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ZOOM VERSION

lack of permanency. The adopted flume section is a rectangular box, four feet deep and seven feet eight inches wide inside, built of two-inch redwood plank supported by frame of native pine. Saw mills will be established near the line, and logs floated down Salt river from the mountain valleys above. This native timber will also be used for false works and other temporary structures about the works.

REPORT ON THE RESERVOIR

Recently Made by Mr. Arthur P. Davis to the Water Storage Commission

Detailed Description of the Plans Cost of the Dam and Incidental Works — The Water Resources of the Region— The Fears of an Accumulation of Silt Dissipated—Everything Has Been Worked Out Scientifically.

The following is the report of Mr. Arthu P. Davis of the geological survey of the investigation of the Tonto Basin reservoir site. It will be found to be very interesting as well as educational reading:

Salt river, though nominally a tributary of the Gila, really brings far more water to their junction than does the Gila. Though it drains a smaller area, its basin is much higher and cooler and receives an average precipitation far beyond that of the Gila basin.

The drainage basin of Salt river and its divisions is about as follows:

	Sq. miles.
Salt river at its mouth	12,760
Salt river at Arizona dam	12,360
Verde river near its mouth	6,000
Salt river above mouth of Verde	6,260
Salt river at dam site below Tonto creek	5,756
Salt river between mouth of Verde and Tonto dam site	504

The elevation at the mouth is about 1,000 feet, while some of the peaks at its headwaters exceed 10,000 feet in altitude; the highest, Thomas peak, being given at 11,496 feet.

In a previous publication it was pointed out that Salt river basin was blessed with rather peculiar conditions favoring a large water supply relative to its drainage area, as follows:

"The southern portion of the territory may be subdivided into two portions, that draining directly into the Colorado and lying to the westward of Prescott, and the greater portion to the south and east, which forms the great Gila river system. The Colorado plateau is partly of igneous origin, and a great portion of it is somewhat pervious to water. Its northern slope for a considerable distance from the summit is very gentle, and though the precipitation is greater than in most portions of the territory, it is very meagerly marked by drainage lines and almost destitute of water. Sharply contrasted with these facts are the conditions on the southern slope. Here, through most of its course the plateau drops off with a very steep slope which is deeply cut with drainage lines in which are living creeks and rivulets of clear, beautiful water, such as San Francisco river, Black creek, White river, Carrizo creek, Cibicu creek, Box creek, Cherry creek, Tonto creek, Wild Rye creek, East Verde river, Pine creek, Fossil creek, Clear creek, Beaver creek, etc.

"The region of high altitude, as before remarked, lies largely north of the divide, while the great bulk of the water flowing from the plateau, as proved both by erosion of drainage lines and by the volume of permanent streams, flows away to the south. The explanation of this is partly the porosity of the strata composing the plateau, which allows the water to sink instead of flowing off the surface. Once underground, its egress to the south is favored by the shorter distance which it must percolate on a given grade before reaching a surface, due to the more abrupt slope.

"Another partial explanation is found in the meteorological condition. The moisture of this region is brought from the Pacific ocean and the Gulf of California by the prevailing southwest wind. As this wind ascends the elevations toward the Colorado plateau, its temperature is lowered, which reduces its capacity for holding moisture and increases its relative humidity. When this quantity reaches 100 per cent in any any part, precipitation occurs. This influence continues until the wind passes the summit where the process is reversed.

HYDROGRAPHIC RESOURCES

"As might be expected, therefore, the hydrographic resources of the country immediately southwest of the Colorado plateau are disproportionately great when compared with those to the northward. For instance, the precipitation at Fort Apache, as shown by a mean of 20 years' observations, is 19.75 inches, the elevation being 5,050 feet, while the precipitation at Holbrook, at an elevation of 5,047 feet, on the northern slope, is 8.47 inches, as indicated by the mean of ten years' observations. This is an important fact, especially when taken in connection with the fact that the great areas of valley land with a semi-tropic climate lie in the southwestern portion of the territory, and are easily covered by the streams which are formed by the conditions above described, and which constitute the main features of the great Gila river system."

The topography of the basin of Salt river proper above the mouth of the Verde, is nearly all of a rough, mountainous character. The chief tributary above this point is Tonto creek, and about half a mile below its junction with Salt river, the latter enters a profound canyon with precipitous sides and narrow bottom, in which is located the proposed dam site. The Salt and Tonto both occupy comparatively open valleys above this gorge, and have a moderate fall. The combined effect is one of the most capacious reservoirs in the west. The dam might be built to a height of 300 feet or more, if such a height were justified by the water supply. The capacity of the reservoir was determined by a planetable survey for each 10-foot contour to a height of 200 feet above the bed of the river in the gorge. These capacities are given in the following table:

SALT RIVER RESERVOIR.

