THE SALT RIVER IRRIGATION PROJECT

BY

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I recommend that the thesis prepared under my supervision by LLOYD SIDNEY TREUTHART entitled The Salt River Irrigation Project be approved as fulfilling this part of the requirements for the degree of Bachelor of Science in Civil Engineering.

Recommendation approved:

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FOREWORD.

Irrigation is not a new subject, although it is only within the last fifteen years that we, in the United States, have had our attention called strongly to it. Irrigation was carried on long before this in other countries, Egypt being the first country in which it was extensively practiced. At present Egypt has about six million acres of irrigated land, India forty million acres, most of which is of recent development. Irrigation is used also in Europe, although on a comparatively small scale. Italy leads with an irrigated area of four million seven hundred thousand acres, Spain has about three million acres and France four hundred thousand acres, also China, Japan and Australia irrigate extensively. The above mentioned works represent a cost of about seven hundred million dollars, and the annual income from the crops has an average annual value of about seven hundred twenty five million dollars. This shows that the average annual income per acre is a trifle over eleven dollars.

These works are variously controlled. In India, practically all are under government control, the government owning, operating and collecting rentals for both land and water. In most of the other countries the land is owned by individuals, and in some by the government. In the cases where the government owns the water supply, the individuals pay, according to an agreement, a certain amount per acre irrigated, or according to the amount of water used. In the United States the larger part of the irrigated works are owned by individuals or corporations, who collect for water rental. In many cases the land
owner holds no property share in the irrigation works. In cases of individual ownership, trouble frequently arises over methods of water distribution, especially when the system is heavily loaded, and also over lack of capital to make the systems sufficiently extensive.

There are traces of pre-historic irrigation in this country, especially in the district of the Salt River Valley. Modern irrigation was begun in this valley about 1863. Water was first diverted from the river through small ditches to the lower lands, then larger ditches were opened higher up the valley. These were run parallel to the first, and later a canal was built on each side of the river. In this manner an irrigation system was built up, commanding over two hundred thousand acres of irrigable land. The low water discharge which was used by the system, was insufficient for over one-eighth of the area. However, during a series of wet years, about 1890 to 1896, the region underwent great development. Farms and orchards were brought to a state of productivity, and the region appeared prosperous. From 1898 to 1901 there came a series of dry years. The farms and orchards dried up, leaving the region in imminent danger of depopulation. It was then that the matter came before the Government for action. Either the region must be supplied with water, or it would again become a desert. Through an act passed by the United States Congress in 1902, the government purposed, by means of the Secretary of the Interior and the Reclamation service, to carry on an extension of the irrigation work in this country, the system being so arranged that ultimately the land owners receiving benefit from the project shall pay for it. It was the above act that made the Salt River Irrigation Project possible, also it was the necessity for the Salt
River Project that practically forced the act.

Under the irrigation act of 1902, plans for the Salt River Project were made. It is the purpose of this thesis to describe the construction of the project, with especial regard to costs and methods in connection with the Roosevelt Dam and Reservoir.

GENERAL SCOPE.

The Salt River Irrigation Project is located in the south central part of Arizona, in Gila and Maricopa counties, the city of Phoenix being near the center of the irrigated territory. The dam and reservoir are about sixty-five miles east and slightly north of Phoenix, about one-fourth mile below the junction of Tonto Creek and Salt River, the reservoir covering about twenty-five and five-tenths square miles. This is about fifty miles from the nearest railroad — the Atchison, Topeka, and Santa Fe, at Mesa. The elevation of the irrigated area is from one thousand to thirteen hundred feet above sea level, the drainage areas from nineteen hundred fifty to eleven thousand five hundred feet above sea level.

The project embraces, in all, about two hundred and fifty thousand acres, or about three hundred and ninety square miles, one-fifth of which is to be irrigated by pumping from wells, the rest by water from the Salt River Reservoir. The entire water supply is under the control of the Water Users Association, which is an organization composed of all consumers, the supply being divided as fairly as possible among the lands in private ownership, and is paid for by the acre foot.

The soil is very fertile, mostly sandy loam. It is easy to cultivate and irrigate. There is some hardpan in the region, but deep
enough not to interfere with irrigation. Snow, ice, cold winds and bad storms are unknown in this region, the temperature never reaching the freezing point. The highest recorded temperature is one hundred and sixteen degrees Fahrenheit, but the humidity is low and the heat is not oppressive. There are occasional sand storms, sometimes accompanied by lightning and thunder with heavy precipitation. Irrigation is necessary, however, throughout the entire year, since the rainfall over the territory to be irrigated is only from three to ten inches per year, falling mostly during the winter months. The supply, over the six thousand two hundred and sixty square miles on the upper Salt River, and the six thousand square miles on the Verde River is ten to twenty inches per year.

The products of the region are, alfalfa, barley, wheat, oats, fruits, and garden vegetables. Horses, cattle, hogs and sheep are raised and much wool is produced. Ostrich farming is also a profitable industry here, and dairying is carried on extensively and profitably.

It was with the view of utilizing the wealth of the soil and favorable climate that the Salt River Irrigation Project was started and pushed to completion at the expense of the Government. A financial arrangement has been made whereby the government shall be repaid so it shall be at the ultimate expense of the water users of the district.

PRELIMINARY CONSTRUCTION.

The roughness of the country between the dam site and Mesa, the nearest railroad station, made road construction very difficult. This fact made hauling of materials costly and necessitated reducing of haulage to a minimum. This called for much preliminary work before
the actual construction of the dam could be begun. It was, however, necessary to build as good roads as possible from Mesa for hauling of supplies that could not be produced at Roosevelt. Also, a good road was built around the reservoir, and to different parts of the work for construction purposes. In all, about one hundred and forty six miles of road were built.

All the construction on the project was done by contract, the work being under government supervision. The contract for the construction of the dam was let to John W. O'Rourke and Company of Galveston, Texas, April 8, 1905. This contract provided that the government should furnish cement, sand, and power. It was found that excellent cement materials existed near the dam site, and believing that cement could be made cheaper than it could be delivered a cement mill was erected. The contract was let to the Wilcox and Rose Company. The mill was a "dry process" type, using oil for fuel, having an actual capacity of about four hundred barrels per twenty four hours. The manufacture of cement started early in 1905. The mill never ran at full capacity, but in five years about three hundred thousand barrels of cement were manufactured.

