WESTERN CONSTRUCTION

EQUIPMENT DIRECTORY

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A pre-bid look at site and construction problems of . . .

GLEN CANYON DAM

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CONSTRUCTION of the second highest dam in the United States will begin early this year. It is the Glen Canyon Dam, a key structure of the Bureau of Reclamation's Colorado River Storage Project. The project was authorized by the Congress in the spring of 1956 to develop the land and water resources of the Upper Colorado River Basin, a 10,000-sq. mi. area containing a rich potential of agricultural, industrial, and recreational assets.

Glen Canyon Dam, to be about 700 ft. high above its foundation—second in height only to the 726-ft. Hoover Dam—will be built on the Colorado River in north-central Arizona, about 15 river miles upstream from Lees Ferry and 12 river miles downstream from the Arizona-Utah state line. It is about 370 mi. upstream from Hoover Dam on the Lower Colorado River.

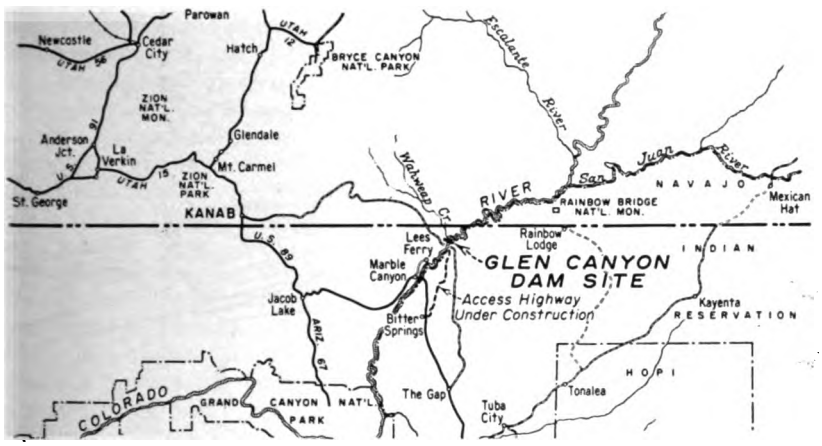
Glen Canyon Dam is designed to serve multiple purposes by creating a reservoir for conservation storage, power generation, silt retention, recreation, and fish and wildlife conservation. It will be a concrete arch structure having a volume of 4,770,000 cu. yd., a crest length of 1,500 ft., and a maximum thickness at the base of 300 ft. The reservoir will have a capacity of 28,040,000 ac. ft. and will extend 186 mi. up the Colorado River and 71 mi. upstream on the San Juan River. Glen Canyon reservoir and other storage units in the Upper Colorado River Basin will provide hold-over reserves of water to meet terms of the 1922 Compact of the Colorado River. Glen Canyon Powerplant, to be built concurrently with the dam, has been designed to include an installed capacity of 900,000 kw.

Problem of access

By virtually any construction standard, access to the remote Glen Canyon area imposes major problems in the transportation of supplies and equipment from established areas to the site. As an illustrative example, although it is approximately 1,200 ft. from one rim of the canyon to the other at the dam site, it was necessary, until recently, for vehicular traffic to go 225 mi. to get from one side of the canyon to the other.

Flagstaff, Ariz., a railhead, is 135 mi. from the dam site; the railhead at Marysvale, Utah, is 200 mi. from the dam site, via Kanab, Utah, the nearest town.

First major construction at the dam site began Oct. 2, 1956, following award of a $2,452,340 contract to Mountain States Construction Co., Denver, for construction of the right (west) diversion tunnel. The 2,740-ft. tunnel has a diameter of 43 ft. 6 in. in its upstream portion and a diameter of 46 ft. 6 in. in its downstream portion.



REMOTENESS of location is a major problem in construction plans for Glen Canyon Dam. Kanab, Utah, is the nearest town, and Flagstaff, Ariz., 135 mi. south, is the nearest railhead. Until recently it was necessary to drive 225 mi. to get a vehicle from one side of the site to the other.

