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Water-Supply and Irrigation Paper No. 73 Series J, Water Storage, 7

DEPARTMENT OF THE INTERIOR

UNITED STATES GEOLOGICAL SURVEY

CHARLES D. WALCOTT, DIRECTOR

WATER STORAGE

ON

SALT RIVER, ARIZONA

BY

ARTHUR POWELL DAVIS

WASHINGTON
GOVERNMENT PRINTING OFFICE
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LETTER OF TRANSMITTAL.

DEPARTMENT OF THE INTERIOR,
UNITED STATES GEOLOGICAL SURVEY,
DIVISION OF HYDROGRAPHY,
Washington, D. C., June 12, 1902.

SIR: I have the honor to transmit herewith a manuscript by Mr. Arthur P. Davis, giving the results of surveys and investigations for water storage on Salt and Verde rivers, Arizona, and request that it be published in the series of Water-Supply and Irrigation Papers.

The results described in this report were obtained by Mr. Davis mainly during the year 1901. Assistance was rendered by the local authorities, committees, and citizens of Maricopa County, Ariz., and through the cooperation thus had it was possible to go into details which under other circumstances could not have been discussed. The work is of great value, not only to the Salt River Valley, but to other portions of the arid region where water storage will in the future be undertaken, as the careful work of Mr. Davis has demonstrated the feasibility of utilizing natural resources, particularly in the making of cement and turning to advantage previously unsuspected means for conserving water. Throughout Arizona and the entire Southwest the development of agriculture, and to a less extent of mining and other industries, rests upon water conservation, since in these vast areas the streams are for the most part of small volume and are subject to occasional destructive floods. The impounding of these is one of the most important fundamental steps to be taken toward the utilization of the vast area of vacant public land.

Very respectfully,

F. H. NEWELL,
Hydrographer in Charge.

Hon. CHARLES D. WALCOTT,
Director United States Geological Survey.

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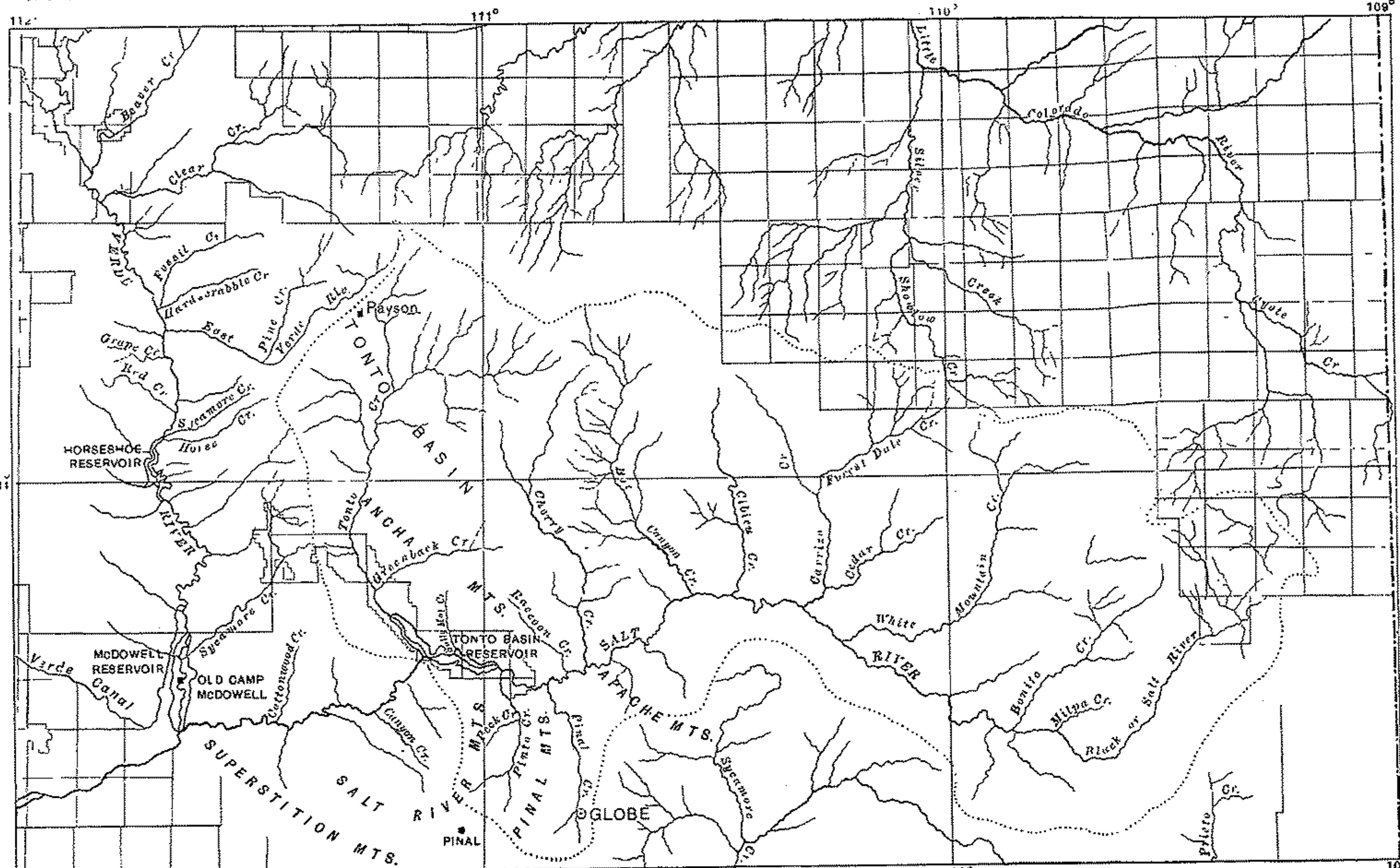


DRAINAGE LINES OF SALT RIVER BASIN.

WATER STORAGE ON SALT RIVER, ARIZONA.

By Arthur P. Davis.

INTRODUCTION.

Salt River Valley lies south of the center of the Territory of Arizona, and contains by far the largest irrigated area in that Territory. Its water supply is obtained from Salt River, forming below the confluence of Verde River the largest stream in Arizona.

Verde River drains the central portion of Arizona, and Upper Salt River the east central portion. Both streams are more or less torrential in character, the combined flow dwindling at times to about 100 cubic feet per second, and at other times reaching a volume more than one hundred times as great.

The development of Salt River Valley has been carried on by diverting the natural flow of the river, which is not sufficient for the adjacent lands. Settlement and cultivation, encouraged by years of large or normal water supply, have reached a point where dryer years do not furnish sufficient water for the proper irrigation of lands already in cultivation, and unless the water supply can in some way be increased not only must agricultural development entirely cease, but some of the land already in cultivation must be abandoned.

The unprecedented drought of the last three years has brought the people of this region to a most vivid realization of this condition, and to a strong determination to by some means secure the construction of reservoirs for the storage of the waters which now go to waste during the melting of the snows in the spring, and during the torrential rains of the late summer. The agitation for storage led to the formation of the citizens' committee in Phoenix for promoting investigations and for developing some project for the storage of water. The action taken is set forth in the following communication received in November, 1900, by the Secretary of the Interior, from Mr. B. A. Fowler, president of the Salt River Valley water-storage committee:

> The citizens of the Salt River Valley of Arizona have, as a result of a protracted drought, become thoroughly aroused to the vital importance of forest protection, and especially of water conservation through the construction of reservoirs. Mass meetings have been held and an organization formed representing all of the diverse interests of the valley. As president of this organization, I have been instructed and empowered to take active steps toward bringing about better conditions.

A careful study of the situation has shown that, as preliminary to the construction of systems of water storage, we must have a full knowledge of all of the physical conditions of topography, water flow, depth of bed rock, amount of sediment carried by the water, and other facts. With these fundamental facts, and with estimates of the capacity and cost of construction, it will be possible to discuss alternative projects, and to lay before the people the data by which they car be guided in future action, and by which Congress may consider the advisability of public works for the regulation of the streams and for the reclamation of arid lands.

We understand that one of the bureaus of the Department of the Interior, viz. the United States Geological Survey, has been authorized by Congress to ascertain these facts relating to the reclamation of the arid region, the storage of water, and related subjects. Also that the demand for work of this kind far exceeds the funds available for carrying it on, and that as a consequence work is being concentrated in localities where the greatest public interests are to be served, and particularly where cooperation is offered by the people or their legislatures.

In view of these conditions, I am authorized to bring before you the great importance of this work to the people of Arizona, and as an evidence of our earnestness in the matter to offer to cooperate to the extent of furnishing $1,500, to be disbursed upon the usual approved vouchers, an equal amount to be allotted from the funds of the United States Geological Survey, to be expended by the latter in making these investigations. My conference with the officials of the Geological Survey has shown that this proposition is acceptable to them, being similar to the cooperation now in force with the Water and Forest Association of California and also with officials in various States.

I trust that this matter will meet your hearty approval and this greatly needed investigation can be begun at once.