A plant was erected to crush rock for sand. The plant consisted of a "Blake jaw-crusher", two sets of crushing rolls thirty six inches in diameter, elevator, screen, bins, and other necessary appliances. A "Gates No. 4 crusher" was added later. The rock first used was a dolomite limestone. This did not give a sufficiently fine sand for good mortar. To improve the quality, a white friable sandstone was mixed with the limestone, half and half, giving an excellent sand for mortar.
Because of the difficulty of obtaining fuel for power purposes, it was found desirable to build a power canal, water being conveyed nineteen and one-fourth miles from the upper Salt River to the dam site. The canal has a capacity of two hundred and twenty five cubic feet per second, and a drop at the dam site of two hundred and twenty feet. Although built specifically to furnish power during construction, it is a permanent feature. The power is to be transmitted to the plains below and used for pumping water to irrigate about fifty thousand acres. The water for this canal is obtained by a concrete diversion dam, four hundred and fifty feet long, raising the water in the Salt River six feet. The head-gates, waste-gates and culverts are of concrete, and the twenty one tunnels, with a total length of about two miles, are lined with concrete. The lower one and one-half miles of the canal are concrete lined, because of the soft nature of the material of which the steep hillsides are composed. This canal was put in operation April 1st, 1906. It connects, at the lower end, with a penstock, seven feet in diameter. This penstock dips under the south spillway of the dam, to the power house. The upper half of the penstock is concrete, and the lower half is riveted steel, backed with concrete. The power house is located immediately below the dam. It is one hundred and twenty five feet by thirty eight feet. The first machine installed was a one thousand kilowatt horizontal turbine and generator. The final equipment is to consist of six "S. Morgan Smith vertical" turbines, each to operate a one thousand kilowatt "General Electric" twenty three hundred volt, twenty five cycle generator, besides the auxiliaries, as oil feed pumps, operating board, switch gallery, etc. Below the power house, the electric current is transformed to forty five
thousand volts, it then passes to Mesa and Phoenix by a six wire transmission line, suspended on steel towers, there to be used for additional pumping.

A saw mill was erected in the Sierra Ancha Mountains, about thirty miles northeast of the dam site. About three million feet B.M. of lumber was sawed and hauled to the dam site for general use about the camps and construction work.

CONSTRUCTION OF DAM.

Although the construction of the project was authorized in 1905, it was not until 1905 that work actually commenced. During the summer and fall of 1905 the construction camp was established and the plant equipped, the quarries stripped and piles driven for the cofferdams. On Nov. 27th, there came down the Salt River the second largest flood on record. This destroyed all work on the cofferdams and flumes, and washed away considerable machinery. The river had risen thirty feet at the dam site, the discharge increasing from the normal flow of two thousand second feet to one hundred and thirty thousand second feet. Work was recommenced in March, trouble again being caused by smaller floods. The original idea of carrying the river partly by a flume was abandoned, leaving a sluicing tunnel with a capacity of thirteen hundred second feet to carry the river. The two cofferdams (one being below, and one above, the excavation) were completed June 15th, 1906, and the water was diverted through the tunnel. Work could be carried on in the bed of the river only when the discharge was under thirteen hundred second feet. Favorable conditions prevailed for about three months, the cofferdams were made water tight, and
the loose material and rock were removed from the bed of the river in preparation for the foundation.

The loose material was removed, for the most part, by two Campbell hydraulic elevators, the material being thrown up into a flume and washed downstream. The water used for this purpose was furnished from the power canal under a head of about two hundred and fifty feet above the pit. This method was rather unsuccessful, because of the nature of the materials encountered. Hydraulic jet pumps were used for all the pumping on the work, because they appeared to operate more economically under the circumstances. Only a small amount of excavation was necessary for the bed of the dam, as the river bottom was bed-rock.

The first stone was laid in the dam on Sept. 20th, 1906. Work was continued without interference until Dec. 2nd, when another flood destroyed the coffer-dams, and prevented further work until the following spring. In the early months of 1907 the coffer-dams were rebuilt, the upper one being made of masonry, and the pit re-excavated. The laying of masonry on the dam was resumed June 18th. Floods gave considerable trouble during the summer of 1907, work being carried on only about one-half of the time. During November and December of 1907, and January of 1908 excellent progress was made. A large flood came on Feb. 4th, but at that time the south end was at an elevation of twenty-five feet, and the rest at an elevation of nine feet. A point on the bed of the river was taken as zero elevation, (see Plate I). The dam was now too far along to be seriously damaged by floods and the coffer-dams were no longer needed.

The gates for the sluicing tunnel were next put in and the operating devices installed. By June 2nd the tunnel was in shape to
carry the river again. The tunnel being blocked during the placing of the gates, the river had been deflected over the north of the dam. Work had been carried on at the south end from February until June, and it was brought up to an elevation of seventy five feet. From June until September the north end was built up to an elevation of forty feet. The north end was kept considerably lower than the south end of the dam, during the construction, in order that any floods could pass over without interfering with the power house. On Dec. 19th, 1908, with the south end of the masonry at an elevation of eighty eight feet and the north end at an elevation of sixty five feet, a great flood occurred which filled the reservoir to elevation ninety, two feet above the highest part of the masonry. The fall of the water washed out about twelve thousand cubic yards of stone at the toe of the dam. This was not repaired until in May, 1910, when a coffer-dam was built and the pool pumped out. The bed rock was found to have been disintegrated to an elevation of minus sixty, eighteen feet out from the line of masonry. There was some undercutting between elevation minus twenty two feet and minus thirty feet, but the masonry itself was intact. A buttress of about one thousand cubic yards of masonry was built, starting at elevation minus sixty feet and coming up to elevation minus fourteen feet. Except for the above, work went on smoothly all through 1909, and October, 1910 found the masonry of the dam proper practically complete.
METHODS AND DETAILS OF CONSTRUCTION OF DAM.

Specifications for the masonry demanded as great a proportion of rock and as little cement mortar as possible. The dam is of gravity section, but is also arched upstream with a radius of about four hundred feet. No joints are less than two inches, except on the face of the dam. Rock and spalls were rammed into the vertical joints. The main body of the dam is broken range cyclopean rubble masonry. The rock used is a fine-grained dolomitic sandstone, a great part coming from the spillways. Not less than one-third of the area in any part of the upstream face was required to be headers, on the downstream face not less than one-fourth of the area. The mortar used on the upstream face was one part of cement to two parts of sand; that on the downstream face was one part of cement to two and one-half parts of sand. On the upstream face, joints are broken not less than one foot horizontally projected. Stretchers were not less than three feet long, or over two feet in any other dimension; headers were not less than six feet long or under two feet in any other dimension. The upstream face was kept at least one course higher than any other part of the dam.