Height above low water. Feet	Area. Acres	Capacity of Section. Acre-ft.	Total Capacity Acre-ft.
10	24	120	120
20	128	760	880
30	224	1,760	2,640
40	461	3,125	5,765
50	694	5,475	11,240
60	1,085	8,896	20,135
70	1,458	12,715	32,850
80	2,103	17,805	50,655
90	2,930	25,165	75,820
100	3,682	33,060	108,880
110	4,391	40,365	149,245
120	5,526	49,635	198,880
130	6,324	59,650	258,530
140	7,293	68,435	326,965
150	8,411	78,520	405,485
160	9,564	90,375	495,860
170	10,769	102,165	598,025
180	12,158	114,635	712,660
190	13,459	128,085	840,745
200	14,617	140,380	981,125
		981,125	

It will be noticed that for a dam of a height of less than 100 feet, the capacity of the reservoir formed is not extraordinary, but above this height it increases more rapidly, and at a height of 200 feet is nearly a million acre-feet. It would be entirely practicable to construct a reservoir of several times this capacity, but this is not justified by the conditions; the limit to the economical height of a dam is determined by the supply of water available for storage.

WATE RSUPPLY.

The only available rainfall observations in the basin tributary to the proposed reservoir are those at Payson and Camp Apache. The record at Payson is so short and broken that it is of no real value in the discussion of the water supply, so only that of Camp Apache remains. Fortunately this station is located near the center of the basin, and the record is reliable and complete from 1876 to date—about 26 years. This affords excellent means of obtaining monthly and annual maxima, minima and means at this point, which, so far as known, may be assumed to represent an average of the entire basin, as nearly as any one point that might be selected.

Measurements of the flow near the dam site below Tonto creek were begun in February, 1901, and are still continued. Besides these are measurements of Salt river above the mouth of Verde from April, 1897, to November 30, 1899, and Salt river below the Verde, for several previous years, and for 1900. The measurements below the Verde were made in the various canals in dividing the waters for irrigation purposes. When there was a surplus of water there was no necessity for accurate measurements and at such times the results are only approximate; they are, however, for a considerable period the only available records, and are considered sufficiently accurate to justify their use. To render available the latter records in estimating the water supply to the proposed reservoir, it is necessary to determine the proportion of water received from the Verde and Salt. For this purpose the records are taken where these two streams were separately observed, and the ratio of each stream to their sum is computed month by month, with results as given below:

DISCHARGE OF SALT RIVER, PER CENT OF TOTAL.

Month	1897	1898	1899	1901
January		.587	.520	.618
February		.555	.541	.539
March		.531	.660	.631
April		.720	.740	.855
May	.513	.719	.862	.836
June	.720	.647	.590	.728
July	.575	.573	.564	.587
August	.495	.503	.619	.425
September	.419	.516	.469	.657
October	.654	.494	.323	—
November	.523	.522	.461	—
December	.515	.594	—	—

Month.	Mean per cent Salt.	Mean per cent Verde.
January	.574	.426
February	.545	.455
March	.607	.393
April	.772	.228
May	.808	.192
June	.672	.328
July	.570	.430
August	.510	.490
September	.515	.485
October	.492	.508
November	.502	.498
December	—	—

The drainage area between the reservoir and the mouth of the Verde is nearly ten per cent of the whole area above the Verde, and therefore to reduce the discharge of the Salt to that intercepted at the reservoir, the discharge at the mouth of the Verde was reduced by about 10 per cent, this percentage being slightly modified according to the season. From these data and computations we obtain the table of discharges for the Verde at McDowell, and Salt river at the reservoir site. In reducing the discharge of Arizona dam to the required amounts the following percentages were used:

Month.	Verde at McDowell.	Salt at reservoir site.
January	.42	.52
February	.45	.50
March	.39	.56
April	.29	.72
May	.19	.76
June	.30	.63
July	.42	.52
August	.49	.46
September	.48	.46
October	.56	.44
November	.50	.45
December	.59	.45
Mean	.40	.54

The values thus obtained cover the periods from August 1, 1888, to December 31, 1894, and from December 1, 1899, to December 31, 1900. Observations of the discharge of Salt river above the Verde were taken direct from February 4, 1895, to July 31, 1896. During which period direct observations were made by the Hudson Reservoir company, and the period from April 20, 1897, to November 30, 1899, observed by the Geological survey. The discharge from February 27 to December 31, 1901, was observed at the reservoir site and requires no reduction.