This letter was referred to the Director of the Geological Survey, who replied to the Secretary of the Interior on January 14, 1901, as follows:

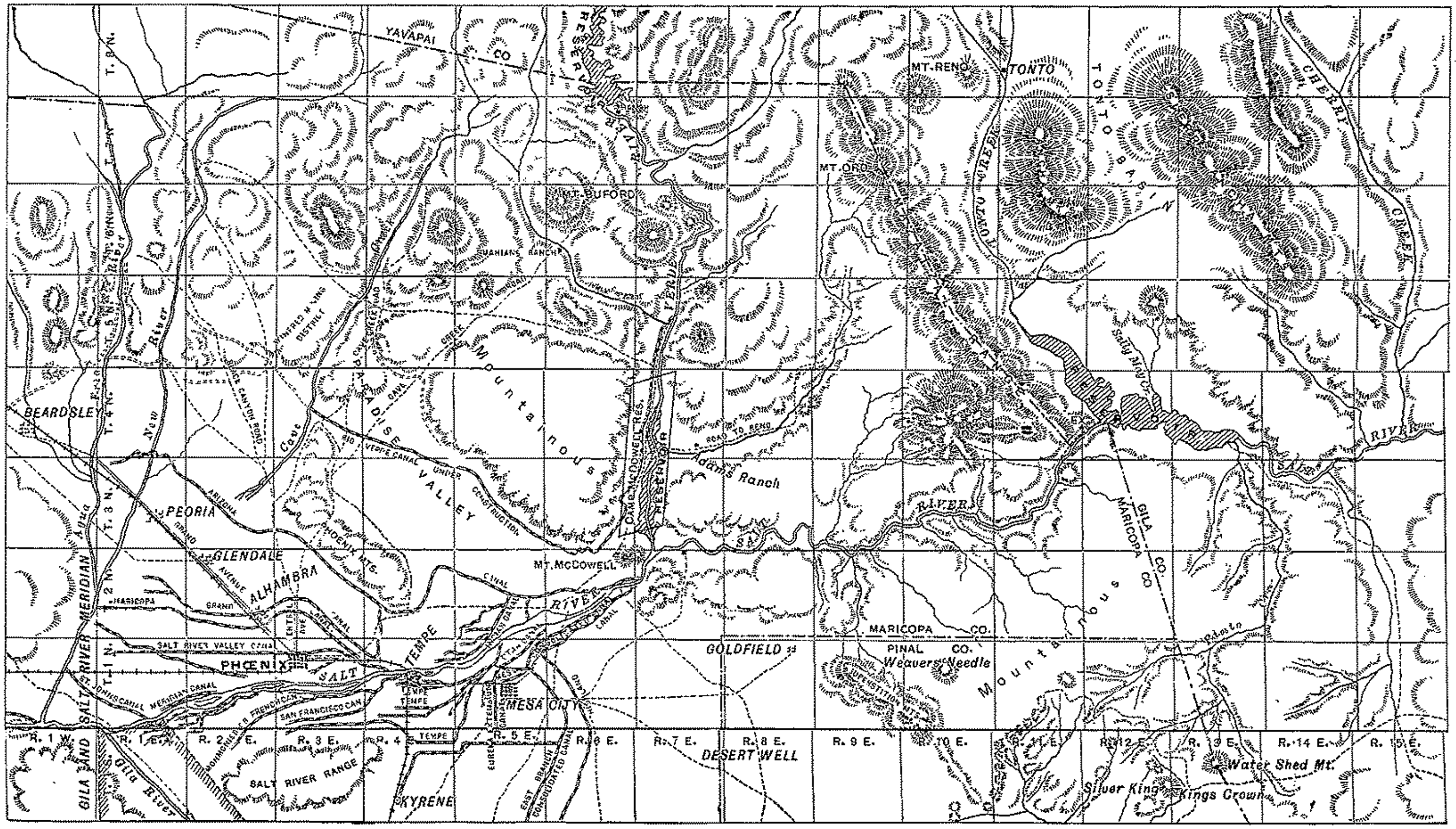
I have the honor to acknowledge, by reference from the Department of December 31, for early report and return of the papers, a letter dated November 20, from Mr. B. A. Fowler, president of the Salt River Valley storage committee.

In this Mr. Fowler offers to cooperate to the extent of furnishing $1,500 in the investigation of the water resources of the portion of country above the Salt River Valley. This offer of cooperation should, in my opinion, be met with hearty approval and investigations pushed forward energetically in those regions where the people testify to the need of this work by furnishing financial aid.

The offer of the Arizona people is comparable to that of the California Water and Forestry Association, which has paid one-half of the field expenses of similar investigations in California during the past year.

Mr. Fowler, after presenting his letter of November 20 to you, and having a personal conversation, filed in this office a copy of the letter. In view of the necessity of beginning work immediately, while the climatic conditions are favorable, I authorized the beginning of this Arizona work, and will have it pushed forward to completion if it continues to meet your approbation, as I understand informally that it does.

The work now in hand consists of a thorough examination of the drainage basin of Verde River, the gaging of the streams, and the determining of the water supply; this latter involving the survey and examination of possible reservoir sites. After this is completed, it is possible that work will be continued on the Salt River above the Verde.



MAP OF SALT RIVER BASIN, SHOWING RESERVOIR SITES.

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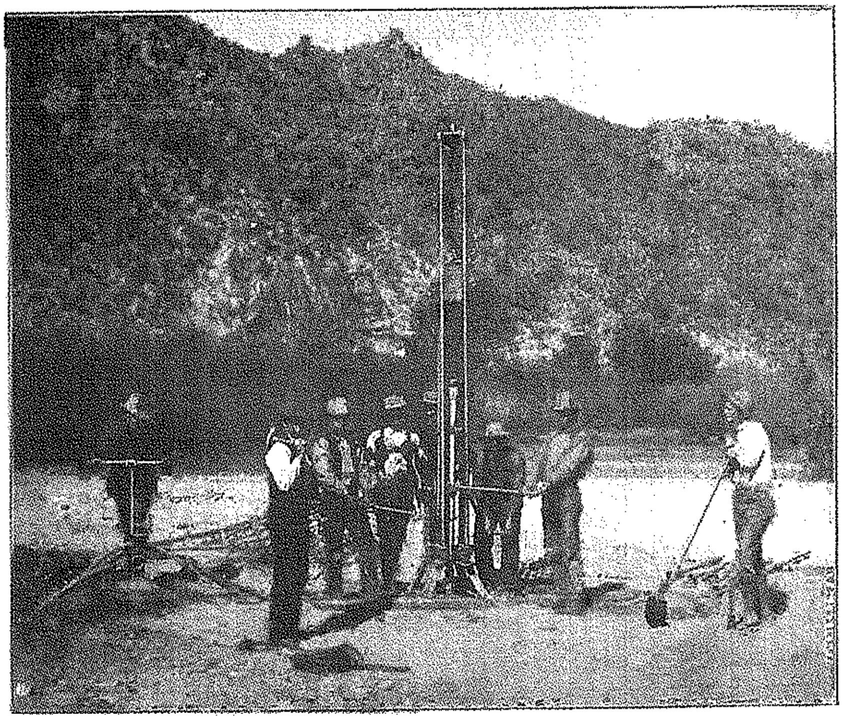
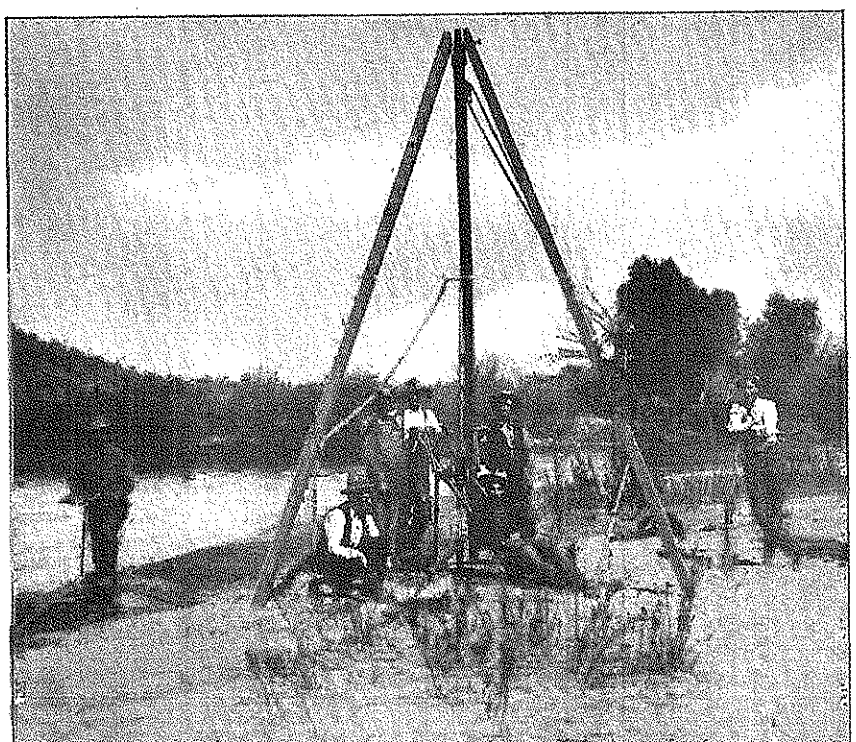


A DRILL PARTY ON VERDE RIVER; "PIERCE RIG"



B DRILL PARTY ON VERDE RIVER; DIAMOND DRILL.