To handle the materials, two two and one-quarter inch "Lidgerwood Cableways" were placed to span the river. They are about twelve hundred feet long and at an elevation of about three hundred and fifty feet. One is on the line joining the ends of the dam, and the other is parallel to it about eighty-five feet upstream. These are used to bring down mortar and concrete to the mixing plant on the south hillside and also to carry rock from the quarries at either end.
of the dam. A "Lescher aereal tramway" seventeen hundred feet long, provided transportation between the mixing plant and the cement mill. It was used for carrying cement and sand to the mixer, the sand plant being between the terminals. The tramway was supported at three intermediate points.

The mixer used at the mixing plant was a "Smith mixer", handling one and three-tenths cubic yards per batch. The carriers were boxes of three and one-half cubic yards capacity, which carried two batches at a time from the mixer and were rolled out from it to the cableway on tracks. Derricks of the stiff-leg A-frame type were used on the dam for handling materials and guy derricks were used in the quarries. The hoisting engines were furnished with five hundred volt direct current. There was also an air compressor, with a capacity of seven hundred cubic feet per minute, at the power house. This was used to run drills.

The rate of progress of the entire mass of masonry, barring the building of the buttress at the toe, and the building of the parapets, was thirteen and two-tenths cubic yard for each derrick hour of work. Mr. Chester Wason Smith, the constructing engineer, claims this to be the most rapid rate ever attained on any large work, and gives credit for the speed to the manner of laying the masonry, the vertical joints having been filled with wet concrete, largely dumped into place and spalls thrown in. The method usually employed has been to fill the vertical joints with a trowel, using a stiff mortar.

The proportions of the masonry are: mortar fourteen percent, concrete thirteen percent, spalls ten percent, and large stone forty percent. One cubic yard of masonry on an average required about
seventy-six-hundredths barrels of cement.

OPENINGS IN THE DAM.

The dam is provided with three openings. One is at elevation zero, one from elevation seventy-five on the upstream face to elevation twenty-five in the power house below the dam; the third opening is at elevation one hundred seventeen and five-tenths. The first is a tunnel four hundred and fifty feet long and having one hundred and eight square feet in cross-section, driven through the wall of the canyon around the south end of the dam. The inlet is located about one hundred and twenty-five feet above the upstream face of the dam, and is screened by a reenforced concrete tower seventy-eight feet in height. This tunnel was used to pass the river while work on the foundation was being done, and serves permanently as a sluicing tunnel. There are six gates near the intersection of the upstream face of the dam, one set being provided for service, the other set, about ten feet upstream from the first, for emergency gates. Each opening is about four and one-half feet by nine feet. There is a chamber above the openings, and in it are two hydraulic cylinders, two feet in diameter. The floor of the chamber is at an elevation of thirty feet. A pressure of one thousand pounds per square inch is obtainable for starting the gates. This chamber is at the foot of a shaft built out on the upstream face of the dam. The shaft will eventually be fitted with an elevator. The floor of the chamber is seven feet thick, and the rods to the gates pass through stuffing boxes set in the reenforced concrete floor. These gates were built and installed by the Llewellyn Iron Works of Los Angeles,
California in the spring of 1908, the river being diverted through
then in June of the same year.

The second opening, from elevation seventy five to elevation
twenty five in the power house, is a riveted steel penstock, ten
feet in diameter. The opening is rectangular, five feet by twenty
feet, covered by a heavy cast iron grating set in the face of the
dam. The rectangular opening is changed by warped steel plates to
the cylindrical shape of the penstock. Screens are provided to fit in
grooves over the opening; also a steel shutter is provided to close
the opening. A small chamber is located just under the roadway, and
in it is installed the hoisting apparatus for the screen and shutter.
A balanced valve is located between the dam and the power house. The
machines operated from this are of one thousand kilowatt power.

The third opening, at elevation one hundred seventeen and five-
tenths, is near the north end of the dam. It consists of three lines
of five foot cast-iron pipes passing from the upstream face of the
dam through the masonry at the junction of the masonry and the nat-
ural rock, and converging into a concrete lined tunnel nine feet in
diameter. This tunnel discharges out of the cliff about one hundred
feet below the dam. The entrances to the pipes are closed by balanced
valves, anchored to the upstream face of the dam. These valves oper-
ate as follows: - A plunger fits into the round pipe and is operated
by a piston working in a casing. Water is permitted to leak between
the piston ring and the cylindrical casing, until the chamber is
filled; then the valve closes by the action of the water on the
larger area of the piston. The rapidity of action depends on the
rate of leakage. For opening the valve, a three inch pipe leads from
the cylinder, back of the piston, through to the downstream face of the dam. This pipe can carry more water away than can leak by the piston to the chamber, so the pressure is reduced, and the valve opens. To keep the valve open, the small pipe is left open, and to close the valve, the small pipe is closed.

**THE GRANITE REEF DAM.**

The water which is passed through the openings of the Roosevelt Dam, as mentioned above, goes down the bed of the Salt River about fifty-five miles to the diversion dam, located at the head of the canals to the irrigated land. This dam is the Granite Reef Dam, which forms a reservoir having an intake at both the north and south sides, one leading to each of the main distributing canals.

At this point of the river, bed rock is at such a depth that it was found impracticable to extend the foundation to it. Three curtain walls were built, extending across the stream. (Plate 5). The one under the upper toe is six feet in width and is run to a depth of eighteen feet below the elevation of the apron below the dam. The one under the lower toe is carried to a depth of fourteen feet below the surface of the apron. Through this second apron, openings, six inches square, and spaced five feet apart, were placed at about six feet above the bottom of the wall. These openings permit the escape of water that may collect. The apron is of concrete, laid on a foundation of placed boulders, about four and one-half feet thick. The apron itself is one and one-half feet thick. It is laid in squares of ten feet on a side, with three inch openings between the squares. These prevent water from collecting under the apron, and exerting an upward pressure,
as the water could not otherwise escape because of the third curtain wall which is twelve feet deep at the downstream edge of the apron.

After the sluiceways at the ends of the dam were closed, water began to rise in the cracks which were left in the apron. The greatest flow was not over three cubic feet per second, and no flow whatever could be noticed under flood conditions.