The storage of flood waters on Salt river will not only utilize such waters by holding them until needed, but will greatly increase the utility of the floods of the Verde river by providing a much larger irrigated area to receive such floods, and at the same time holding back the waters of the Salt as long as the Verde is able to fill the requirements. An examination of the records shows that with such manipulation the Verde will usually supply all requirements during the four months of December, January, February and March, and that a very large proportion of the flood waters of the Verde which now run to waste would be thus utilized.

The record since 1888 is taken in connection with the proposed reservoir and 660,000 acre-feet annual consumption, and from this a table has been constructed, showing what would take place if the past experience should be repeated after the construction of the reservoir.

This table shows that if the proposed reservoir were operated in conjunction with the natural flow of the Verde river, and an annual supply of 660,000 acre-feet were desired, this could have been furnished every year in the record except 1900. In that year there would have been a shortage of about 16 per cent. It is believed that such a shortage is permissible in a storage project if it does not occur oftener than once in, say 20 years, which is the fact in the present case.

The duty of 660,000 acre-feet per annum is that of the combined Salt and Verde rivers, with a reservoir on Salt river operated in conjunction with the Verde, the waters of Salt river being held in the reservoir as long as the waters of the Verde are sufficient to supply demands. If the flood waters of the Verde are to be stored and used independent of Salt river they will not be available for this use, and the manipulation of Salt river reservoir will be radically different. Under these conditions the draft on the reservoir becomes constant the year round; the requirement for storage is lessened, and the irrigation duty of Salt river alone is of course much less. Our records indicate that a duty of about 450,000 acre-feet can be depended upon by using the rest of our storage capacity for reserve storage.

PLANS FOR THE DAM.

The gorge on Salt river is an especially favorable site for a masonry dam, the most permanent, conservative and secure form of construction for a high dam that is known to engineering science. The formation is sedimentary, with the strata inclined to an angle of about 50 degrees to the horizontal, dipping toward the reservoir, a most favorable condition for retaining stored waters and for the stability of the dam. The foundation and abutment of hard, tough, fine-grained sandstone are all that could be desired. The building stone, of the same material is at hand, and above the site. As elsewhere set forth good Portland cement can be made near the site. Sand for mortar can be obtained from the river bed, but will have to be washed and screened, and it is thought that the best plan will be to manufacture sand by crushing quartzite, which occurs in abundance near the site. This will provide an ideal sand and as power is abundant its cost will not be great.

The dam must be so designed and constructed as to be safe from destruction by any or all of the forces acting upon it. It is possible for a masonry dam to fail in any one of three ways:

1. By overturning.
2. By sliding on the base, or on any horizontal joint.
3. By crushing its foundation or masonry near the base.

A factor of safety of at least two is secured against overturning by so designing the dam that under all conditions the resultant of all the forces acting will fall within the middle third of any horizontal joint. This also eliminates the possibility of any tensile strains in the masonry, a very desirable result. The same condition also secures safety against sliding, which is insured in a still greater degree by constructing the masonry of random rubble, and by the use of hydraulic mortar, bonding it together and to its base, so that it becomes a true monolith—a part of the solid rock to which it is firmly joined. Under these conditions the structure cannot slide without shearing the masonry which provides a large margin of safety. In addition to these precautions the dam planned is to be built in the form of a circular arch, which greatly increases its safety against both sliding and overturning. In fact, neither can occur without overcoming the gravity and cohesion of the masonry, and also crushing the masonry or abutments. The total factor of safety against failure by the first and second methods cannot be exactly known, but it is unquestionably very great. The third method, that of the crushing of the masonry, is not affected by the curved plan, and there is room for considerable difference of opinion as to what are safe limits of pressure. The best guide, when intelligently followed, is the experience of the past. The following table gives pressures in some existing structures:

PRESSURES ON MASONRY IN EXISTING STRUCTURES.

Bridge Bont-y-Prydd, Wales: material, limestone rubble, lime, mortar; pressure, 20.7 tons per square foot; authority, I. O. Baker.

Brooklyn bridge; material, granite masonry; pressure, 29.5 tons per square foot; authority, Duryea & Mayer.