Accordingly, early in January the investigation of the McDowell reservoir site, near the mouth of Verde River, was begun. Measurements of the flow of the river were also begun at once, and borings were made in order to ascertain the nature of the foundation for the proposed dam. While the borings were in progress surveys were carried on to determine the capacity of the reservoir and the cubical contents of the dam. The work at the McDowell dam site was concluded on April 20, when the public funds available for the work were almost exhausted. About this time the water-storage commission was appointed, under the act of the Arizona legislature, as follows:

No. 65.

AN ACT to authorize any county in the Territory of Arizona having an assessed valuation of eight million dollars or over to prepare plans and specifications for a storage reservoir or reservoirs, dam or dams, to acquire the site for the same, and to provide the necessary funds to defray the expenses incurred.

Be it enacted by the legislative assembly of the Territory of Arizona:

SECTION 1. Any county in the Territory of Arizona having an assessed valuation of eight million dollars or over may avail itself of the benefits of this act by complying with the provisions as hereinafter provided. The board of supervisors, upon the petition of fifty qualified electors and freeholders of said county, shall request the district judge in which the county is located to appoint a board of water-storage commissioners, and the judge shall within ten days thereafter appoint five qualified electors, who shall be resident freeholders of said county, who shall be known and designated as the board of water-storage commissioners. Each of said commissioners shall hold office for one year and until his successor is appointed and qualified. Before entering upon the duties of his office he shall give bond in the sum of one thousand dollars, payable to the said county, for the faithful performance of his duty. Said bonds shall be approved by and filed with the board of supervisors of said county. At its first meeting the board shall organize by the election of one of its members as president. It shall also elect a secretary, who may or may not be of its number. The compensation for the members of said board shall be five dollars per day for each day actually employed. They shall also be allowed their actual traveling expenses. The salary of the secretary shall be fixed by the board. The board shall establish and maintain an office at the county seat of the said county. It shall be the duty of said water-storage commissioners to examine reservoir sites, cause to be made surveys and soundings, determine the capacity and estimate the cost of construction of said proposed reservoir or reservoirs, dam or dams, determine the extent of the watersheds and rainfall thereon; to collect such other information as shall show the water available for storage use in said county for irrigating purposes; to provide for the accumulation of such other information as may be required therefor, and cause abstracts therefrom to be published in some newspaper published and of general circulation in said county; to employ and fix the compensation of a competent engineer or engineers; to prepare plans, specifications, and estimates for said reservoirs and dams and file a copy of the same with the clerk of the board of supervisors of said county; to employ and fix the compensation of legal counsel in any matters arising under this act, or necessary to authorize the construction of the dams or reservoirs referred to in this act, and to select the most available reservoir site or sites, and to acquire the same, together with any rights of way necessary over public or private property, by purchase or through eminent domain, in the name of said county of Maricopa, and for the benefit of the people of said county; and to negotiate with and obtain agreements from canal companies in relation to the distribution of water or its delivery to the point of ultimate use, and to cooperate with or contribute towards the expenses of any investigations now being made or hereafter to be made by the United States Geological Survey, and to transfer to the National Government any reservoir site or rights therein or thereto, or connected therewith, which may have been acquired hereunder, in the event that the National Government should undertake the construction of the reservoir.

SEC. 2. For the purpose of defraying the expenses of the board of water-storage commissioners, the board of supervisors of any county availing itself of this act shall at the time of levying Territorial and county taxes in the years 1901 and 1902 levy an additional tax of one and one-half mills on the dollar on all taxable property within the said county, to be collected as other taxes are collected; and the same shall be denominated and known as a water-storage fund. The board of water-storage commissioners shall audit and approve all bills for expenses incurred under the provisions of this act, and present the same, together with the claims for their salaries and expenses, to the board of supervisors, who shall, if found correct, pay the same out of any money in the water-storage fund.

SEC. 3. All acts and parts of acts in conflict with the provisions of this act are hereby repealed.

SEC. 4. This act shall take effect and be in force from and after its passage.

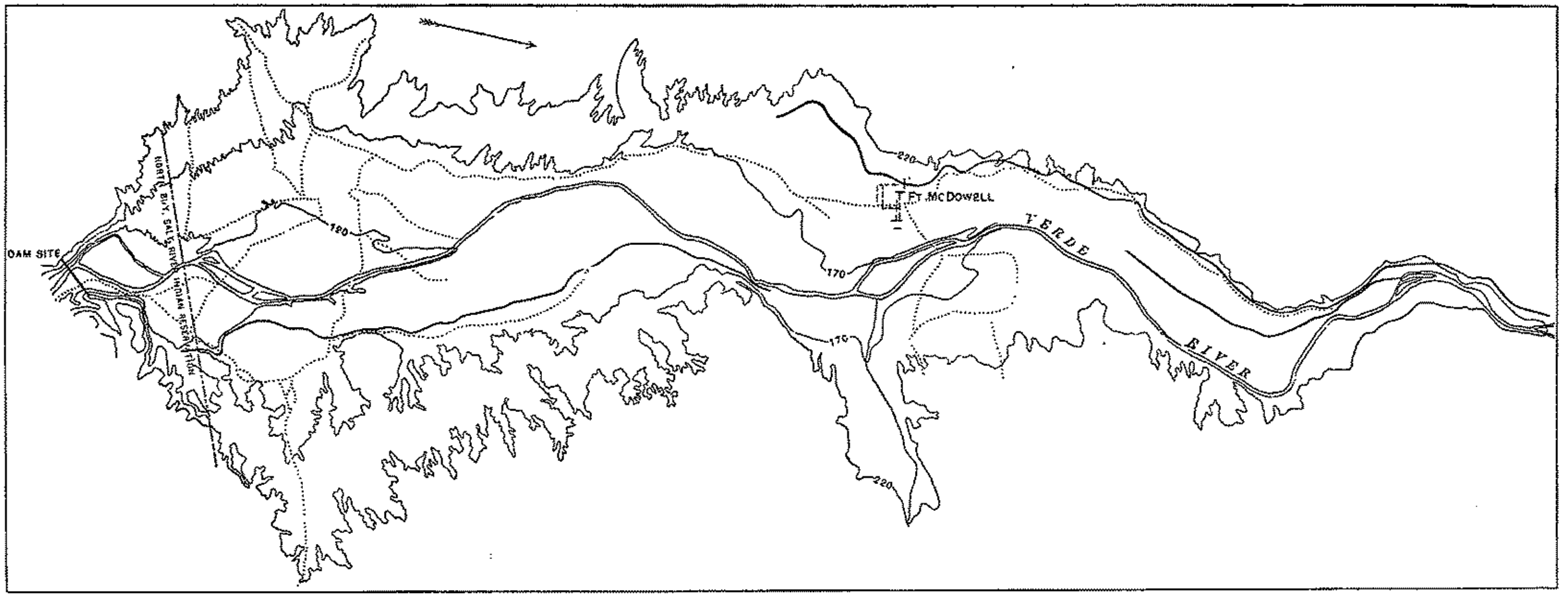
Approved, March 20, 1901.

The water-storage commission consisted of J. T. Priest, Charles Goldman, W. D. Fulwiler, Dwight B. Heard, and J. G. Peterson. Arrangements were made by which the officers of the Geological Survey were to prosecute investigations at the reservoir site on Salt River at the mouth of Tonto Creek, with the machinery and camp equipment of the Geological Survey, the water-storage commission to furnish subsistence and to pay the laborers and incidental camp expenses. Borings and surveys were carried on for about three months, resulting in a thorough knowledge of the foundation conditions for a high dam, the cubical contents of the same, and the capacity of the reservoir site for each 10 feet of elevation above the river from 10 to 200 feet. The results of all these investigations and the plans founded thereon are given in the following pages.