The Roosevelt dam equalizes the flow to be handled by the Granite Reef Dam, and greatly reduced the maximum flow, which, it will be remembered, was very great at times. The diversion dam is one thousand feet long, so that the largest flood quantities can be handled without danger from the water being too high above the dam. The intake structure at the south side is to a canal of twelve hundred second feet capacity. The sluiceway to this canal has a floor forty feet wide, with a grade downstream one and one-half percent. At the line of the dam it is eight feet lower than the crest of the dam. At the river side the sluiceway has a wall fifteen feet higher than the dam. Through this wall are nine openings five feet high and seven feet wide for the nine regulator-gates. These gates are four feet below the crest of the dam and from three to four feet higher than the floor of the sluiceway. At the lower end of the sluiceway, and in line with the dam, are two sluice-gates, nine feet high and fifteen feet wide, with the sills eight feet below the crest of the dam.

The object of the arrangement of the regulator-gates was to have the bottom of the stream feeding the gates, in order that the heavier grit, of which there is a large amount, would not pass into the feeding canal, and the bed may be kept clear by allowing the sediment to pass out through the sluice-gates. The water which passes
through the sluice-gates is not entirely wasted, for there are some independent irrigation canals below, which are entitled to a certain amount of water, and that used for sluicing is largely cleared before reaching them. The two sluice-gates may be opened and closed simultaneously. They are either kept open slightly, or are opened and closed alternately at short intervals.

The intake structure at the north side is similar to the one at the south side, there being slight differences in detail. The North Canal has a capacity of two thousand second feet and the sluiceway is eighty feet wide. There are eighteen regulator-gates, and four sluice-gates. The general arrangement is the same as that at the south side, which is described above.

The sluice-gates are operated by a chain and rope passing over a system of pulleys, through a tunnel under the gates and around a drum to the cross-head of a hydraulic piston. The gates have, at the upstream face, a cast-iron curved shell three-fourths inch thick, made in halves and riveted together by a number of five-eighths inch by two and one-half inch tie bars. The gates are filled with concrete, giving a total weight of about thirty thousand pounds each, and are suspended by one and one-half inch chains by which they are operated.

CANALS.

The operation of the canal system of the Salt River Project by the United States reclamation service was begun May 15th, 1907, when the north side system was taken in charge. As mentioned above, a system of canals had been gradually built up to supply the needs, most of the work having been done from about 1885 to 1900. These first
canals were of the cheapest possible construction, being ditches with wooden structures. These canals did not have good headgates, and as a result, sand from the river, added to that washed from the canal banks, had collected, and much cleaning and dredging was necessary before the canals were in serviceable condition. Many repairs were also necessary on the wooden structures, which are now planned to be made of a more permanent material. A large item of expense in the maintenance of the canal system is the keeping down of Johnson grass, sour clover and weeds which flourish on the moist banks. The amount of sand entering the headgates has been greatly lessened since the Granite Reef Dam has been in operation, but the settling of silt washed from the canal banks still gives some trouble.

The following lists contains the names of the canals operated by the reclamation service in Salt River Valley, with the mileage of main canals and laterals and sub-laterals:

<table>
<thead>
<tr>
<th>Name</th>
<th>Miles.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arizona canal</td>
<td>42</td>
</tr>
<tr>
<td>Arizona canal, laterals and sublaterals</td>
<td>196 1/2</td>
</tr>
<tr>
<td>Cross Cut canal</td>
<td>5 1/2</td>
</tr>
<tr>
<td>Grand Cross Cut canal</td>
<td>1/2</td>
</tr>
<tr>
<td>Joint Head canal</td>
<td>1 1/2</td>
</tr>
<tr>
<td>Salt River Valley canal</td>
<td>15</td>
</tr>
<tr>
<td>Salt River Valley canal, laterals and sublaterals</td>
<td>3 1/2</td>
</tr>
<tr>
<td>Maricopa canal</td>
<td>15 1/2</td>
</tr>
<tr>
<td>Maricopa canal, laterals and sublaterals</td>
<td>3</td>
</tr>
<tr>
<td>Grand canal system</td>
<td>19 1/2</td>
</tr>
<tr>
<td>Grand canal system, laterals and sublaterals</td>
<td>12 1/2</td>
</tr>
</tbody>
</table>

Total—--------527

Note.—List from Reclamation Service Report of 1909.
COSTS.

When the Salt River Project was begun, the cost of construction gave promise of being exceedingly high. The cost was increased by the great amount of hauling necessary to bring fuel and supplies from here, as well as all machinery used, and any material that could not be obtained at the dam site. The lumber used had to be hauled thirty miles from the saw mill. This hauling necessitated the building of about one hundred and forty six miles of road, at a total cost of approximately five hundred thousand dollars.

The lowest bid received by the government for cement was four dollars and eighty nine cents per barrel delivered at the dam site. The cement manufactured at the dam site cost about two dollars and seventy cents per barrel as detailed in Table 2. The fuel used in the cement mill was California crude oil, which cost three dollars and forty eight cents per barrel of forty two gallons, delivered at Roosevelt.

The Government furnished power to the contractors at one-half cent per horse power hour. This was about the actual cost of the development of the power. The prices paid for labor and the cost of sand crushing, cement manufacture, and placing of masonry can be found in detail in Table 2. The costs are given for only two months, March, 1908 and March, 1909, but the costs in those months represent average conditions.

On Dec. 51st, 1910, the total cost as estimated by the engineers of the Salt River Project was nine million, six hundred and
sixty five thousand dollars. The allotments made up to December 31st, were nine million, one hundred and seventy thousand dollars. The project was opened in March, 1911 and the above total estimated cost is practically the amount of the investment of the Government.

The cost of the project was greatly reduced by the natural resources of the region. Stone for the masonry was found at the dam site and cement making materials were near at hand. Power was developed at a reasonable cost, considering that the plant is permanent and that the power is still to be used in pumping.

COMPARISON WITH OTHER PROJECTS.

Following is a brief comparison of the Salt River Project with five other of the largest projects in charge of the reclamation service.

<table>
<thead>
<tr>
<th>Project</th>
<th>Total Area Irrigated. Acres.</th>
<th>Total Estimated Cost.</th>
<th>Cost per acre.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Salt River</td>
<td>250,000</td>
<td>$9,665,000</td>
<td>$42.02</td>
</tr>
<tr>
<td>Yuma</td>
<td>131,000</td>
<td>7,700,462</td>
<td>58.78</td>
</tr>
<tr>
<td>Payette-Boise</td>
<td>243,000</td>
<td>10,852,435</td>
<td>44.66</td>
</tr>
<tr>
<td>Sun River</td>
<td>522,000</td>
<td>10,000,000</td>
<td>51.05</td>
</tr>
<tr>
<td>Truckee-Carson</td>
<td>206,000</td>
<td>7,000,000</td>
<td>55.93</td>
</tr>
<tr>
<td>Shoshone</td>
<td>164,000</td>
<td>7,628,000</td>
<td>47.75</td>
</tr>
</tbody>
</table>

The Salt River project compares favorably with the other projects, comparing only estimated costs per acre irrigated. The estimated cost given of the Salt River Project is practically the final cost. The Sun River and Shoshone Projects are hardly near enough to
completion to be considered completed, although there is little danger of a variation of over one dollar in cost per acre irrigated. The Salt River Project stands third in the number of acres irrigated by any one project under the reclamation service, but has the largest reservoir.