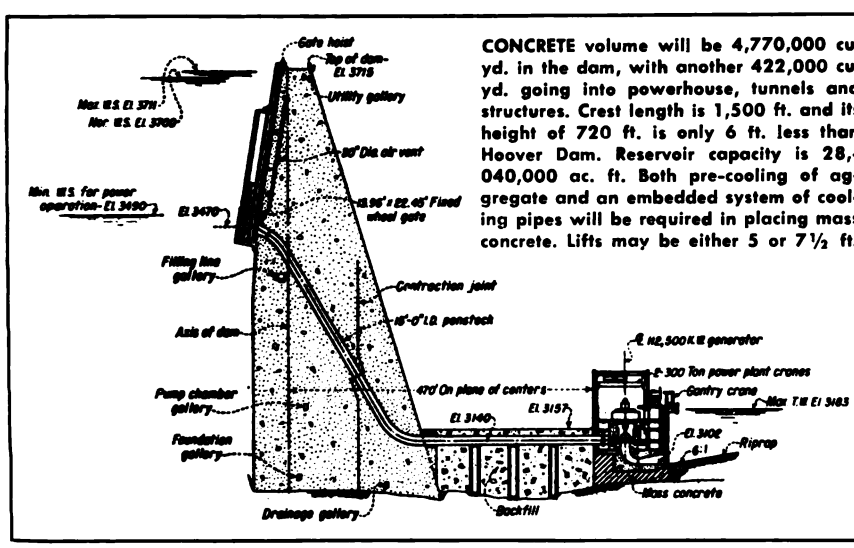
GLEN CANYON DAM AND POWERPLANT

Principal Quantities Required for the Dam, Spillway, Outlets and Power Features

Excavation, common, for dam and powerplant	985,000	cu. yd.
Excavation, rock, for dam and powerplant	1,650,000	cu. yd.
Excavation, all classes, in open cut for spillways	1,325,000	cu. yd.
Excavation, all classes, in spillway tunnels	132,000	cu. yd.
Excavation, all classes, in diversion tunnels	182,000	cu. yd.
Concrete in dam	4,770,000	cu. yd.
Concrete in spillway and diversion tunnel lining	110,000	cu. yd.
Concrete in appurtenant structures, except powerplant	155,000	cu. yd.
Concrete in powerplant	157,000	cu. yd.
Reinforcement	28,900,000	lb.
Tubing and fittings for grouting	755,000	lb.
Tubing and fittings for cooling concrete	4,650,000	lin. ft.
Spillway radial gates and hoist	1,950,000	lb.
Penstock and outlet pipes	21,000,000	lb.
Fixed-wheel gates and hoists for penstocks	3,180,000	lb.
Ring-follower gates and hollow-jet valves for outlets	1,300,000	lb.
Trashrack metalwork	1,880,000	lb.
Structural steel for powerplant superstructure	4,250,000	lb.
All other metalwork required for the dam, outlets, spillways and power features	5,140,000	lb.

Specifications calling for bids for construction of the dam, powerplant, and the left diversion tunnel, having the same diameters as the right diversion tunnel but a length of 2,900 ft., were planned to be issued early in January.

The principal quantities required for the dam, spillway, outlets, and power features are shown in the accompanying tabulation. Most of the materials listed will be supplied and installed by the general contractor during the period of the contract, which is expected to extend for about 7 years. In addition to these materials, the Bureau will purchase the larger items of special machinery and equipment under separate advertisements to be issued as soon as designs have been completed.



CONCRETE volume will be 4,770,000 cu. yd. in the dam, with another 422,000 cu. yd. going into powerhouse, tunnels and structures. Crest length is 1,500 ft. and its height of 720 ft. is only 6 ft. less than Hoover Dam. Reservoir capacity is 28,040,000 ac. ft. Both pre-cooling of aggregate and an embedded system of cooling pipes will be required in placing mass concrete. Lifts may be either 5 or 7½ ft.

In the following summary, plans for construction of the Glen Canyon Unit of the storage project are briefly discussed to indicate the scope of the development and the many challenging construction problems to be resolved.