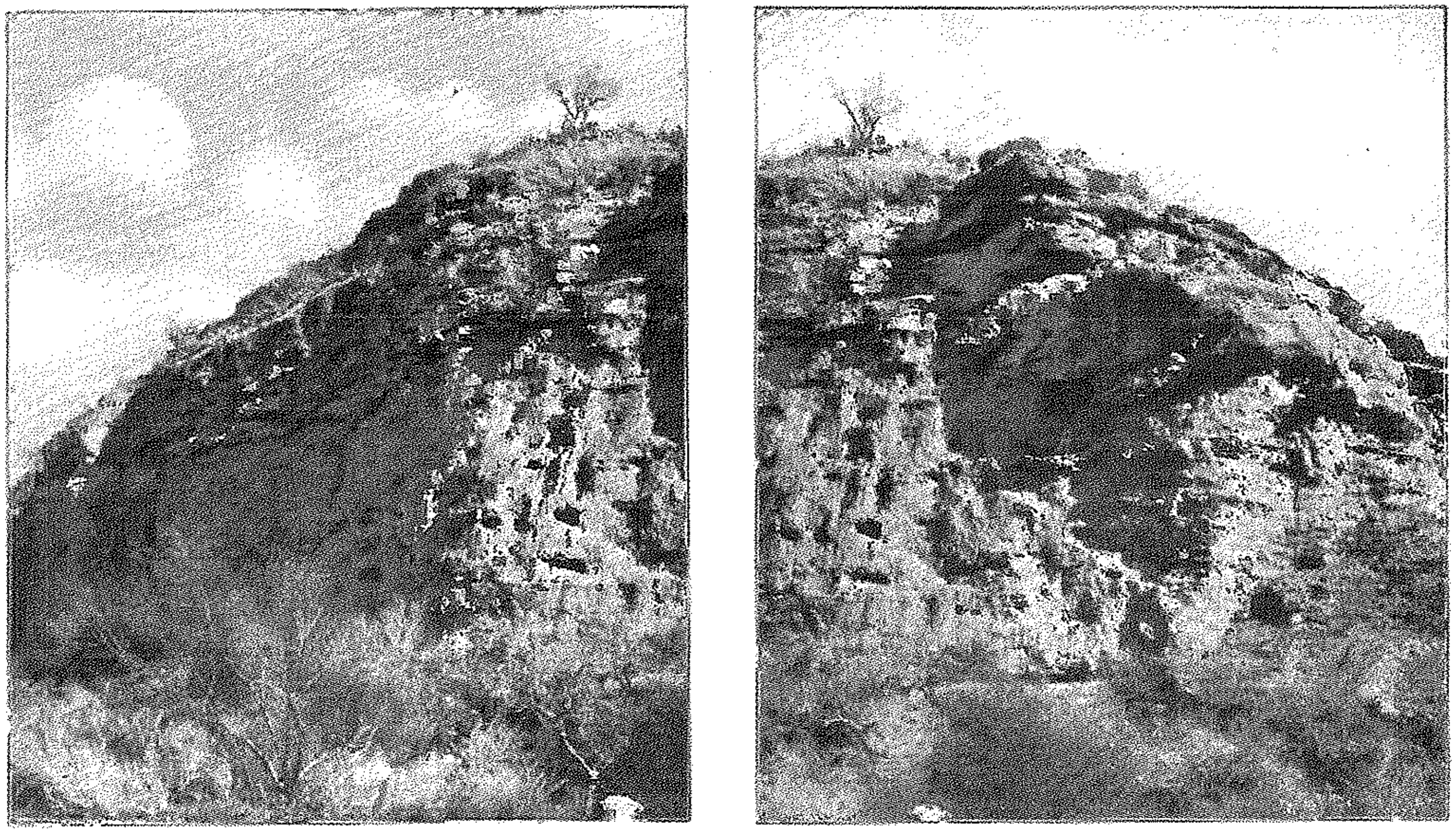
WATER STORAGE ON VERDE RIVER.

CHARACTER OF DRAINAGE BASIN.

Verde River rises in the Black Forest, near the line of the Atchison, Topeka, and Santa Fe Railway. Its general course is a little east of south, draining the Black Hills and Black Mesa. The principal tributaries from the east are Dragoon Fork, Oak Creek, Beaver Creek, Clear Creek, and East Verde River. All are of considerable length and come from mountainous country, with relatively high rainfall, and furnish the main portion of its waters. The only tributaries of consequence from the west are Walnut Creek, near the head, and Granite Creek, which rises near Prescott and flows northward. These creeks are usually dry. The total area drained by the Verde is about 6,000 square miles, ranging in altitude from 1,250 feet at Camp McDowell to over 8,000 feet. The topography of the basin is widely varied in character.



OUTLINE OF McDOWELL RESERVOIR SITE.



CONGLOMERATE CLIFF, McDOWELL RESERVOIR SITE, SHOWING WIND EROSION.

Near the headwaters are Big Chino, Williamson, Little Chino, and Lonesome valleys, each of which is an extensive plain yielding little run-off to the river. The greater portion of the basin, however, is of a mountainous character, being cut with profound canyons and dotted by rugged mountains. Only a small proportion is wooded and the soil is kept nearly bare by excessive grazing. As might be expected, the run-off is largely torrential in character, and the floods carry some silt. In this respect it is not as favorable for storage as the basin of the Salt.

WATER SUPPLY.

The flow of Verde River at Mount McDowell was directly observed by the Hudson Reservoir Company from February 4, 1895, to July 31, 1896; and by the Geological Survey from April 20, 1897, to November 30, 1899, and during 1901. The balance of the record from August 1, 1888, to January 1, 1901, is derived from the record of the discharge of Salt River at Arizona dam below the mouth of the Verde, according to principles set forth on page 24. As these records are necessary in connection with the study of the duty of Salt River reservoir they are given by months in connection therewith, on page 26.

The monthly discharges, as far as completely known, are as follows:

Estimated monthly discharge of Verde River at McDowell.

[Drainage area 6,000 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	Depth in inches.
1888.[a]						
August			172	10,547	0.03	0.03
September			168	9,996	.03	.03
October	175	150	166	10,178	.03	.03
November	2,880	213	421	25,050	.07	.078
December	21,745	823	3,349	205,964	.56	.645
The year				261,735		
1889.[a]						
January	10,480	699	2,498	153,611	.42	.48
February	1,773	690	1,172	65,059	.20	.21
March	13,180	1,390	3,411	209,749	.57	.65
April	1,112	499	795	47,302	.09	.10
May	639	118	197	12,141	.03	.03
June	185	107	141	8,390	.02	.02
July	551	140	208	12,819	.04	.04
August	370	191	204	12,556	.03	.03
September	562	187	250	14,880	.04	.04
October	352	160	220	13,530	.04	.05
November	315	266	288	17,136	.04	.04
December	12,686	279	2,843	174,845	.67	.77
The year	13,180	107	1,018	742,028	.18	2.43
1890.[a]						
January	6,615	578	2,092	128,685	.35	.40
February	64,480	470	4,544	252,172	.76	.79
March	6,719	1,001	2,504	153,967	.62	.71
April	415	274	368	21,896	.06	.07
May	260	120	174	10,680	.03	.03
June	202	119	153	9,121	.03	.03
July	366	167	220	13,535	.04	.04
August	3,760	546	1,904	117,074	.32	.37

[a] Obtained by taking proportional part of the discharge of Salt River at Arizona dam.

Estimated monthly discharge of Verde River at McDowell.—Continued.

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	Depth in inches.
1890.[a]						
September	1,769	348	1,123	66,802	.19	.21
October	3,733	377	1,384	80,116	.02	.02
November	15,252	383	2,359	140,331	.39	.43
December	15,183	555	3,130	192,464	.52	.59
The year	64,480	119	1,666	1,186,843	.278	3.69
1891.[a]						
January	7,193	445	1,435	88,244	.22	.25
February	135,000	371	17,467	970,051	2.91	3.03
March	8,460	525	1,928	118,535	.32	.37
April	606	459	534	31,775	.09	.10
May	361	365	458	28,190	.08	.09
June	539	280	401	23,849	.07	.08
July	405	252	314	19,291	.05	.06
August	368	251	278	17,113.	.05	.06
September	631	229	395	23,478	.06	.07
October	310	231	258	15,833	.04	.04
November	314	231	256	15,233	.04	.04
December	346	294	328	20,168	.05	.06
The year	135,000	229	2,004	1,371,760	.332	4.25
1892.[a]						
January	360	257	284	17,458	.05	.06
February	----------	----------	----------	[b]11,046	----------	----------
March	----------	----------	----------	[b]9,832	----------	----------
April	----------	----------	----------	[b]5,213	----------	----------
May	----------	----------	----------	[b]5,608	----------	----------
June	----------	----------	----------	[b]3,106	----------	----------
July	215	136	152	9,374	.02	.02
August	276	162	198	12,172	.03	.03
September	188	157	164	9,768	.03	.03
October	875	164	223	13,712	.04	.04
November	435	225	257	15,263	.04	.04
December	296	263	282	17,309	.05	.06
The year	----------	----------	----------	129,861	----------	----------
1893.[a]						
January	231	231	231	14,204	.04	.04
February	4,781	248	672	37,318	.11	.11
March	144,306	230	5,386	331,168	.90	.04
April	495	141	290	17,244	.05	.06
May	380	64	150	9,253	.02	.02
June	106	44	68	4,052	.01	.01
July	478	117	225	13,842	.04	.04
August	1,240	233	802	49,321	.13	.15
September	1,164	284	530	31,532	.09	.10
October	244	276	376	23,120	.06	.07
November	339	280	296	17,613	.05	.06
December	325	313	315	19,338	.05	.06
The year	144,306	44	778	568,000	.13	1.76
1894.[c]						
January	264	231	244	15,030	.04	.04
February	284	236	259	14,395	.04	.04
March	996	205	530	32,565	.09	.10
April	269	95	171	10,187	.02	.02
May	89	60	68	4,159	.01	.01
June	133	66	79	4,713	.01	.01
July	223	66	119	7,334	.02	.02
August	923	140	439	26,996	.07	.08
September	715	139	292	17,365	.05	.06
October	714	122	242	14,880	.04	.04
November	303	207	230	13,656	.04	.04
December	820	233	442	27,147	.07	.08
The year	923	60	259	188,427	.04	.54

[a] Obtained by taking proportional part of discharge of Salt River at Arizona dam.
[b] Approximate, from minimum discharge recorded for same months in 1900.
[c] Obtained by taking proportional part of discharge of Salt River at Arizona dam. Using Mr. Trott's computations.