The Roosevelt dam is exceeded in height forty four and one-half feet by the Shoshone, and in length thirty seven hundred feet by the dam of the Yume project. The dam of the Salt River Project has the greatest yardage of masonry and, as an engineering feat, it is the largest and most difficult yet undertaken in irrigation engineering in America.

Below is given a rough comparison of the size of reservoirs and dams of the above projects.

<table>
<thead>
<tr>
<th>Type of Dam.</th>
<th>Length of Crest. Ft. of Dam</th>
<th>Height of Reservoir. Ft.</th>
<th>Storage Capacity Gal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Salt River---</td>
<td>Rubble Masonry</td>
<td>1060</td>
<td>284</td>
</tr>
<tr>
<td></td>
<td>Arch Gravity</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yuma---------</td>
<td>Indian Weir</td>
<td>4780</td>
<td>19</td>
</tr>
<tr>
<td>Payette-Boise</td>
<td>Three Dams and Reservoirs</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sun River-----</td>
<td>Hydraulic Fill</td>
<td>1945</td>
<td>110</td>
</tr>
<tr>
<td></td>
<td>Concrete Sluicing Regulator</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Rubble</td>
<td>(Three Dams and Reservoirs)</td>
<td>1,263,000</td>
</tr>
<tr>
<td>Shoshone-----</td>
<td>Concrete Arch</td>
<td>200</td>
<td>523 1/2</td>
</tr>
</tbody>
</table>

CONCLUSIONS.

The policy of the Government in building irrigation for the land owners and allowing them to repay later, is commended as a matter of public policy. It makes possible the building of projects too costly to be undertaken by individuals, and it proves a profitable investment to the Government, as there are increased tax returns from the irrigated areas. The value of the land under the Salt River Pro-
ject was increased from a value of fifty dollars to seventy five dollars before being irrigated to a value of from seventy five dollars to seven hundred and fifty dollars after being irrigated. This increased value will be even greater when the orchards have had time to mature, and the land has become fully improved.

When the building of a cement plant and the manufacture of cement for the dam was considered by the government, a vigorous complaint was made by the cement manufacturers. They claimed that it was a discrimination against them, since other manufactured articles were bought, and further that the act of the Government was not for the best interests of the country, since it discouraged commercial development and manufacturing by individuals. They also claimed that it would be impossible for the Government to get fuel to Roosevelt, and make the cement cheaper than it could be bought from them. Experience has proven that the Government was able to make the cement cheaper by two dollars and twenty cents per barrel and thus reduced the expense of the construction.

All the work having been done by contract, and the contracts having been let to the lowest responsible bidders, it appears that the work was done as cheaply as possible. There was very little opportunity for the usual claims of graft, because the contractor worked under Government inspectors, and these in turn were under the chief engineer of the service, giving assurance of the work being as required by the specifications.

The name given the great new "Roosevelt Dam" is a fitting tribute to ex-president Theodore Roosevelt, since it was his foresight and untiring perseverance which made possible the Reclamation Act of
June 17th, 1902, under which the Reclamation Service is bringing water to our inland deserts, and making the arid lands productive.
Bibliography:

Reclamation Service Reports, Volumes 6, 7, 8 and 9.

   " " March 9th, 1905.
   " " May 50th, 1907.
   " " June 25th, 1908.
   " " Sept. 10th, 1908.
   " " Oct. 1st, 1908.
   " " Jan. 7th, 1909.
   " " Feb. 2nd, 1911.

Engineering Record, June 20th, 1908.
   " " Dec. 31st, 1910.

<table>
<thead>
<tr>
<th>Firm</th>
<th>Time Excavation for Foundation</th>
<th>Masonry</th>
<th>Concrete</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class 1</td>
<td>Class 2</td>
<td>Class 3</td>
<td>Dam</td>
<td>Coping</td>
</tr>
<tr>
<td>John M. O'Brien + Co., Galveston, Texas</td>
<td>2 yrs.</td>
<td>£ 1.75</td>
<td>£ 5.00</td>
<td>£ 3.15</td>
</tr>
<tr>
<td>Bledsoe &amp; Company, St. Louis, Mo.</td>
<td>17 mo.</td>
<td>0.96</td>
<td>3.50</td>
<td>2.75</td>
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<tr>
<td>Geddes &amp; Co., Denver, Colo.</td>
<td>33 yrs.</td>
<td>2.00</td>
<td>4.00</td>
<td>1.00</td>
</tr>
<tr>
<td>Edw. Malley + Co., San Francisco, Cal.</td>
<td>26 yrs.</td>
<td>2.50</td>
<td>7.00</td>
<td>3.00</td>
</tr>
<tr>
<td>Carl Leonard + Los Angeles, Cal.</td>
<td>23 yrs.</td>
<td>2.30</td>
<td>1.50</td>
<td>1.50</td>
</tr>
<tr>
<td>Mason Hoge + Co., Frankfort, Ky.</td>
<td>3 yrs.</td>
<td>1.65</td>
<td>2.60</td>
<td>2.50</td>
</tr>
<tr>
<td>MacArthur + Bros. Co., Chicago, Ill.</td>
<td>33 yrs.</td>
<td>1.75</td>
<td>3.50</td>
<td>2.50</td>
</tr>
<tr>
<td>Griffiths + McDermott, Chicago, Ill.</td>
<td>30 yrs.</td>
<td>2.25</td>
<td>4.00</td>
<td>2.00</td>
</tr>
<tr>
<td>Deeks + Deeks, St. Paul, Minn.</td>
<td>2 1/2 yrs.</td>
<td>4.00</td>
<td>8.00</td>
<td>1.25</td>
</tr>
<tr>
<td>E. B. + A. L. Stone Co., Oakland, Cal.</td>
<td>40 yrs.</td>
<td>5.00</td>
<td>10.00</td>
<td>2.00</td>
</tr>
<tr>
<td>Mosler De Graff + Co., Buffalo, N.Y.</td>
<td>22 yrs.</td>
<td>2.50</td>
<td>3.50</td>
<td>1.50</td>
</tr>
<tr>
<td>Winters, Parsons + Moore, Spokane, Wash.</td>
<td>21 yrs.</td>
<td>5.40</td>
<td>8.00</td>
<td>1.25</td>
</tr>
<tr>
<td>San Francisco Bridge Co., San Francisco, Cal.</td>
<td>35 yrs.</td>
<td>2.50</td>
<td>5.00</td>
<td>3.00</td>
</tr>
<tr>
<td>Johnson + Sherman Constr. Co., Okla. City, Okla.</td>
<td>27 yrs.</td>
<td>0.75</td>
<td>6.50</td>
<td>3.40</td>
</tr>
<tr>
<td>Bentley-Tuttle + Pelton Constr. Co., St. Louis, Mo.</td>
<td>28 yrs.</td>
<td>3.70</td>
<td>7.50</td>
<td>4.15</td>
</tr>
<tr>
<td>Perdue + Clarkson Constr. Co., Chicago, Ill.</td>
<td>700 days</td>
<td>2.85</td>
<td>7.00</td>
<td>2.35</td>
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<tr>
<td>Faris + Kesel Constr. Co., Ltd., Boise, Idaho.</td>
<td>2 yrs.</td>
<td>3.35</td>
<td>5.25</td>
<td>2.50</td>
</tr>
<tr>
<td>The American Constr. Co., Denver, Colo.</td>
<td>3 yrs.</td>
<td>1.50</td>
<td>3.00</td>
<td>2.50</td>
</tr>
<tr>
<td>B. M. Zadek Co., Chicago, Ill.</td>
<td>22 yrs.</td>
<td>7.50</td>
<td>8.30</td>
<td>2.00</td>
</tr>
<tr>
<td>R. H. Hood Co., New York City, N.Y.</td>
<td>2000 yrs.</td>
<td>3.00</td>
<td>3.35</td>
<td>10.00</td>
</tr>
<tr>
<td>Bentley-Tuttle + Pelton Constr. Co., San Francisco, Cal.</td>
<td>23 yrs.</td>
<td>3.70</td>
<td>7.50</td>
<td>4.15</td>
</tr>
<tr>
<td>Burrell Constr. Co., Oakland, Cal.</td>
<td>3 yrs.</td>
<td>3.00</td>
<td>6.00</td>
<td>2.00</td>
</tr>
</tbody>
</table>