Glen Canyon dam site

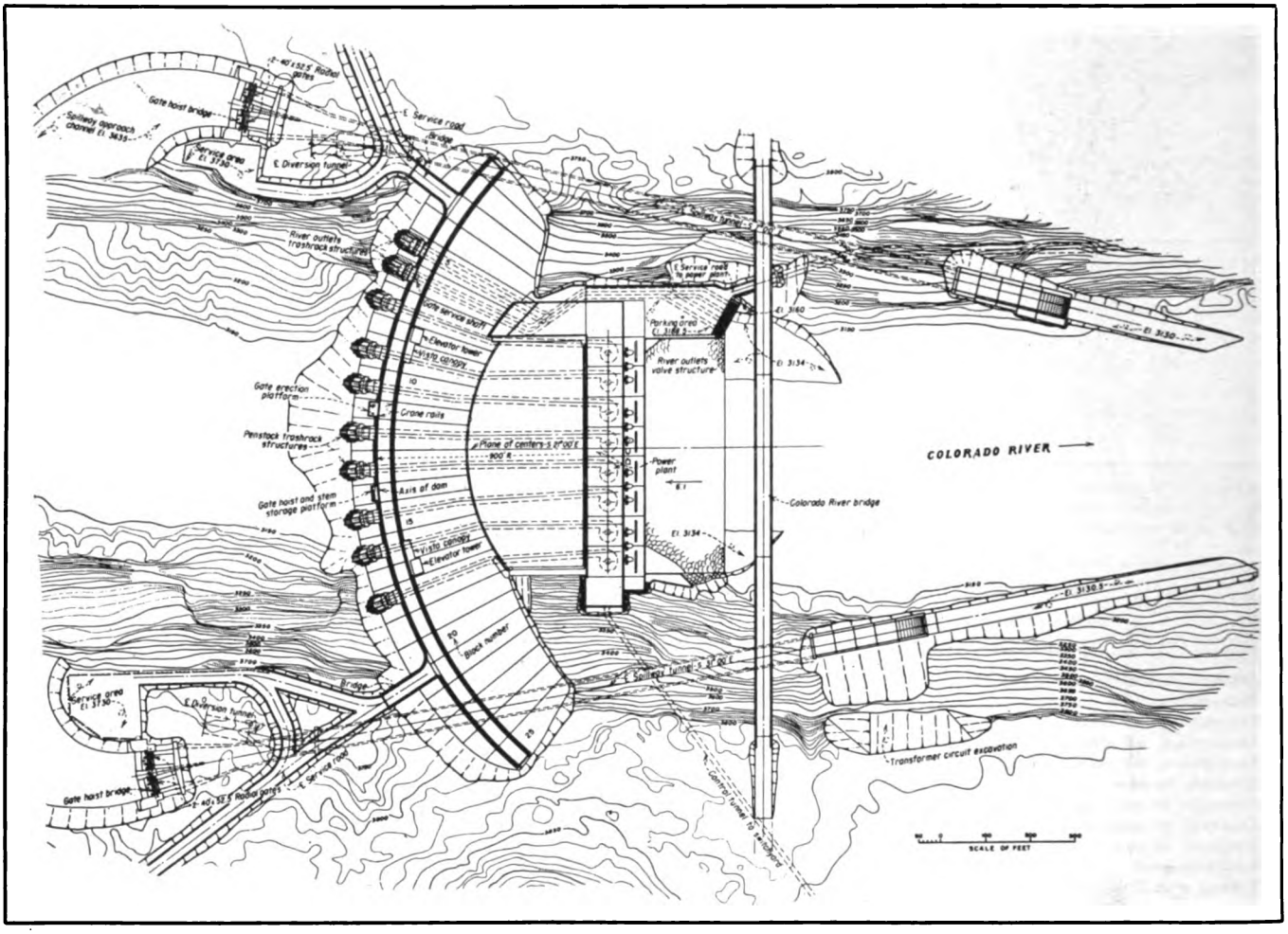
Glen Canyon covers a 176-mi. section of the Colorado River Basin from the lower end of Cataract Canyon, 14 mi. above Hite, Utah, to Lees Ferry, Ariz. This canyon is one of the spectacular cuts by the Colorado River. Throughout most of its length, Glen Canyon is a narrow river gorge confined by massive sandstone walls variable in height, the maximum being 1,200 ft. above river level. At Lees Ferry, the lower terminal of the canyon, the nearly vertical walls recede, and the river flows for a short distance in a relatively open valley before entering the narrow gorge of Marble Canyon.