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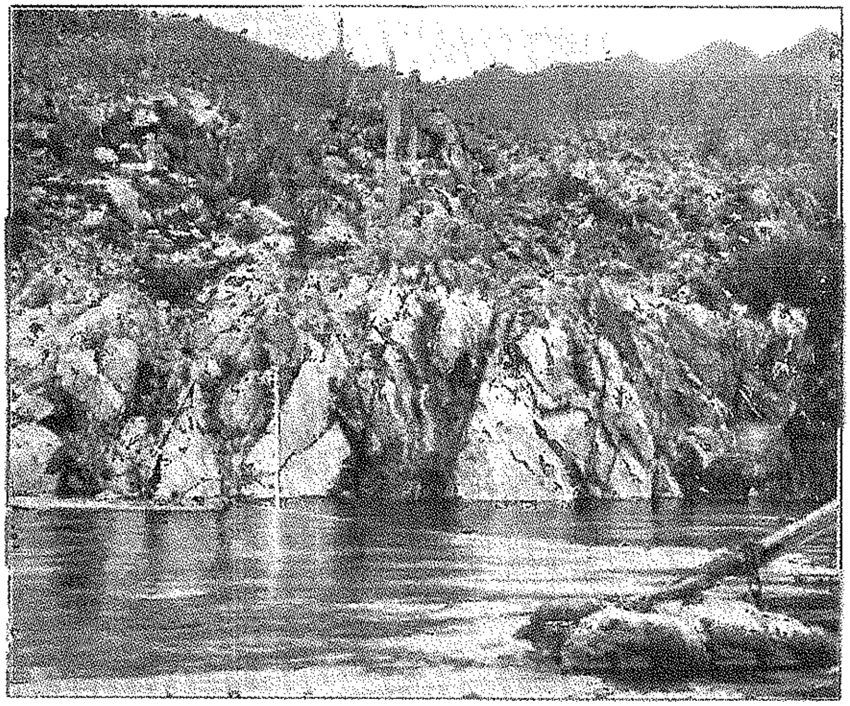
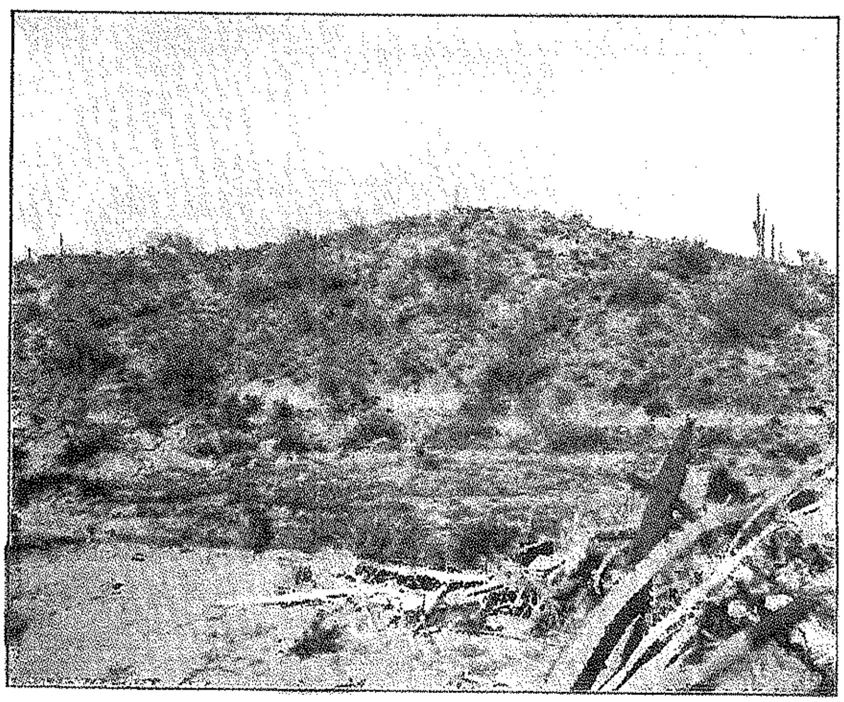


A. WEST ABUTMENT OF McDOWELL DAM SITE, SHOWING GAGE ROD.



B. EAST ABUTMENT OF McDOWELL DAM SITE.

Estimated monthly discharge of Verde River at McDowell—Continued.

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	Depth in inches.
1895.[a]						
January	33,000	527	4,037	248,225	.67	.77
February	5,800	583	1,688	93,747	.28	.29
March	8,400	1,887	3,720	228,734	.62	.71
April	2,800	280	750	44,628	.13	.14
May	429	127	258	15,864	.04	.04
June	180	129	153	9,104	.03	.03
July	275	116	145	8,916	.02	.02
August	1,426	185	359	22,074	.06	.07
September	348	141	176	10,473	.03	.03
October	3,912	197	475	29,207	.08	.09
November	1,800	241	463	27,550	.08	.09
December	881	345	391	24,042	.07	.08
The year	33,000	116	1,051	762,564	.18	2.36
1896.						
January	354	314	324	19,923	.05	.06
February	352	278	154	8,852	.03	.03
March	338	258	276	16,971	.05	.06
April	237	206	220	13,090	.04	.04
May	206	138	172	10,576	.03	.03
June	137	101	117	6,962	.02	.02
July	3,380	98	864	53,127	.14	.16
August[b]	5,323	272	849	52,213	.18	.21
September[b]	4,466	252	557	33,132	.06	.07
October[b]	630	301	452	27,823	.05	.06
November[b]	747	334	492	29,306	.05	.06
December[b]	444	326	352	21,644	.04	.05
The year[b]	5,323	98	402	293,629	.06	.85
1897.						
January[b]	15,687	252	2,138	131,474	.36	.41
February[b]	2,245	487	873	48,484	.15	.16
March[b]	4,013	706	1,504	92,492	.25	.29
April[b]	2,706	316	1,189	70,774	.20	.23
May	460	170	269	16,540	.045	.052
June	185	120	150	8,920	.025	.028
July	230	90	130	7,993	.022	.025
August	1,590	110	439	26,993	.073	.084
September	5,000	240	992	59,028	.165	.184
October	390	260	309	19,000	.051	.059
November	265	260	262	15,590	.044	.049
December	280	260	267	16,417	.045	.052
The year	15,687	90	710	513,705	.12	1.61
1898.						
January	1,680	120	253	15,556	.04	.04
February	800	290	496	27,546	.08	.09
March	1,535	210	639	39,291	.11	.13
April	710	180	319	18,982	.05	.06
May	280	130	184	11,314	.03	.03
June	160	130	139	8,271	.02	.02
July	1,890	115	323	19,861	.05	.06
August	1,730	165	400	24,595	.07	.08
September	1,380	165	338	20,112	.06	.07
October	180	160	169	10,391	.03	.03
November	230	165	195	11,603	.03	.03
December	440	220	303	18,631	.05	.06
The year	1,890	115	313	226,153	.05	.70
1899.						
January	560	295	350	21,521	.06	.07
February	375	295	344	19,105	.06	.06
March	325	225	260	15,987	.04	.05
April	230	170	205	12,198	.03	.03
May	210	118	152	9,346	.03	.03
June	230	118	152	9,045	.03	.03
July	1,400	118	365	22,443	.06	.07
August	2,170	100	434	26,686	.07	.08
September	2,500	135	357	21,243	.06	.07
October	3,770	160	549	33,757	.09	.10
November	250	235	203	13,240	.03	.03
December	364	223	292	13,343	.05	.06
The year	3,770	100	305	217,914	.05	.68

[a] Obtained by taking proportional part of discharge of Salt River at Arizona dam. Using Mr. Trott's computations.

[b] Computations made from Mr. Trott's figures.

Estimated monthly discharge of Verde River at McDowell—Continued.