* Bids s, t, and u were informal.

Table 2
Cost of Manufacturing
107,589 Bbls. of Cement in 1908

<table>
<thead>
<tr>
<th>Items</th>
<th>Cost per Bbl.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Office Salaries, Supt., Chemist, etc.</td>
<td>$0.049</td>
</tr>
<tr>
<td>Operating Labor</td>
<td>.292</td>
</tr>
<tr>
<td>Maintenance Labor</td>
<td>.055</td>
</tr>
<tr>
<td>Maintenance Material</td>
<td>.085</td>
</tr>
<tr>
<td>Clay Digging</td>
<td>.054</td>
</tr>
<tr>
<td>Clay Hauling</td>
<td>.078</td>
</tr>
<tr>
<td>Limestone Quarry</td>
<td>.121</td>
</tr>
<tr>
<td>Supplies</td>
<td>.051</td>
</tr>
<tr>
<td>Fuel Wood for Drying Clay</td>
<td>.067</td>
</tr>
<tr>
<td>Fuel Oil</td>
<td>.922</td>
</tr>
<tr>
<td>Power</td>
<td>.122</td>
</tr>
<tr>
<td>Depreciation about</td>
<td>.80</td>
</tr>
</tbody>
</table>

Total: 2.696

Labor Costs on Masonry of Roosevelt Dam
During March, 1909.

Cement Tramway, 1700 ft. long. Takes cement and sand to mixer.
Worked two shifts per day, and took over 13,538 buckets of sand
at 8 cu.ft. and 9,822 buckets of cement at 5.2 cu.ft.
Day, 29 1/2 Shifts—

Ave. force
\[
\begin{align*}
1 \text{ Engineer} & \ldots @ 2.50 \\
1 \text{ Laborer} & \ldots @ 3.00 \\
3 \text{ Laborers} & \ldots @ 2.50 \\
\end{align*}
\]
Total - $379.88

Night, 28 Shifts—

Ave. force
\[
\begin{align*}
1 \text{ Engineer} & \ldots @ 3.00 \\
5 \frac{1}{2} \text{ Laborers} & \ldots @ 2.50 \\
\end{align*}
\]
Total - $484.15

Two Lidgerwood Cableways, 2 1/4 in. diameter, 1200 ft. long. Took from
mixer to dam 1056 skips of mortar, and 2,571 skips of concrete.
Took from quarries to dam 1,376 skips of spalls.
Day shift for the two cableways, average force:
2 Cableway Engineers - - - - @ $4.00
2 Signalmen - - - - - - - - - - - - - - - - @ 2.50
4 Tagmen @ $3.00 \times 28 \text{ Shifts} = $795.06^{26}

1 Oiler \times @ 3.50

Night crew takes down stone, includes collecting stone in quarry, transporting to dam, and some passing around on the dam; also moved the derricks on the masonry. Took onto dam about 7,900 cu. yds.

\[
\begin{align*}
\text{Ave.} & \quad \text{1 Watchman} \quad @ \quad 2.50 \\
\text{force} & \quad \text{2 Cableway Engrs.} \quad @ \quad 4.00 \quad \text{29 \text{ Shifts}} \quad $4,756.73 \\
& \quad \text{2 Signalmen} \quad @ \quad 2.50 \\
& \quad \text{7 Engineers} \quad @ \quad 3.50 \\
& \quad \text{18 or 19 Laborers} \quad @ \quad 2.50 \\
\end{align*}
\]

Transporting Material:

Per cu. yd. $0.260 = $4,756.73

Quarries on North side of River:

Produced large stone, about 5,000 cu. yd. for dam.

Produced spalls, about 2,100 cu. yd. for dam.

Produced waste, about 3,150 cu. yd. for which they received excavation price $1.50 per cu. yd.

\[
\begin{align*}
\text{Day} & \quad \text{20 Laborers} \quad @ \quad 2.50 \\
\text{Shift} & \quad \text{4 Laborers} \quad @ \quad 2.25 \quad \text{29} \frac{1}{2} \text{ Shifts} \\
\text{Ave.} & \quad \text{3 Drillers} \quad @ \quad 3.00 \\
\text{Force} & \quad \text{3 Helpers} \quad @ \quad 2.50 \\
& \quad \text{1 Blacksmith} \quad @ \quad 4.00 \\
& \quad \text{1 Helper} \quad @ \quad 3.00 \\
& \quad \text{1 Powder man} \quad @ \quad 5.00 \\
& \quad \text{1 Helper} \quad @ \quad 2.50 \\
\end{align*}
\]

Quarry on South side of River:

Produced large stone, about 2,900 cu. yds. for dam.