Above the rim of Glen Canyon and extending for some distance on either side is a gently rolling upland plain dotted with isolated buttes and mesas and cut at intervals by deep narrow canyons leading into the Colorado River. The entire area is a vast expanse of wasteland, uninhabited except for a few ranchers on the northwest side of the river and scattered Indian families on a reservation to the southeast.

The Glen Canyon area is a small but typical part of the Colorado Plateau Province, a vast area of nearly horizontal sedimentary rocks that have been elevated without materially disturbing the component layers. It is essentially a country of broad, cliff-edged mesas cut by narrow, steep-walled canyons.

The dam site lies in a narrow straight-walled section of Glen Canyon about 1 mi. below the mouth of Wahweap Creek. At this site, the sides of the canyon rise abruptly from the bed of the river in nearly vertical walls 650 ft. high.

Both abutments and the foundation area at the site are in the Jurassic Navajo sandstone. The Navajo formation is a massive, highly cross-bedded, buff to red, medium- to fine-grained sandstone made up essentially of white and pink quartz grains and a few grains of other minerals.



EIGHT generators will have a combined capacity of 900,000 kw. The double spillway will handle 276,000 sec. ft. Diversion during the construction period will be through the spillway tunnels. Mass concrete will rise in columns, as large as 55 x 170 ft. in section at the base. Cement content is now anticipated to be 2 sacks of portland cement and 1 of pozzolan por yd. Concrete will be placed at 50 deg.

GLEN CANYON DAM, RESERVOIR, AND POWERPLANT
Physical Data

DAM	
Type	Concrete arch
Height above river bed	580 ft.
Height above lowest point in foundation	700 ft.
Crest length	1,500 ft.
Crest width (width of roadway)	35 ft.
Base width	300 ft.
Concrete in dam	4,770,000 cu. yd.
Crest elevation	3,715
Maximum discharge through spillways	276,000 sec. ft.
RESERVOIR	
Capacity	28,040,000 ac.-ft. at normal water surface elevation 3,700
Area	164,000 ac. at normal water surface
Elevation maximum water surface	3,711
Length	186 mi.
POWERPLANT	
Capacity	900,000 kw.
Number of units	8
Capacity of each generator	112,500 kw.
Capacity of each turbine	155,500 hp.

The climate in the vicinity of the dam site is dry. Summers are hot and winters are relatively mild. Maximum recorded temperatures for June and July are 114 deg., a minimum temperature of 2 deg. has been recorded in December and January. Snowfall is light and will not create any construction problem. For the past 20 years of record at Lees Ferry, the average annual snowfall was about 4 in. Annual precipitation is 6 in.

DAM CONSTRUCTION

For construction of the dam, the contractor will be required to erect and maintain a complete concrete plant. The plant will include equipment for processing, conveying, and stockpiling concrete aggregates; storage and handling facilities for both cement and pozzolan; mixing and batching facilities; refrigerating equipment for cooling aggregates and mixing water; and a cableway or other means of conveying the concrete to and placing it in the dam.

Aggregates to be used in the concrete for the dam will probably be obtained from Government-owned property known as the Wahweap deposit, located on Wahweap Creek about 7 mi. upstream from its junction with the Colorado River. The aggregate will require washing and some wastage to obtain the desired quality and grading. As the aggregates are potentially reactive with alkalis in cement, low-alkali cement will be called for in the dam.

It is anticipated that the mass concrete for the dam will contain about two sacks of portland cement and one

sack of pozzolan per cubic yard. About 3,000,000 bbl. of cement and 225,000 tons of pozzolan will be used.

The dam is to be divided into columns or blocks by radial and circumferential contraction joints. Blocks will range in size from 55 x 170 ft. in the downstream portion at the base to 70 x 130 ft. in the upstream portion. To insure monolithic action of the dam and to secure the desired stress distribution in the structure, the contraction joints will be grouted. For the injection of grout into the joints, a system of pipes is to be embedded in the concrete adjacent to the contraction joints.

Contraction joints are to be interlocked by keys formed to provide a maximum cross-sectional area for resistance to shear after grouting. The contractor will have the option of placing the concrete in the dam in either 5- or 7½-ft. lifts. The rate of placing concrete in any block will be restricted so that not more than one horizontal lift can be placed in 72 hr. A maximum vertical difference of 25 ft. in the top surface of adjacent blocks will be permitted.