Washington monument in wind: material, cut marble; pressure, 25.4 tons per square foot; authority, Col. T. L. Casey.

St. Louis bridge, before completion: material, cut limestone; pressure, 38.0 tons per square foot; authority, History St. Louis Bridge, p. 370.

South Street bridge, Philadelphia: material, cut limestone; pressure, 15.7 tons per square foot; authority, Trans. Am. Soc. S. E. Vol. VII, p. 505.

Rookery building, Chicago: material, cut granite; pressure, 30.9 tons per square foot; authority, I. O. Baker.

Bear Valley dam: material, granite rubble; pressure, 40.0 tons per square foot; authority, J. D. Schuyler.

All Saints Church, Angers: material, Ferneaux stone; pressure, 43.0 tons per square foot; authority, J. T. Fanning, p. 403.

Chapter House, Elgin: material, red sandstone; pressure, 20.0 tons per square foot; authority, J. T. Fanning, p. 403.

St. Paul's, London; material, Portland limestone; pressure, 19.7 tons per square foot; authority, J. T. Fanning, p. 403.

St. Peter's, Rome: material, calcareous tufa; pressure, 16.7 tons per square foot; authority, J. T. Fanning, p. 403.

Various arch bridges: material, cut masonry; pressure, 60.0 tons per square foot; authority, J. T. Fanning, p. 403.

Quaker bridge dam (projected): material, rubble masonry; pressure, 15.9 tons per square foot; authority, Rep. Acqueduct Com., p. 65.

Almanza dam (300 years old): material, rubble masonry; pressure, 14.3 tons per square foot; authority, Edward Wegman, p. 24.

VARIOUS EXPERIMENTAL TESTS.

Material crushed.

1—Concrete prisms cut from Vrynwy dam; pressure, 131 tons per square foot; authority, Sir Andrew Clark.

2—Granite ashlar, with mortar 1:2; pressure, 532 tons per square foot; authority, Austrian Society E. & A.

3—Sandstone rubble, mortar 1:2; pressure, 255 tons per square foot; authority, Austrian Society E. & A.

4—Sandstone rubble, mortar 1:3½; pressure, 134 tons per square foot; authority, Austrian Society E. & A.

5—Gravel concrete 1:2:3; pressure, 128 tons per square foot; authority, Austrian Society E. & A.

6—Gravel concrete 1:3:5; pressure, 66 tons per square foot; authority, Austrian Society E. & A.

Two cubes of one cubic inch each were cut from briquetts of neat cement, manufactured from materials obtained near the site. These were tested at the U. S. navy yard in Washington.

Sample 1 crushed at 6690 pounds or 532 tons per square foot.

Sample No. 2 crushed at 5840 pounds or 836 tons per square foot.

Two cubes with edges of two inches were cut from samples of the rock to be used in Salt river dam and crushed in the testing machine at the U. S. navy yard in Washington.

Sample No. 1 crushed at 59,650 pounds, being 14,912 pounds per square inch, or 1,074 tons per square foot.

Sample No. 2 crushed at 100,000 pounds, this being 1800 tons per square foot. These results are so high that the strength of the rock is entirely eliminated from the discussion.

Test No. 3 in the above table, made by the Austrian Society, is very nearly representative of the masonry to be used in the proposed Salt river dam. A coefficient of safety of ten in such masonry would permit of pressures of over 25 tons per square foot. As will appear later the maximum pressures permitted in the proposed dam will be far below this figure.

The recorded failures of high masonry dams are as follows:

1. Habra dam in Algiers. Poor hydraulic lime was used and a red earth with a large percentage of clay was used in the mortar instead of sand. This combination made a poor mortar, and the rock was also poor, both in the masonry and the foundation, being a calcareous grit of varying quality, and all porous. It is supposed that the failure occurred by the crushing of the foundation under a computed stress of 13 3-10 tons per square foot.

2. Bouzy dam in France. The foundation was fissured and permeable, and not on solid rock, allowing an immense upward hydrostatic pressure; the section was so light as to permit great tension in the masonry in the back. It was straight in plan and when the reservoir was nearly filled the central portion of the wall was shoved forward about a foot, causing ruptures and leakage. This was afterward repaired and the foundation reinforced. Six years later when the reservoir was full the dam suddenly overturned at a plane about 33 feet below the top. The above recited defects were the undoubted cause.