Produced spalls, about 100 cu. yds. for dam.
Produced stone, about 2,570 cu.yds. for crusher. Includes feeding crusher and one man inside of bins.

<table>
<thead>
<tr>
<th>Foreman -- @ $5.00</th>
</tr>
</thead>
<tbody>
<tr>
<td>4 Engineers -- @ 12.00</td>
</tr>
</tbody>
</table>

**Day**

<table>
<thead>
<tr>
<th>1 Laborer -- @ 3.00</th>
</tr>
</thead>
<tbody>
<tr>
<td>16 7-10 Laborers -- @ 2.50</td>
</tr>
<tr>
<td>7 8-10 Laborers -- @ 2.25</td>
</tr>
<tr>
<td>13 6-10 hrs. driller and helper -- @ .68</td>
</tr>
<tr>
<td>1 Powder man -- @ 4.00</td>
</tr>
</tbody>
</table>

Drillers 26.8 of shifts. All others 26.8 Shifts.

Cost -- $2,621.68

**All Quarries, Night Shifts:**

<table>
<thead>
<tr>
<th>Foreman 10 hrs -- @ $4.82</th>
</tr>
</thead>
<tbody>
<tr>
<td>Engineer 14 hrs -- @ 6.10</td>
</tr>
<tr>
<td>Driller and helper</td>
</tr>
<tr>
<td>24 6-10 hrs -- @ 16.91</td>
</tr>
<tr>
<td>Labor 106 hrs -- @ 33.29</td>
</tr>
</tbody>
</table>

Driller and helper 30 Shifts. All others 26

Cost -- $1,656.46

Total -- $8,365.49

Quarry Cost:

- Of stone handled, wasted 3,150 cu.yds., used 12,670 cu.yds.
- Cost per cu.yd. of stone handled -- $0.529
- Cost per cu.yd. of masonry, not allowing any credit for stone wasted -- $0.456

Cutting stone for upstream face; used enough for 7,500 sq.ft. face area; with headers it would average 3 ft. thick, say 833 cu.yd.

<table>
<thead>
<tr>
<th>Foreman 24 1/2 days @ $5.00</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stone Cutter 177 days @ $4.00</td>
</tr>
<tr>
<td>Laborer 82 days @ $2.50</td>
</tr>
</tbody>
</table>

Total Labor -- $1,035.50

Equals $1.24 per cu.yd. of cut stone or $0.057 per cu.yd. of masonry.

Mixing Mortar and Concrete. Materials drawn from bins into car, transferred 10 ft. and dumped into a 40 cu.ft. capacity Smith mixer dumped into a skip on a car and hauled by a stationary engine either 50 ft. to No.1 cableway or 125 ft. to No.2 cableway.
Mixed 2112 batches of mortar, 2323 cu. yd.
Mixed 5142 batches of concrete, 6736 cu. yd.

<table>
<thead>
<tr>
<th>Foreman</th>
<th>@ $3.50</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ave.</td>
<td>1 Engineer</td>
</tr>
<tr>
<td>Force</td>
<td>3 Laborers</td>
</tr>
<tr>
<td></td>
<td>1 Laborer</td>
</tr>
</tbody>
</table>

Total Cost: $478.13

Cost per cu. yd. mixed: $0.053
Cost per cu. yd. masonry: $0.026

Laying masonry with 5 Derricks. Total time, 28 1/2 shifts.

Average Gang for 5 Derricks:

<table>
<thead>
<tr>
<th>Foremen</th>
<th>@ 6.00</th>
<th>1 Foreman</th>
<th>@ 6.00</th>
</tr>
</thead>
<tbody>
<tr>
<td>Engineers</td>
<td>@ 4.00</td>
<td>1 Engineer</td>
<td>@ 4.00</td>
</tr>
<tr>
<td>10 Tagmen, mostly</td>
<td>@ 2.50</td>
<td>10 Tagmen</td>
<td>@ 2.50</td>
</tr>
<tr>
<td>7 Masons, mostly</td>
<td>@ 5.00</td>
<td>7 Masons</td>
<td>@ 5.00</td>
</tr>
<tr>
<td>23½ Laborers, mostly</td>
<td>@ 2.50</td>
<td>23½ Laborers</td>
<td>@ 2.50</td>
</tr>
<tr>
<td>1 Dogger</td>
<td>@ 3.50</td>
<td>1 Dogger</td>
<td>@ 3.50</td>
</tr>
</tbody>
</table>

Total Cost: $4840.50

Laid 18,328 cu. yd. of masonry in 1073 derrick hours.
Equals 17.1 cu. yd. per derrick hour.

Cost per cu. yd.: $0.264

Repairs:
To derricks in quarries, 117½ men-days: $422.75
To derricks on dam, 27 men-days: $102.00
To cableways, 21 men-days: $73.00
To cement tramway, 5 men-days: $18.50
Total: $616.25

Per cubic yard of masonry: $0.034

Pointing upstream face, cleaning up, etc.
46½ men-days: $160.25
Per cu. yd. of masonry: 0.009

General expense: Includes superintendent, electrician, two-thirds time of master mechanic, timekeeper and book-keeper:
185 men-days: $848.00
Per cu. yd. of masonry: 0.046
Power:
Labor, 3 men at power house - - - - - - - - $256.50
Power from Government, 165,013 hp-hours at $0.005 - - - - - - - - 825.00
Per cu. yd. of masonry - - - - - - - - - - - - - - - $1081.56
Summary:

<table>
<thead>
<tr>
<th>Cost of</th>
<th>18,328</th>
<th>Per</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transporting materials</td>
<td>$4,756.73</td>
<td>$0.260</td>
</tr>
<tr>
<td>Quarrying</td>
<td>8,365.49</td>
<td>0.456</td>
</tr>
<tr>
<td>Cutting upstream face stone</td>
<td>1,035.50</td>
<td>0.057</td>
</tr>
<tr>
<td>Mixing mortar and concrete</td>
<td>4,781.13</td>
<td>0.026</td>
</tr>
<tr>
<td>Laying masonry</td>
<td>4,840.50</td>
<td>0.264</td>
</tr>
<tr>
<td>Repairs</td>
<td>616.25</td>
<td>0.034</td>
</tr>
<tr>
<td>Pointing upstream face</td>
<td>160.25</td>
<td>0.009</td>
</tr>
<tr>
<td>General expense</td>
<td>484.00</td>
<td>0.046</td>
</tr>
<tr>
<td>Power</td>
<td>10,815.56</td>
<td>0.059</td>
</tr>
<tr>
<td>Total</td>
<td>$22,182.41</td>
<td>$1.211</td>
</tr>
</tbody>
</table>

The foregoing includes all labor, ordinary repairs for month, and power; does not include first cost of erection of equipment, nor any materials or supplies.