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	Depth in inches.
1900. [a]						
January	195	179	189	11,621	.03	.03
February	211	184	199	11,046	.03	.03
March	187	144	160	9,832	.03	.03
April	125	74	88	5,213	.01	.01
May	190	46	91	5,608	.02	.02
June	75	36	52	3,106	.01	.01
July	105	36	52	3,176	.01	.01
August	555	68	151	9,235	.02	.02
September	305	92	121	7,198	.02	.02
October	408	107	183	11,252	.03	.03
November	2,469	163	430	25,617	.07	.08
December	272	205	224	13,775	.04	.04
The year	2,469	36	161	116,679	.025	.33
1901. [b]						
January	1,557	259	351	21,575	.06	.07
February	6,613	394	1,859	103,249	.30	.31
March	2,863	211	895	55,018	.15	.17
April	221	155	184	10,988	.03	.03
May	185	125	139	8,606	.02	.02
June	164	59	104	6,222	.02	.02
July	1,430	29	210	12,916	.04	.04
August	1,755	163	627	38,561	.11	.13
September	172	45	93	5,514	.01	.01
October	495	82	134	8,210	.02	.02
November	336	187	245	14,571	.04	.04
December	291	247	268	16,485	.04	.04
The year	6,613	29	426	301,915	.07	.90
1902.						
January	262	197	224	13,785	.03	.03
February	248	227	239	13,277	.04	.04

[a] No observations made during 1900 by United States Geological Survey. Computations made from Mr. Trott's figures.
[b] Computations made from observations taken by United States Geological Survey.

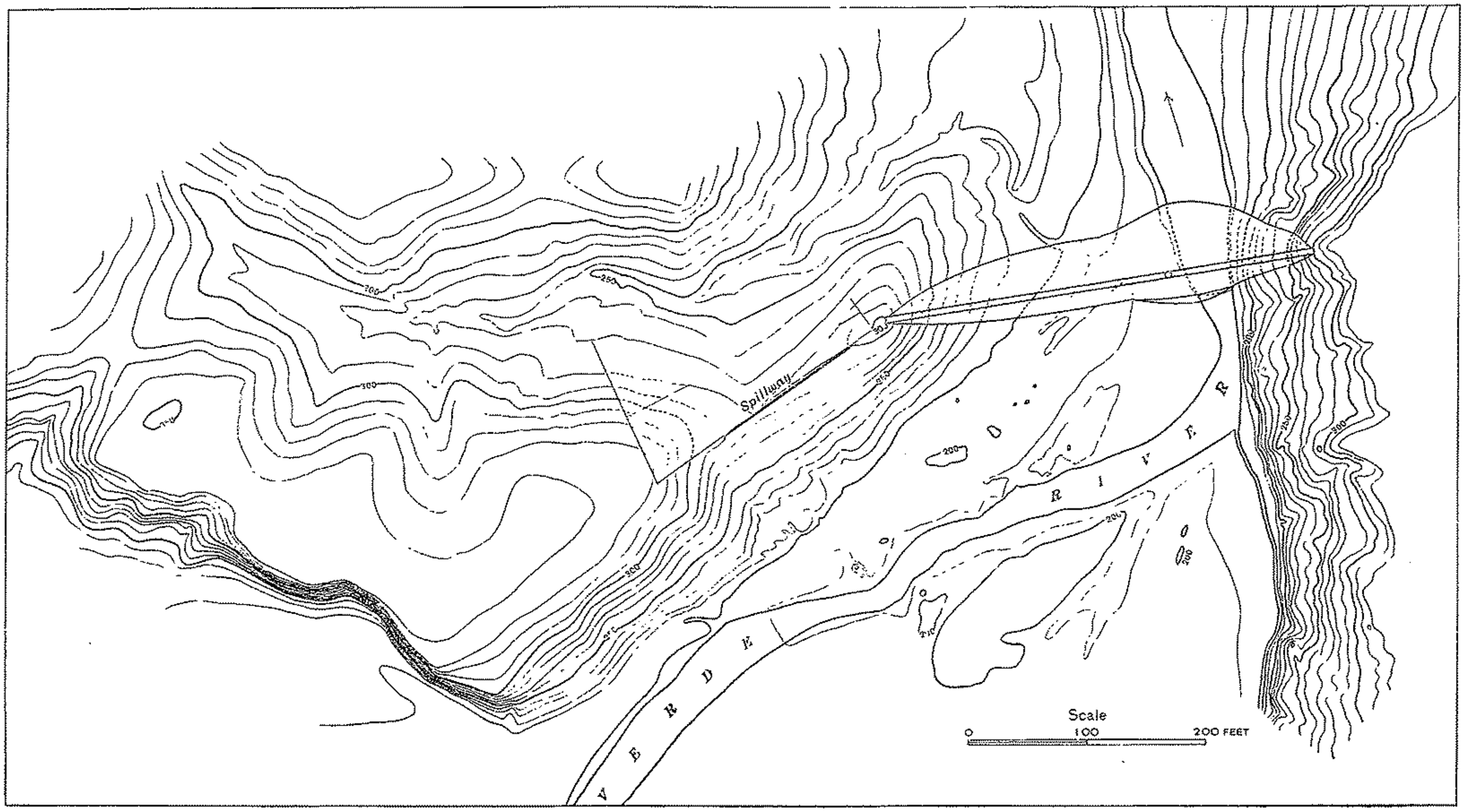
Two storage reservoirs have been proposed upon Verde River. The Horseshoe reservoir, which is described in Water-Supply and Irrigation Paper No. 2, page 62, is situated about 30 miles above old Camp McDowell, near the mouth of Limestone Creek. An outlet tunnel has been cut and a portion of the canal has been built, but work has been suspended for several years. The capacity of this reservoir would be about 200,000 acre-feet.

McDOWELL RESERVOIR.

This reservoir site is situated above Mount McDowell, near the mouth of the Verde, and includes the site of old Camp McDowell. The dam site is about 2 miles above the mouth of the Verde. This reservoir site was suggested and partly surveyed by Mr. Frank P. Trott, the water commissioner of Salt River Valley.

BORINGS.

Early in January, 1901, field work was begun by the Geological Survey, and an examination of the McDowell reservoir site on Verde River was made. Two pipe-driving machines and a diamond drill were taken to the ground, and borings were begun to determine the position and character of bed rock at the site of the proposed dam, Mr. W. E. Jones, of Des Moines, Iowa, being employed as drill foreman.



PLAN OF McDOWELL DAM.

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Mr. C. R. Olberg was intrusted with the construction of a map of the reservoir site in 10-foot contours, on a scale of 1,000 feet to an inch, and a detailed map of the dam site was made on a scale of 100 feet to an inch. The field work was under the general direction of Mr. F. P. Trott, whose duties as water commissioner, however, prevented his continued presence on the ground, so that the immediate charge was assigned to Mr. E. G. Hamilton.

The borings began by attempting a straight row of holes along the axis of the dam proposed by Mr. Trott. The conditions were found to be very difficult. At a depth of about 30 feet a bed of very hard cemented gravel was encountered, into which it was impossible to drive the pipe, except with the assistance of blasting, but which was not sufficiently coherent to be classed as solid rock.

The work was also hampered by the fluctuation of the river, the floods threatening several times to wreck or sweep away the machinery.

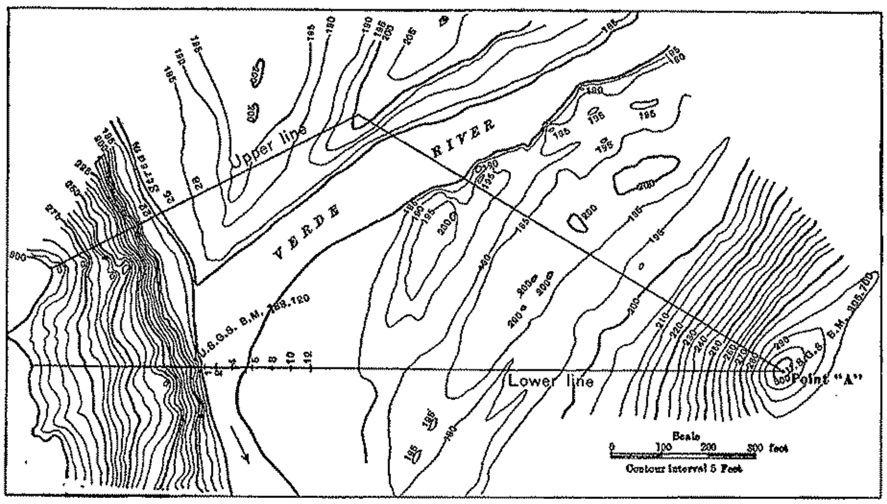


FIG. 1.—Plan of borings at McDowell dam site.

By February 26 it had been demonstrated that it was at least more than 70 feet to bed rock in hole No. 6 on the main axis of the proposed dam, and the work being hampered here by fluctuating water, Mr. Trott determined to try along an alternate location, shown in fig. 1, farther upstream, and both machines were set to work there on holes Nos. 21 and 25. The former was soon completed, showing a depth to rock of 21 feet. The machine was removed to the site of No. 28. Work was pushed on 25 and 28 until the former reached a depth of 90 feet without striking rock. This was considered a prohibitory depth for this location and the machinery was returned to the first location to continue the exploration of the main line. This was completed on April 20.

The location of the borings on both lines is shown in fig. 1. The depths of borings are shown in the table following.

Borings at McDowell dam site.

Hole number.	Distance from bench mark.	Depth to bed rock.	Total depth.	Character of bed rock.
	Feet.	*Feet.*	*Feet.*	
1	20	22	22	Granite.
2	40	35	38	Rotten granite.
4	80	90	99	Broken granite.
6	120	80	92	Do.
8	160	49	59	Granite.
10	200	40	46	Hard gray granite.
12	240	52	65	Broken granite.
21		22	26	Granite.
25			90	No bed rock reached.
28			50	Do.