3. Puente dam in Spain. The central portion of this dam was founded upon piles driven in earth. When the rising water applied a heavy hydrostatic pressure, this portion of the foundation suddenly gave way and left the top and ends of the dam standing in the form of an arched bridge.

4. Austin dam, Austin, Texas. This was an overflow dam built of limestone rubble, the stone being very soft and of poor quality. The foundation was on a geological fault, and was of soft limestone in thin, horizontal layers, which had little adhesion, and probably very little friction upon one another, and the failure, which was by sliding, is supposed to be due to this fact.

In all four of the above cases the foundation was defective. In three the stone was poor and in two the mortar was poor. All were straight in plan except the Puentes, which was polygonal in plan, and arched upstream. This dam seems to have been very well planned and constructed, except for the one fatal defect of being founded on piles.

All of the defects in these failures can easily be avoided in the proposed dam, by a reasonable application of care and skill.

The proposed dam is designed to be 217 feet above datum, which is low water in the river at the dam site, and to store water at a maximum depth of 190 feet the total height of dam above lowest foundation being about 245 feet. Spillways 20 feet deep will be excavated in the solid rock sides of the canyon and the rock used in the construction of the dam. The location lends itself admirably to a curved form of dam, this form containing but little more material than a straight one of the same section. The proposed structure is to be built on a circular curve, convex upstream, the back having a radius of 400 feet, and the face a shorter radius from the same center. The dam is to be of uncoursed rubble masonry, and to have a section on modern conservative ideas as a simple gravity structure, and the added stability due to its curved form will greatly increase its factor of safety. The rock of which the dam will be constructed will be excavated from the spillway and is a tough, close-grained sandstone. A sample was taken from each side of the canyon and tested for specific gravity in the laboratory of the United tStates Geological survey. The following are the results of this test:

SPECIFIC GRAVITY OF TWO SPECIMENS OF SANDSTONE.

I. Determined on lumps.

(A) In ordinary distilled water as quickly as possible. No. 1, 2.42 room temp. No. 2, 2.47 room temp.

(B) After soaking in distilled water 24 hours. No. 1, 2.44 room temp. No. 2, 2.49 room temp.

(C) After standing in distilled water under the air pump for 24 hours. No. 1, 2.50 room temp. No. 2, 2.52 room temp.

II. Determined on the powdered samples. No. 1, 2.583 at 21.5 C, compared with water of same temp. No. 2, 2.611 at 17.5 C, compared with water of same temp.

Tests for crushing were also made and are given elsewhere. The weakest sample crushed at 1,074 tons per square foot.

This rock is to be used in as large blocks as practicable in order to make the number of joints as few and the quantity of mortar as small as may be. It is estimated that the rock will occupy 70 per cent of the structure. Fifteen per cent will consist of cement mortar in which the stones are bedded and 15 per cent will consist of cement concrete rammed into the vertical joints. Taking the weight of the mortar as 115 pounds per cubic foot and that of the concrete as 150 pounds, the masonry will weigh as nearly as can be estimated 146 pounds per cubic foot. On this estimate the strains have been computed and the section of the dam designed. As the dam is to serve as a highway, a top width of 16 feet has been adopted with parapets along the sides. The section adopted is the smallest consistent with the necessary top width, and with the requirement that the resultants of all forces acting upon the dam shall be at all times within the middle third. The pressure on the toe, when the reservoir is full, will be 15.9 tons per square foot computed on the assumption that the dam is a rigid monolith and non-elastic. Any elasticity it may have will tend to relieve this pressure. The maximum possible pressure, 16.54 tons, occurs at the heel when the reservoir is empty, with a strong wind blowing upstream.

The above table shows fourteen instances with pressures greater, some of them many times greater, than those in the proposed dam. The following specifications are proposed for the dam:

SPECIFICATIONS FOR THE CONSTRUCTION OF THE DAM.