Cost of Crushing Sand

September, 1906, to February, 1910, Inclusive

Total plant charge (Gates crusher, Blake jaw crusher, two sets 36 in. crushing rolls, elevator, screens, building, bins, 75 H.P. motor, belts, shafting, cars, track, air drill, compressor) including erection equals - - - - - - - - $31,138.77

Sept.'06 to July '09, inclusive did drilling by hand; 8,500 lin.ft. of hole drilled, cost, (including sharpening steel) $7,815.00 or 92 cents per lin.ft. Aug.'09 to Feb., 1910, inclusive, drilled by machine, 7,851 lin.ft. Cost $2,840.00 or 36 cents per lin.ft. For sharpening steel add about 3 cents, making 39 cents per lin.ft.
Quarry Operation:
They excavated, broke up to crusher size and trammed into the mill 55,727 cu. yd. of rock; which crushed into 83,897 cu. yd. of sand. Also handled 1,879 cu. yd. of waste.

<table>
<thead>
<tr>
<th>Men-days</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drillers</td>
<td>3,597</td>
</tr>
<tr>
<td>Muckers</td>
<td>20,213</td>
</tr>
<tr>
<td>Explosives</td>
<td></td>
</tr>
<tr>
<td>Miscellaneous</td>
<td></td>
</tr>
</tbody>
</table>

Total quarry cost: $67,483.57
Equals $1.21 per cu. yd. of rock handled, 2.75 cu. yd. rock handled per 8 hours mucker.

Mill Cost:
Ran Crusher: 9,197 hours.
Ran Rolls: 8,191 hours.

Labor: 4,575 men-days, cost: $16,090.03
Power: 60 to 65 H.P. made a somewhat arbitrary division between the different features of the work.

Charged to sand plant: $2,450.84
Miscellaneous (includes oil, supplies, small repair parts, and shop charges): 5,604.29
Total Mill cost: $24,145.16
Total Quarry cost: $67,483.57
Mill cost: $91,628.73

For 83,897 cu. yd. of sand: equals $1.09 per cu. yd. of sand produced, including superintendence, not including plant depreciation nor any portion of engineering and office charges.
Rolls produced 10.2 cu. yd. per hour.
Including depreciation, engineering and office charges, would bring cost to about $1.50 per cu. yd.

Analysis of Labor Cost,
Roosevelt Dam March, 1908

Cement Tramway, 1700 ft. long
takes cement and sand to mixer.
Worked two 8 hr. shifts per day, and
took over 8,958 buckets of sand at
8 cu.ft. and 5,626 buckets of cement
at 7 cu.ft.
Day: 5 men, 27½ shifts - - - - - $437.00
Night: 6 men, 25 shifts - - - - - 472.00
Two Lidgerwood Cableways, 24 in.
diam., 1200 ft. long, took from mixer
to dam 2,117 skips of mortar and
concrete; and from quarries to dam,
took 630 skips of spalls - - - - - 688.00
Night crew takes down stone (almost
entirely from quarries on north side
of river). Includes collecting stone in
quarry, transporting to dam, and
some passing around on dam.
Took on to dam 5,400 cu.yds.
stone and some spalls:
Night shift Ave. 30 men, 29 shifts - 2,829.00
Transporting Materials, Cost 4,426.00 $0.369
Quarries on North side of river
produced 4,800 cu.yds. large stone,
1,134 cu.yd. spalls, 2,170 cu.yd. waste,
234 cu.yds. crushed rock:
Day shift Ave. 52 men, 29½ shifts - 4,155.00
Night shift Ave. 21 men, 29 shifts 1,677.00
Quarry on south side produced
334 cu.yds. large stone, 1,442 cu.yds.
stone for crusher. Includes also
feeding the crusher:
One shift per day, Ave. 20 men,  
28 1/2 shifts ——— $1612.00

The 7,944 cu. yds. for the dam and 
the 2,170 cu. yds. wasted, cost $7444 
or say 0.74 per cu. yd. excavated —— 7444.00 

$0.620

Stone for upstream face: this 
month it was nearly all taken 
from storage. Used about 200 cu. yds. 
It would cost about $6.00 per cu. yd. 
of cut stone ——— 1200.00 

0.100

Mixing mortar and concrete: 
materials drawn from bins into car, 
transferred 10 ft., and dumped into a 
40 cu. ft. capacity Smith mixer, 
dumped into a skip on car; and 
hauled by a stationary engine either 
50 ft. to No. 1 cableway or 125 ft. to 
No. 2 cableway. Mixed 4,234 batches:

One shift per 6 men, 26 1/2 shifts ——— 517.00 

Cost per cu. yd. mixed: $0.099

Laying Masonry: Three derricks, 
676 hrs. derrick, laid 12,000 cu. yds. 
= 17.7 cu. yds. per derrick hr. For 6 
shifts, one gang was split, and 
with an extra engineer and tag-
man ran another derrick. 
Average force per derrick: 1 fore-
man, 1 engineer, 2 tagmen, 2 masons, 
52 laborers: 26 1/2 shifts cost 3,506.00 

0.291

Miscellaneous: 
Moving derricks and cleaning 
up underneath ——— 46 
Moving derricks from, and 
back to the wall on account of 
on anticipated flood ——— 31
Repairs chargeable to masonry--85
General expense, includes super-
intendent, mechanic, electrician,
time-keeper, man at power
house, etc. -- -- -- -- 225
Total 387 $1,478.00 $0.123

Power 144 236 H.P. hrs. from
Government -- -- -- -- -- 721.18 0.060
Total -- -- -- -- -- $1,606

The above includes all labor, ordinary repairs for the month,
and power; does not include any portion of equipment, and
erection cost, nor any material and supplies.

Plate No. 1

Map of Roosevelt Dam and Vicinity
(Eng. News, Sept. 10, 1908)

Profile of Dam Site
Plate No. 2

Maximum Cross-section, Roosevelt Dam, Arizona.

From: Wilson's Irrigation Engineering, Page 469.
CROSS SECTION
OF THE
GRANITE REEF DIVERSION DAM

From Eng. News Oct. 1, 1908