CAPACITY.

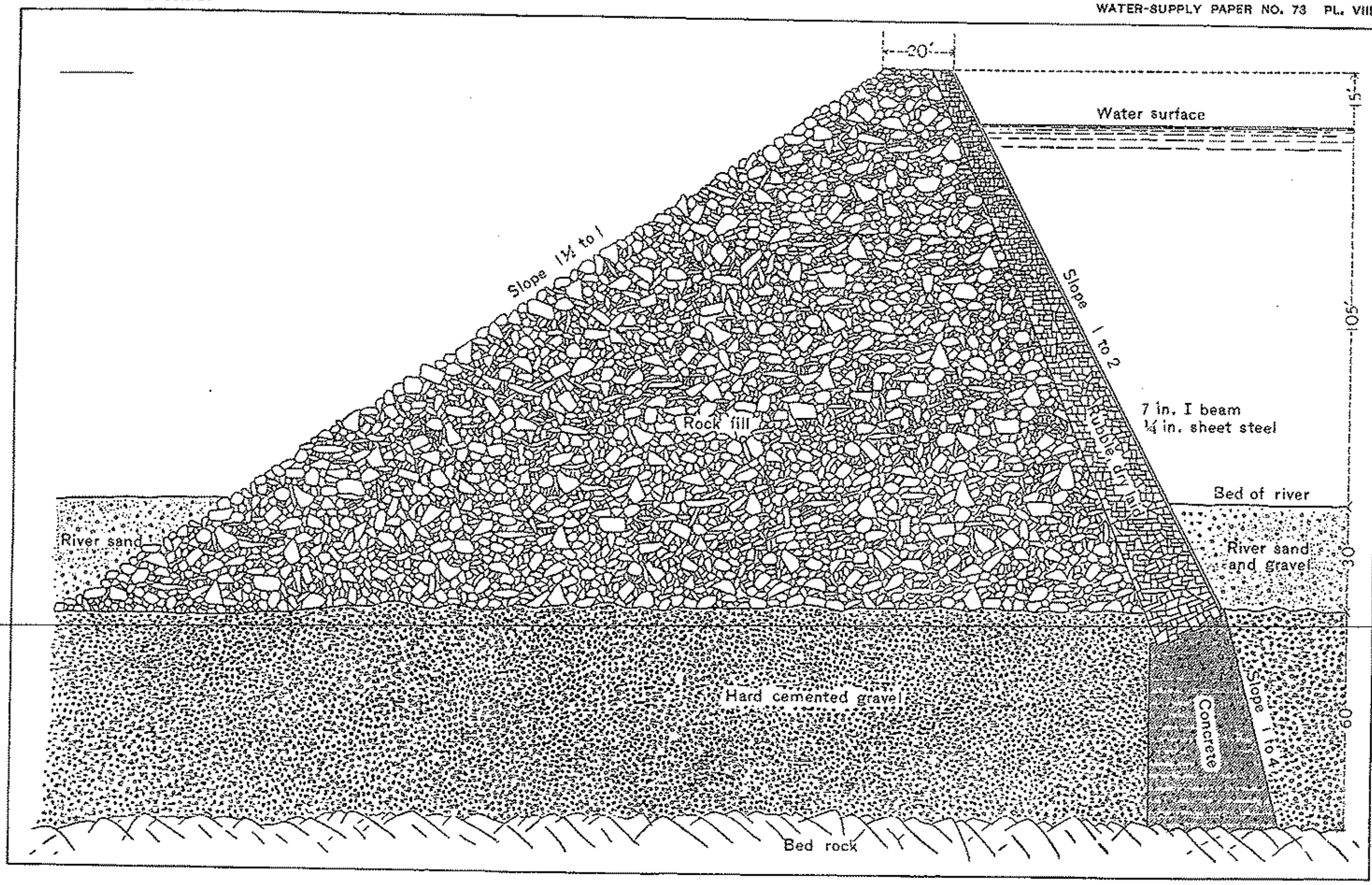
Capacity of McDowell reservoir.

Elevation above lowest foundation.	Area.	Capacity of section.	Total capacity.
Feet.	*Acres.*	*Acre-feet.*	*Acre-feet.*
100	14	70	70
110	91	525	595
120	331	2,110	2,705
130	717	5,240	7,945
140	1,073	8,950	16,895
150	1,661	13,670	30,565
160	2,292	19,765	50,330
170	3,134	27,130	77,460
180	4,034	35,840	113,300
190	4,990	45,120	158,420
200	6,020	55,050	213,470
210	7,213	66,165	279,635
220	8,493		

PLANS FOR THE DAM.

The map of the reservoir site was made on a scale of 1,000 feet to an inch, with a contour interval of 10 feet. A reduced outline of it is given in Pl. IV. The map of the dam site was made on a scale of 100 feet to an inch, with a contour interval of 5 feet. A reduction is shown in Pl. VII.

The capacity of the reservoir is very large, so far as it goes, but the practicable height of dam is limited by the height of the east abutment. The total excavation to bed rock is large, and much of the material to be excavated is hard. At a depth of 30 feet, more or less, the river gravel is underlain down to bed rock by a very hard cemented mixture of sand and gravel, which would be very expensive to excavate in case a masonry dam was constructed, but is sufficiently firm to serve as foundation for a rock-fill structure. The cost of a masonry dam would be prohibitory. The moderate height, the great length, and the abundance and convenience of suitable rock are all additional arguments in favor of the rock-fill type, and it is without doubt the most suitable. The most unfavorable feature of the whole project is



CROSS SECTION OF McDOWELL DAM.

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the character of the east abutment at the dam site. The granite bed rock appears on the surface on the east side of the river, but seems to enter the hill on a nearly horizontal grade. The hill above the granite, which constitutes the upper 90 feet of the abutment, is composed of an indurated mixture of coarse sand and gravel of the same character as the foundation described above, too hard to excavate with a pick, but not to be classified as rock, and inclined to disintegrate upon exposure to the air. It is probable that under high head, water might percolate through this material to some extent, at least where the abutment is thinnest; and to insure against this a concrete core is to be carried into the hill a distance of about 300 yards, where the hill becomes over 1,000 feet thick. Supposing this core to be 6 feet in thickness, the excavation and masonry would cost about $600 per running yard, and hence would add $180,000 to the cost of the construction. The bond between the concrete core and the adjacent natural deposit should be made as thorough as possible by filling the joint with Portland cement concrete, well rammed in place, so that there can be no creeping of water along the wall. With proper precautions it is believed that a dam of the proposed height, 120 feet, could be safely built and maintained.

At the site of the dam the river bed is composed of ordinary sand and gravel to a depth of about 30 feet, when the compact cemented gravel is encountered. The depth to bed rock is about 90 feet at the deepest point. It is proposed to carry a concrete wall down to bed rock across the canyon, at the upstream toe of the dam. This wall will be 35 feet thick at the base on bed rock and diminish to 15 feet at the top. Downstream from this wall the river sand and gravel will be excavated down to the cemented material above mentioned, and upon this will be founded the main dam, which is to be of the rock-fill type, the upstream face to be on a slope of 1 in 2, and the downstream slope 3 in 2, with a top width of 20 feet. The rock will be obtained from the mountain of granite that rises abruptly from the west abutment. The rock can be transported down grade on a cable way, and dropped on the dam in large blocks, from a considerable height, which will serve to ram it solidly in place, and it is believed very little settlement will occur. On the upstream face is to be a wall of rubble masonry resting on the concrete wall that goes down to bed rock. The masonry will have a thickness of 20 feet at the bottom, diminishing to 5 feet at the top. Against its downstream side will be built the mass of dry rock fill; on the water face, which will have a slope of 1 in 2, will be placed, at intervals of 20 feet, a series of 7-inch steel **I**-beams, each extending from the bottom to the top of the dam. To these beams will be fastened a floor of one-fourth inch steel plates, dipped in asphalt and riveted together to form a water-tight skin over the entire water slope of the dam. The space between the steel plates and the masonry will be filled with concrete tightly rammed. The concrete and rubble walls will unite at the ends with the concrete core, which is to be carried into the east abutment, as above described.

The outlet will be through a tunnel of concrete built through the dam along the bed of the river, provided with Stoney gates, similar in construction and mechanism to those for the Salt River reservoir, illustrated in Pl. XXII. All water will be drawn from the bottom of the reservoir, and whenever the spillway begins to discharge, the gates will be opened to full capacity for the purpose of discharging the maximum quantity of silt and of reenforcing the spillway.

For diverting the river during construction a temporary diversion dam could be placed across the river about 4,000 feet above the dam site, and the water diverted into a large flume and carried along the east side of the river over the portion of the foundation where granite bed rock appears on the surface. The underflow can probably be sufficiently checked by driving sheet piling down to the bed of indurated gravel, with which the valley is underlain at a depth of about 30 feet. After the dam becomes too high to use this flume the discharge will be through the outlet tunnel. The flume should be removed early in the spring, at the beginning of the low-water season, and construction pushed rapidly, so as to have a large storage and discharge capacity ready for the first flood.