DIVERSION OF THE RIVER. The diversion of the river will be accomplished by means of sheet piling driven as deeply as practicable directly across the canyon, beginning at the south side and reaching as nearly as practicable to bedrock, the piling to be reinforced at and above the surface by a heavy wall of sand and gravel excavated from the site of the dam, the water to be diverted through the outlet tunnel, which will be constructed in advance. The gravel wall will be built at least one foot higher than the top of the outlet channel, and three-fourths of its length, about 50 feet of the southern end of the embankment being left at an elevation six feet lower, to be utilized as a spillway for excessive floods which may occur too large for the capacity of the outlet tunnel. The excavation for foundation will begin at the southern wall of the canyon, and as rapidly as completed to solid foundation will be filled with masonry. As soon as 40 or 50 feet of the southern end of the foundation is completed a wooden flume will be placed at the above mentioned spillway on the embankment reaching down stream over the completed portion of the foundation, discharging into the stream bed at least 300 feet down stream from the toe of the dam. This flume will be about 1,000 feet long, and in that distance will have a fall of nearly eight feet, which will give it a high velocity and enable it to discharge any floods likely to occur. The pumps employed in drying the foundation excavations will discharge into this flume. In case sheet piling cannot be driven deep enough to cut off the under flow pipes shall be driven along the line across the canyon and cement grout pumped in until the desired result is obtained.

FOUNDATION. All earth, sand, gravel, boulders, disintegrated, loose and seamed rock will be excavated and removed from the entire area of the base of the dam, in order to secure a firm foundation on solid rock. Explosives shall not be used when excavating the rock unless absolutely necessary and when used shall be only in small quantities and in shallow holes to avoid fracture of the rock forming the foundation of the dam. The entire foundation shall be thoroughly washed with wire brooms, first with water and then with thin grout. Throughout the length of the foundations a trench six feet wide and six feet deep, 15 feet from the heel of the dam, and parallel thereto, shall be cut in the solid rock of the foundation.

MASONRY. The main body of the dam shall be constructed of broken range cyclopean rubble. The stone shall be quarried from the walls on each side of the canyon, shown in the drawing as proposed spillways. If a sufficient quantity of hard, fine-grained stone cannot be obtained in these spillways it shall be quarried elsewhere. All stone shall be thoroughly washed and laid in Portland cement mortar, and each stone shall be laid on its largest bed. The stone for the upstream face shall be rough pointed so as to lay with horizontal beds and vertical joints. No mortar joint in the face shall exceed one inch in thickness. At least one-fourth of the area in the face must be headers evenly distributed throughout the wall, and every header shall be laid over a stretcher of the underlying course. The stone shall be so arranged as to form a proper bond, in no case less than one foot, with the stone of the underlying course. The stretchers must not be less than three feet long, nor less than two feet in any other dimension. The headers must not be less than six feet in length, nor less than two feet in any other dimension. The body of the dam shall be composed of as large stone as practicable, well shaped, and laid so as to break joints and thoroughly bond the work in all directions. Each stone shall be laid on its largest face in a bed of Portland cement mortar of the quality hereafter specified. Vertical joints between stones in the body of the dam must be nowhere less than four inches and must be carefully and thoroughly filled with Portland cement concrete, which shall be rammed into place by hand. To secure thorough bedding, each stone must be lifted and the bed examined to the end that all space in the dam not occupied by stone shall be absolutely filled with mortar so as to make a water-tight construction. The masonry shall be kept wet during the time of construction. The aim shall be to use the largest proportion of mortar and concrete in the dam that can be practicably secured. To this end facilities shall be provided for handling stones weighing 12 tons, and large stones shall be used as far as practicable. To the same end, the stones shall be split from the large masses found in the quarry, by the "plug and feather" method, or any similar process that may be found efficient in breaking the stones along regular lines, so that joints to be filled with mortar may be reasonably thin and uniform.

MORTAR AND CONCRETE. All mortar used in the lower 30 feet of the dam shall consist of one part of Portland cement, to two parts of good sharp sand, and all concrete used in this portion of the dam shall consist of one part cement, two parts sand and three parts of broken stone graded to such size as will pass through a screen with meshes two inches square. The mortar and concrete used in the upstream face of the dam for a thickness of 20 feet shall be of the quality above specified. In all parts of the dam which are more than 20 feet from the upstream face and 30 feet from the base the mortar shall be one part Portland cement, three parts sand and four parts broken stone of a size to pass through a screen with meshes two inches square. All mortar and concrete shall be thoroughly mixed as the work progresses and used so promptly that there will be no danger whatever of incipient setting of the cement previous to the completion of the masonry in which it is placed. No cement shall be used until at least 60 days after its manufacture, and not until it shall show satisfactory tests according to the chemical and physical requirements adopted by the American Society of Civil Engineers.

The reason for using a larger percentage of cement in the base of the dam is that here will be the greatest pressures, and the higher percentage of cement will give a greater power of resistance to crushing. The high percentage of cement is maintained on the water face of the dam, all the way to the top, in order to render it as nearly impervious as possible.