Temperature control measures will consist primarily of precooling the various parts of the concrete mix to obtain concrete placing temperatures of not more than 50 deg. F., and of artificially cooling the concrete by an embedded pipe system to temperatures of between 40 and 50 deg. Precooling measures will include cooling the aggregate either by immersion in an ice-water bath or by refrigerated air blasts, cooling the mixing water and by adding slush or chip ice to the mix.

In addition to the refrigerating capacity required to carry out this precooling, there must be added the cooling load from the embedded pipe system which is needed to cool the concrete so that the contraction joints in the dam can be filled with cement grout before the reservoir water load is placed against the dam. About 950 mi. of pipe or tubing will be embedded in the concrete of the dam to accomplish the artificial cooling.

Foundation treatment

The general plan for grouting the foundation rock will consist of low-pressure shallow grouting at the upstream face of the dam, followed by grouting a high-pressure deep curtain in the same area. The low-pressure grouting will be done through holes drilled on 20-ft. centers to a depth of 25 ft. prior to placement of concrete. After concrete has been placed to a sufficient height, the deep high-pressure grouting will be done through holes drilled from the foundation gallery at 10-ft. centers and at depths varying up to 250 ft.

Drainage of the foundation will be provided by a series of holes drilled into the foundation rock from the floor of a main foundation gallery and from the roof and floor of the foundation tunnels which will extend into each abutment. A second foundation gallery parallel to and downstream from the main foundation gallery will be located in the dam and drainage holes will be drilled from this gallery if future foundation drainage conditions require them. Drainage from the foundation galleries will be collected in a sump off the lowest point in the gallery system and pumped out of the dam.

Powerplant construction

Glen Canyon Powerplant is to be constructed about 470 ft. downstream from the axis of the dam. It will be a reinforced concrete structure 665 ft. long, 113 ft. wide, and 150 ft. high above foundation. The powerhouse superstructure will be a structural steel frame having reinforced concrete enclosure walls. The roof will be built of precast concrete slabs and cast-in-place concrete. Specifications will offer the contractor the alternative of placing either precast panel walls or cast-in-place walls in the superstructure.

Construction of the powerhouse will be carried out in two stages. First-stage construction, which is to be part of the prime contract for the dam, will include placement of 87,000 cu. yd. of structure concrete, 10,700,000 lb. of reinforcing steel, and 4,250,000 lb. of structural steel. In addition, 60,000 cu. yd. of mass concrete are to be placed beneath the powerhouse.

Second-stage construction, which will be carried out under a separate completion contract, will include placement of 30,000 cu. yd. of concrete and 3,000,000 lb. of reinforcing steel. The completion contract, to be awarded after completion of the major portion of the prime contract, will call for installation of the generating equipment, exposed piping and electrical conduits, architectural finish, heating and ventilating equipment, and other finish work.

The powerplant is designed for an ultimate installation of eight 112,500-kw. generating units. Capacity of each turbine is 155,500 hp.; rated head is 450 ft. Water will be conveyed to each generating unit through a 15-ft. steel penstock embedded in the dam. The penstocks emerge at the toe of the dam and span the intervening distance between the toe and the powerhouse on concrete piers.

Hydraulic features

Spillway tunnels having their en-

COLORADO RIVER STORAGE PROGRAM

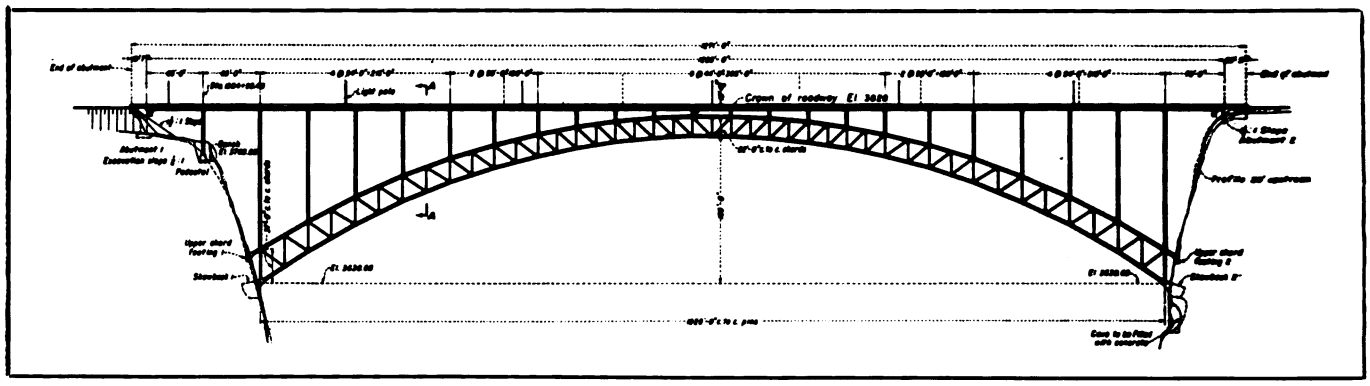
As authorized by the Congress, the Colorado River Storage Project provides for construction of four major units and twelve participating projects. Expenditures, not to exceed $760,000,000, were authorized by the Congress to carry out the construction.

