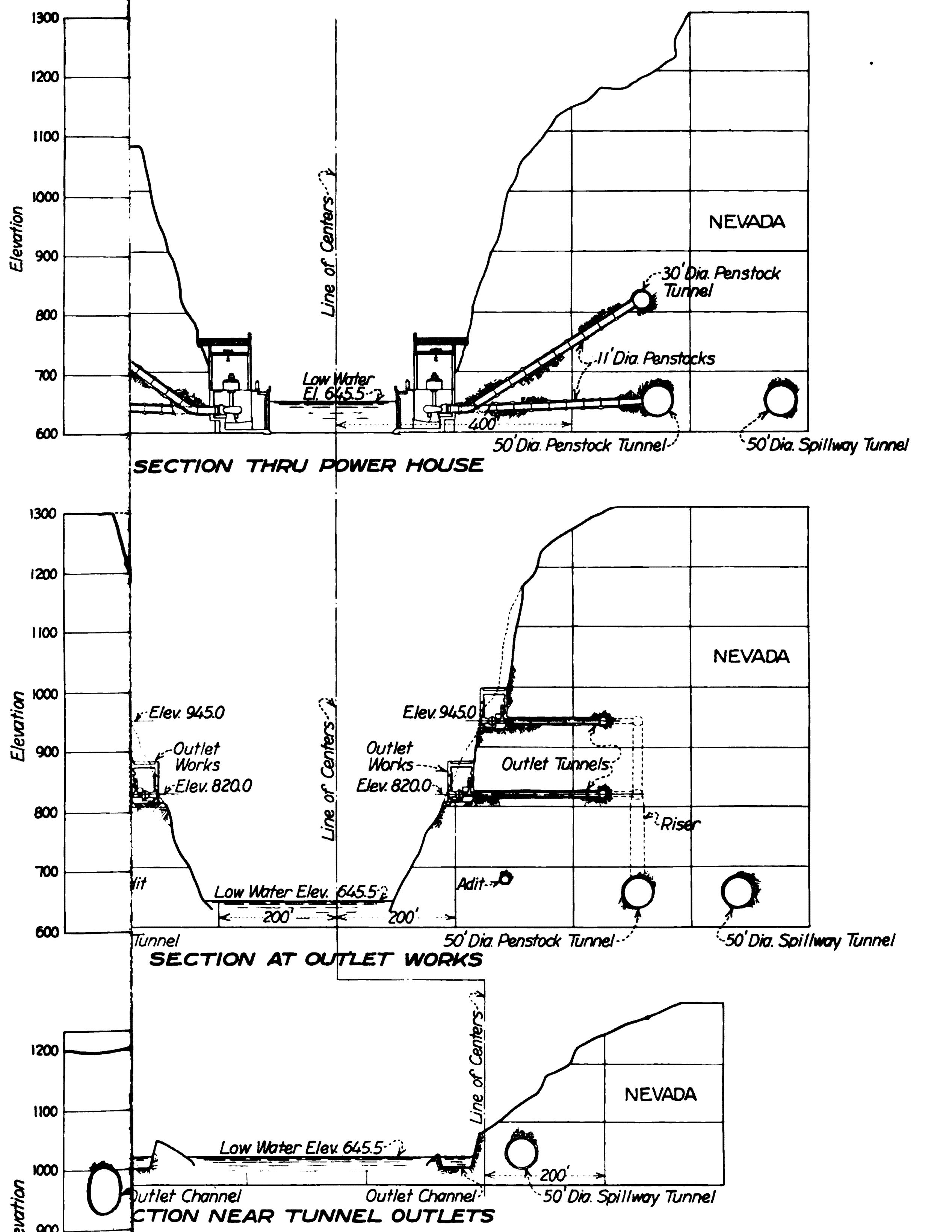


DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
BOULDER CANYON PROJECT

HOOVER DAM
BLACK CANYON HIGHWAY

DRAWN: C.G.A. SUBMITTED: B.H. Steele
TRACED: L.D.B.-C.E.M. RECOMMENDED: J.L. Savage
CHECKED: O.L.B. P.B. APPROVED: R.F. Walter

24175 DENVER, COLO. DEC. 1, 1930 45-D-97



OTES

g Downstream.

DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
BOULDER CANYON PROJECT

HOOVER DAM

CANYON CROSS SECTIONS

DRAWN: J.B.-E.R.S.	SUBMITTED: B. H. Steele
TRACED: C.E.M.	RECOMMENDED: J. L. Savage
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