It may be confidently predicted that a masonry dam at the proposed site, constructed on the above plans and specifications would be absolutely permanent, "safe, solid and secure for all ages to come," as truly as the "everlasting hills," of which it will become an integral part.

SEDIMENT.

Most of the streams of the southwest carry a considerable quantity of solid matter which causes annoyance in canals, and has a tendency to fill any reservoir constructed on the stream. This is true of the Rio Grande, Colorado, Pecos and Gila rivers. There is silt also in the waters of Salt river, as shown by its occurrence in the canals, but it is not nearly as abundant as in the streams above mentioned. The basin tributary to the Salt river reservoir lies in large part in high timbered country and includes the Apache Indian reservation. These Indians constitute, probably, the most efficient forest patrol in the country, and their reservation is almost entirely covered with forest and grass. The basin of Tonto creek, and a few other tributaries, however, are closely pastured and deliver some silt during sudden floods.

Observations of the amount of sediment carried give the results found in the following table:

PERCENTAGE OF SEDIMENT FOUND IN SALT RIVER WATER.

January, 1901, sediment .026 of 1 per cent; total volume acre-feet, 9.27.

February, 1 to 15, .055 of 1 per cent; total volume acre-feet, 34.42.

February 16 to 28, .012 of 1 per cent; total volume acre-feet, 8.28.

March, .6099 of 1 per cent; total volume acre-feet, 9.53.

April 1 to 18, .00021 of 1 per cent; total volume acre-feet, 0.06.

April 19 to May 26, no sediment.

May 27 to 31, .5895 of 1 per cent; total volume acre-feet, 28.74.

June, no sediment.

July, .3924 of 1 per cent; total volume acre-feet, 83.58.

August, .4128 of 1 per cent; total volume acre-feet, 134.16.

September, .13323 of 1 per cent; total volume acre-feet, 23.85.

October, .0054 of 1 per cent; total volume acre-feet, 5.04.

November, .0058 of 1 per cent; total volume acre-feet, 0.65.

December, no sediment.

Total for the year, 337.58 acre-feet.

Note. From January 1 to April 18, 1901, observations were made at McDowell station; balance of the year at reservoir site.

The above table shows that during the period covered by the observations the sediment carried was very small in amount, almost negligible; but the discharge during the year was far below the normal, and it is believed that the proportion of sediment shown by the observations was also below the normal. If we take 1,000 acre-feet as the average inflow of sediment, this will be nearly three times that observed during 1901, and yet it would require 500 years to fill the reservoir if none were drawn off. It would probably be 100 years before the loss of storage capacity would be seriously felt, and it would become necessary to resort to methods of clearing it out.

At all times when the river is in flood, the water in the reservoir will be more or less turbid. The lower the stage of the reservoir and the greater the flood in the river the greater will be the percentage of sediment held in suspension. The greatest amount of sediment will at all times be found in the lower layers of water, and it will therefore contribute to the maintenanceo f the storage capacity to draw all waters from the lowest possible point at all times. Two outlets are provided in the form of tunnels 10 by 13 feet, one around each end of the dam. It should be made an invariable rule that whenever water begins to run over the spillway the gates must be opened to full capacity, not only to draw off the maximum quantity of sediment, but also to reinforce the spillway capacity as much as possible.

Experience at the Sweetwater and other reservoirs shows that the greatest deposits of sediment are in the deepest parts of the reservoir, which in this case are near the dam. The above provision would dispose of a considerable portion of this and any further provision for removing silt would be unnecessary for perhaps a century.

OUTLET WORKS.

For the purpose of facilitating the discharge of sediment from the reservoir and also to furnish the maximum reinforcement to the spillways, it has been decided to draw all water from the reservoir through large openings directly on the bottom. Accordingly the plan adopted is to have two tunnels dug through the solid rock, one on each side of the canyon; each tunnel will be provided with two gates, each 6 feet by 10 feet 2½ inches, with a clear opening of 5 feet 4½ inches by 10 feet, making a total area of 215 square feet clear opening. This would have a discharge capacity of about 1,500 cubic feet per second, with water standing in the reservoir on a level with the top of the tunnels. When the reservoir stands higher than this the head would, of course, increase the possible discharge and when water begins to flow through the spillways the tunnel would have a discharge capacity of about 12,000 cubic feet per second; and with the spillways running full, about 14,000 cubic feet per second. The head on the lower sill of the outlet tunnels would be 190 feet, with water standing at the level of the bottom of the spillways. This will be the maximum head frequently encountered, but the possible head would be 20 feet more, or 210 feet, with water flowing over the spillways 20 feet deep, which is considered the maximum head possible, encountered only at long intervals if ever. This will produce a mean pressure of about 11,600 pounds per square foot on the gates, or a total on each gate of about 350 tons. These pressures and sizes require gates of great strength, and efficient means of controlling their position.