The four storage units—Glen Canyon, Flaming Gorge Dam and Powerplant on the Green River in Utah, Navajo Dam on the San Juan River in New Mexico, and the Curecanti Unit on the Gunnison River in Colorado—will provide about 34,500,000 ac.-ft. of reservoir capacity. Glen Canyon and Flaming Gorge powerplants will have an installed generating capacity of about 1,000,000 kw.

Of the twelve participating projects, which include the existing Eden Project in Wyoming, four are in Wyoming, two in Utah, one in New Mexico, and five in Colorado. These participating projects will supply water to irrigate more than 130,000 ac. of presently dry land and supplemental water to about 230,000 ac. of land now irrigated.

Development of the Upper Colorado River Basin, through the basic storage project and participating projects, will also make possible the development of the Upper Basin's vast resources of fuel, oil, minerals, and timber. It will also meet the urgent need for water to supply municipalities. Other benefits will be obtained in the Upper Basin from recreation, flood control, and fish and wildlife conservation, and in the Lower Basin from sediment retention and river regulation for power production and flood control.

Virtually all of the costs of constructing and developing the four-dam storage project and the participating projects are reimbursable. Power revenues will be used to repay costs of construction which are beyond the ability of the water users to carry. Interest will be paid on costs allocated to power and to municipal water, including interest during construction. Irrigation revenues from the participating projects will pay the operation, maintenance, and replacement costs of these projects allocated to irrigation, and, in addition, will repay a part of the capital cost.



ACCESS TO, and around the Glen Canyon Dam site is a major problem of the construction program. Rather than a temporary bridge for construction, the Bureau will build this 1,028-ft. steel arch located 865 ft. downstream from the dam axis (see plan). Deck is 700 ft. above river level. Arizona and the Bureau of Public Roads will participate in the cost of this permanent highway facility.

trances about 600 ft. upstream from the dam will be used to pass flood waters. The inflow design flood was based on a combination of snow and rain floods during the months of April, May, June, and July. Peak discharge is 380,000 sec. ft. and has a total volume of 29,060,000 ac.-ft. This peak discharge is about 1.7 times as large as the maximum recorded discharge of 220,000 sec. ft. which occurred June 18, 1921. By storing about 1,850,000 ac.-ft. of the flood waters, the maximum discharge through the spillways will be 276,000 sec. ft. An additional 15,000 sec. ft. of the flood will be discharged through the outlets and 10,000 sec. ft. through four units of the powerplant.

Crests of the entrance channels for the spillway tunnels are controlled by two 40 x 52.5-ft. radial gates for each tunnel. Tunnels will each be concrete lined and will have transitions from the crests to 41-ft. diameter tunnels. Lining of both tunnels is to be done under the dam contract. Ski-jump buckets at the downstream ends of the spillways will raise the water so that it will be deflected into the center of the river channel.

Although entrance channels of the spillway tunnels will be unlined, the discharge velocities of the water, as high as 162 ft. per sec., will require that the elbow areas have a special finish to minimize cavitation.

From hydrological investigations, the following flood frequencies have been determined in analyzing the diversion of the river:

PEAK

5-year flood	118,000 sec. ft.
10-year flood	150,000 sec. ft.
25-year flood	196,000 sec. ft.

MAXIMUM 15-DAY VOLUME

5-year flood	2,723,800 ac.-ft.
10-year flood	3,180,000 ac.-ft.
25-year flood	3,550,000 ac.-ft.