Each gate is built of nine parallel 9-inch I beams, two channels horizontally, and three longitudinal beams, the whole enclosed by a half-inch plate solidly riveted to the beams and channels, so as to make the entire gate act as a girder. It will be the aim to make this girder water-tight on the edges and the side exposed to the water, but drainage holes will be provided on the lower side to discharge any chance leakage.

The pillar which will occupy the center of each tunnel is built of plates and angles in the form of a large I beam, and is reinforced on each side by a twelve-inch I beam, and the whole is enclosed by a thin steel skin, to minimize the tendency to produce vibrations; and they are so arranged as to diminish the contractions also, and thus increase the discharge. The sheet steel will be continued along the sides and bottom of the tunnel throughout its entire length. Under these arrangements the velocity of the water through the tunnel, running full, with the water in the reservoir at the level of the top of the tunnel, will be about seven feet per second, and will increase to over 60 feet per second, with the water 20 feet deep over the spillways. Each gate will be worked by two hollow rods running upward through the shaft and tower to the tower houses at the top of the dam, where they will be worked by screws operated by electric motors.

The hollow rods will consist of three-inch double extra heavy steel drive pipe, and will work in guides, as shown in the illustration B1.

The upper section of rod which carries the thread for moving the gates will be solid.

The bearings for the gates will be upon solid steel rollers placed to eliminate friction. A general view is shown in drawing Pl.

The steel is estimated at 8 cents per pound erected.

POWER PLANT.

In the construction of a great dam one of the most important elements is that of power. This is necessary on a large scale for drilling purposes, for handling rock, for mixing and handling mortar, and for crushing rock to be used in concrete. In the present case, furthermore, it has been found possible and very desirable to manufacture on the ground the large quantity of cement required in the dam. This would require about 300 horse power day and night, for grinding rock and clinker, and for handling materials and running machinery. It is usual to provide such power by means of steam engines, but in the present case this is rendered very expensive by the scarcity of fuel. Coal, in quantities, now costs $10 per ton in Globe, and the wagon haul to the dam site would nearly double this. A limited amount of wood is available, but to secure the large quantity which would be required if it were the sole dependence for power would involve a long and expensive haul.

The best means of providing the necessary power is by the development of water power on the river. This will involve the construction of a diversion dam and canal which can afterwards be utilized, if required, for sluicing accumulated silt out of the reservoir. The power developed can afterwards be used in the neighboring mines or transmitted to the valley below for pumping purposes. For either purpose it will be a valuable asset.

The standard canal section adopted has a bottom width of eight feet, water depth of 3.5 feet, total depth of 4.5 feet, with side slopes of 1 to 1 in excavation and 1½ to 1 in embankment. Its slope will be .0006.

In the first 12,000 feet of the line the depth will be slightly increased to provide for seepage losses. Small drainage lines will be crossed by means of concrete culverts. Flume construction will be employed only where absolutely necessary, on account of its lack of permanency. The adopted flume section is a rectangular box, four feet deep and seven feet eight inches wide inside, built of two-inch redwood plank supported by frame of native pine. Saw mills will be established near the line, and logs floated down Salt river from the mountain valleys above. This native timber will also be used for false works and other temporary structures about the works.

There are to be two tunnels on the line, 15,000 and 18,000 feet in length respectively. Both are in coarse gravel and will be lined with concrete.

No detailed surveys have been made of the line, and the estimates which follow should be regarded as only approximate. The estimated cost of earth excavation is 15 cents per cubic yard, and of rock $1 per cubic yard.

The proposed canal would head some distance above the reservoir, follow above its water line and finally discharge just below the dam, with an available head of about 180 feet. It is designed to deliver 100 cubic feet per second and to develop a net energy of about 1,200 horse power, after deducting seepage, friction and losses in water wheels, electric plant, etc. It is designed to use 900 horse power at the dam and 300 horse power at the cement mill.

The power plant will consist of three units of 300 kilowatts each, one of which will be temporarily installed near the cement mill, to be used there in making cement and in drilling for

(Continued on page ten.)