Closure of the left diversion tunnel will be in two stages. Initial work will install the first section of the tunnel plug containing three 4x5-ft. high-pressure slide gates. This will be accomplished during the low-flow season when the flow of the river will be confined to the right tunnel. The gates in the plug section will control the discharge downstream and will allow storage in the reservoir to begin when the right tunnel is closed.

Final closure of the left tunnel will be made when the reservoir fills to the level at which the river outlets in the dam can supply minimum downstream releases of 3,000 sec. ft. At this time, the slide gates will be shut, the gate passages and chambers filled with concrete, and the final section of the concrete plug installed.

Closure of the right diversion tunnel should be scheduled in time to store the spring runoff in the reservoir. It is contemplated that a normal spring runoff with minimum downstream releases will fill the reservoir to minimum power storage level. During the closure the contractor will be required to release 1,000 sec. ft. through his closure structure until sufficient head is available to pass 1,000 sec. ft. through the gates in the left tunnel plug. After final closure at the upstream portal, construction of the concrete tunnel plug can begin.

The river outlets, located on the left abutment, will provide river releases for downstream commitments when the powerplant is not in operation and when final closure is made of the diversion tunnels. Capacity of the outlets is 15,000 sec. ft. at minimum water surface elevation. Outlets consist of four 96-in. steel pipes controlled by hollow-jet valves and have ring-follower gates for emergency closure. The intakes are at an elevation 10 ft. above estimated 100-year silt level, and will be protected from trash and debris by concrete trashrack structures on the upstream face of the dam.

COLORADO RIVER BRIDGE

A striking feature of the Glen Canyon construction is the Colorado River bridge about 700 ft. above river level. The bridge, to be built 865 ft. downstream from the axis of the dam, is to be a single span steel arch, having a rise of arch of 165 ft. and a length of 1,028 ft. It will have a reinforced concrete deck for a 30-ft. roadway and two 4-ft. sidewalks, one on each side of the roadway.

Live load design is based on the loading of a 20-ton truck followed by a 16-ton trailer, in accordance with the latest requirements for the Interstate Highway System. The concrete foundations, or skewbacks, supporting the arches are to be placed in sound rock of the Navajo sandstone formation at each canyon rim where geological joints are at a minimum.

Specifications for the bridge call for the contractor to furnish and install 8,000,000 lb. of structural steel, 250,000 lb. of reinforcing steel, 100,000 lb. of handrailing, and 1,000 cu. yd. of concrete in the bridge deck.

The bridge is to be built under an agreement with the State of Arizona which calls for the Bureau of Reclamation to pay from its own funds $1,800,000 (the amount a temporary bridge would cost), and the Bureau of Public Roads $600,000. Arizona will pay the remaining costs, except in the event that the cost should run over $3,200,000, the United States will pay 75% of the amount of such excess cost.

Access roads are problem

To overcome the difficult problems of access to the remote dam site and to assure a steady flow of materials and supplies for construction, the Department of the Interior entered into an agreement with the State of Arizona which called for construction and maintenance of a 25-mi. access

road 34 ft. wide to the site of the dam and the Colorado River bridge. The agreement with Arizona makes it possible to bring the road up to the standards of a primary highway—beyond temporary construction needs of the Bureau of Reclamation—and is the first step toward a permanent loop off U. S. Highway 89. The terminals are in Kanab, Utah, and Bitter Springs, Ariz., a distance of about 96 mi.

The highway and bridge will permit ready access to the dam site from presently existing improved highways over which construction materials and equipment will be trucked from the railheads. The highway will also provide a tourist route to the scenic recreational area and reservoir created by construction of the dam.

The arrangement with Arizona is made possible by an easement signed by the Navajo Tribal Council for use of land to be crossed in the Navajo Indian Reservation. It is also keyed into participation by the Bureau of Public Roads, which agency will provide additional funds needed to bring the Colorado River bridge to the standards of a primary highway.

Construction of the highway is being carried out under two contracts—a 4½-mi. section, running from Bitter Springs under a $1,156,234 contract held by the Strong Company of Springville, Utah; and a 20-mi. section, completing the highway to the bridge site, under a $1,011,819 contract awarded to W. W. Clyde & Co., also of Springville, Utah. Both contracts are for construction of the roadway up to subgrade and the installation of pipe culverts. Surfacing will be completed under separate contracts. Although the amounts for the two contracts are similar despite the difference in mileage involved, they are offset by the large quantities of rock excavation required under the Strong Company's contract.

The Clyde Company's contract includes construction of the Waterholes Canyon bridge, 9 mi. south of the dam site. The bridge is a reinforced concrete articulated frame structure, having a clear span of 97½ ft. a roadway width of 34 ft., and a total length of 140 ft.

The Bureau has constructed a temporary access road extending from the Colorado River bridge site on the west side of the river to the Utah-Arizona border. Utah has completed a link of largely unimproved road from the border to Highway 89 at Kanab. Arizona has also completed a temporary road from The Gap on Highway 89, which is being used for access to the east side of the dam site.

Ford-Fielding, Inc., of Provo, Utah, under a $36,801 contract, is completing the gravel surface of the 8-mi. road to the Utah border and the 3-mi. road from the Wahweap Creek gravel beds to the road running from the state line to the dam site.

This contractor is also building a 3,000-ft. airstrip 80 ft. wide which will be near the 8-mi. section of road from the dam and which will be suitable for use by light airplanes. The airstrip extends in a northeasterly direction and is about 2 mi. northwest of the dam site.

Glen Canyon community

Because of the remote location of the project from existing towns, it is necessary to construct a complete community near the site. This community will house both the forces required by the contractor in the construction of the dam and powerplant and the Bureau's administrative and engineering personnel supervising construction.

The contractor may employ an estimated 4,000 people at the peak of construction, which would represent a population of about 6,000; to this would be added a Government force of about 500, representing a population of about 2,000. Thus the Glen Canyon community will have a total estimated population of about 8,000.

This town will be similar in many respects to Boulder City, Nev., constructed in the early 1930's by the Bureau for the Hoover Dam Project, except that private enterprise will be encouraged to develop community facilities to the fullest extent practicable.

The Glen Canyon community will be a modern urban development, having bituminous-surfaced streets, electric street lighting, and water purification and sewage disposal systems. The streets will be curved and patterned to conform to the topography. Space will be provided for a school, playgrounds, hospital, shopping center, parks, and other community facilities.

As soon as definite locations are established, the Bureau will construct for its employees 125 three-bedroom permanent houses and 75 two-bedroom houses (masonry unit construction), and 130 three-bedroom and 60 two-bedroom wood-frame temporary houses. Also to be built are an administration building, a garage and fire station, a laboratory, and a warehouse. Current plans call for contemporary architecture in the design of the houses and buildings. They will be air-conditioned to assure comfortable living conditions during hot summer months.

This community construction will be undertaken under various Bureau specifications which will require the contractors to furnish and install all materials. In the meantime, portable, five-room houses for use at the dam site are being built under a contract awarded last August to Transa Homes, Inc., Fullerton, Calif. These portable houses are to be completed with heating, plumbing, and electrical systems and ready for installation and connection to utilities to be provided under future contracts.

Personnel

W. A. Dexheimer, whose offices are in Washington, D. C., is Commissioner of the Bureau of Reclamation. The storage project is in the Bureau's Region 4; E. O. Larson is Regional Director. L. F. Wylie is project construction engineer for the Glen Canyon Unit; his office is at Kanab, Utah.

San Luis Project report to Congress

A BUREAU OF RECLAMATION report on the economic and engineering feasibility of the proposed San Luis Unit of the Central Valley Project in California has been forwarded to the Congress, Secretary of the Interior Fred A. Seaton announced recently.

The San Luis Unit would provide a full water supply to 440,000 ac. of land along the west side of the San Joaquin Valley. Most of this land is presently irrigated by pumping from private wells but the water supply is being rapidly depleted and it is estimated that not more than 150,000 ac. can be sustained in permanent irrigated agriculture without additional water being made available.

The major works reported upon—estimated to cost approximately $229,000,000—include the million-acre-foot initial capacity San Luis Reservoir, the San Luis pumping plant to pump water from the Delta-Mendota Canal, and a system of main canals through the irrigated area. In addition to the major features of the San Luis Unit, other features—principally the distribution system—would cost an estimated $170,000,000.