SPILLWAY PROVISIONS.

The greatest flood that ever occurred in Salt River Valley since its settlement occurred in February, 1891. It is described in the Twelfth Annual Report[a] of the Geological Survey, as follows:

> On February 17 the mean discharge was 835 second-feet, increasing the next day to 154,000 second-feet, and on the 19th to 276,000. This first flood diminished rapidly, averaging on the 20th only 69,100, and on the 22d 14,890. This was followed by a second swell greater than the first, the flood increasing until, on the 24th, a maximum of 300,000 second-feet was reached. This subsided almost as rapidly as it came, so that by the second day after the river was carrying less than 15,000 second-feet.

The drainage area from which this flood was drawn was considerably more than double that above the McDowell reservoir. A smaller drainage basin is, however, liable to a relatively higher flood discharge than a larger one, though the floods are of shorter duration. It is therefore estimated that the basin under consideration may discharge a flood having a maximum volume of 200,000 cubic feet per second, or two-thirds that of 1891 at Phoenix. On the above assumptions a maximum flood has been hypothecated and the behavior of the reservoir under the circumstances investigated. It is assumed that the reservoir is full up to the bottom of the spillway, and that a great flood discharges 100,000 cubic feet per second on an average for one hour, and increases its discharge 10,000 cubic feet per second during

[a] Twelfth Ann. Rept. U. S. Geol. Survey, Part II, p. 313.

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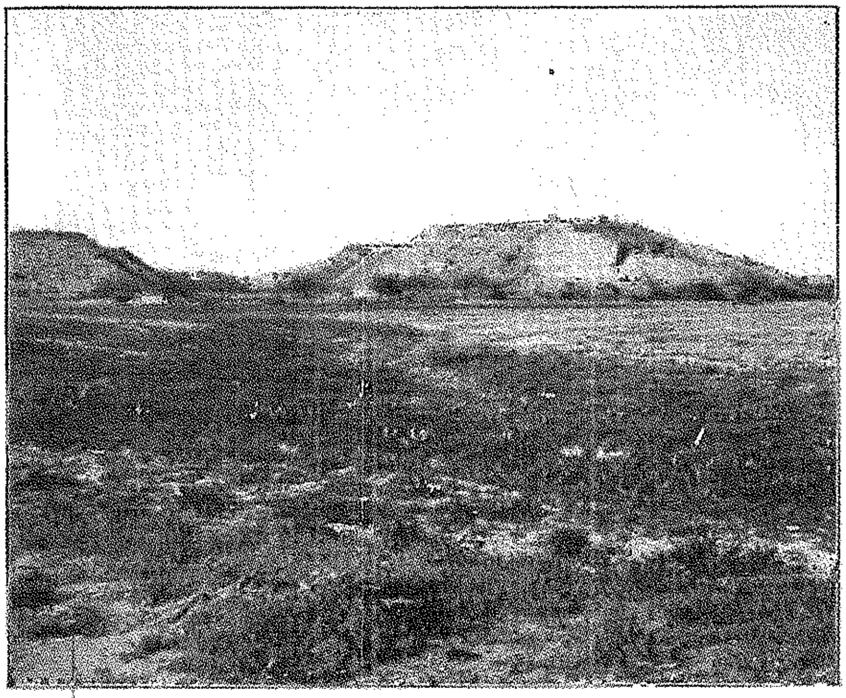
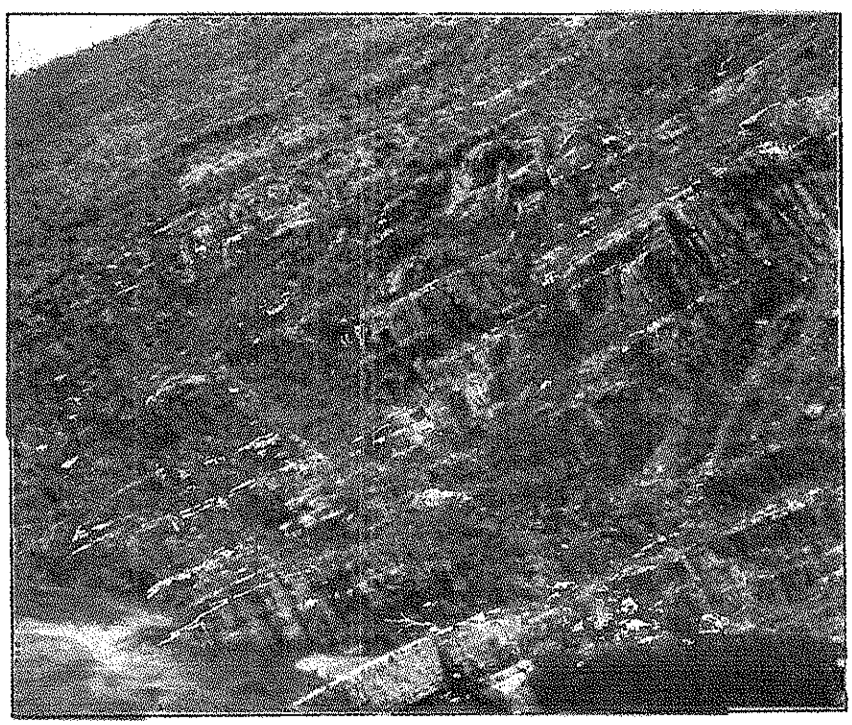


A. VIEW IN McDOWELL RESERVOIR BASIN.



B. CAPE HORN, SALT RIVER CANYON, SHOWING UPSTREAM DIP OF STRATA.

each hour for eleven hours, at the end of which time it has reached its maximum wave of 200,000 cubic feet per second. The discharge then decreases in an arithmetical progression for twenty hours at the rate of 5,000 second-feet per hour, reaching a discharge of 100,000 second-feet as a mean for the thirty-first hour. The spillway, as planned, has a total length of 900 feet, and its bottom is 15 feet below the top of the dam. Its discharge capacity is computed from the formula $Q=H^{\frac{3}{2}}\,3150$. Assuming that the gates will be opened to their full capacity when the spillway begins to discharge, the effect on the reservoir of the hypothetical flood is shown in the following table:

Effect of maximum flood in McDowell reservoir with spillway 900 feet long.

[$Q=H^{\frac{3}{2}}\,3150$.]

Hour.	Inflow.		Outflow.		Net rise.	Elevation.
	Second-feet.	Acre-feet.	Second-feet.	Acre-feet.		
					Feet.	
1	100,000	8,260	6,289	518	1.29	201.29
2	110,000	9,090	13,147	1,085	1.28	202.57
3	120,000	9,920	22,759	1,879	1.26	203.83
4	130,000	10,740	34,176	2,822	1.21	205.04
5	140,000	11,570	46,688	3,857	1.15	206.19
6	150,000	12,390	59,856	4,944	1.09	207.28
7	160,000	13,220	73,371	6,060	1.03	208.31
8	170,000	14,040	86,996	7,185	.97	209.28
9	180,000	14,870	100,552	8,297	.91	210.19
10	190,000	15,690	113,506	9,375	.86	211.05
11	200,000	16,520	127,058	10,494	.81	211.86
12	195,000	16,110	138,676	11,455	.62	212.48
13	190,000	15,690	147,681	12,197	.46	212.94
14	185,000	15,290	154,392	12,752	.33	213.27
15	180,000	14,870	159,128	13,144	.22	213.47
16	175,000	14,460	161,896	13,372	.14	213.61
17	170,000	14,040	163,721	13,524	.07	213.68
18	165,000	13,630	164,349	13,576	.00	213.68
19	160,000	13,220	164,000	13,546	−.04	213.64
20	155,000	12,800	162,597	13,430	−.08	213.56
21	150,000	12,390	161,764	13,361	−.13	213.43
22	145,000	11,980	158,353	13,080	−.15	213.28
23	140,000	11,570	155,587	12,851	−.17	213.11
24	135,000	11,150	152,500	12,956	−.19	212.92
25	130,000	10,740	149,136	12,319	−.21	212.71
26	125,000	10,330	145,484	12,016	−.22	212.49
27	120,000	9,920	141,640	11,699	−.24	212.25
28	115,000	9,500	137,602	11,365	−.25	212.00
29	110,000	9,090	133,297	11,101	−.26	211.74
30	105,000	8,680	129,105	10,664	−.27	211.47
31	100,000	8,260	124,739	10,303	−.28	211.19
Capacity			187,975	15,526		215.00

COST.

The following estimate is based upon the data at hand and worked up April 12, 1902, and is subject to modification:

Estimate of the cost of the McDowell reservoir, on Verde River, with capacity of 186,000 acre-feet.

745,875 cubic yards rock fill, at 80 cents a yard	$596,700
78,155 cubic yards dry-laid rubble, at $2 a yard	156,310
7,865 feet, or 117,975 pounds, I beams, at 7 cents a pound	8,258
140,680 square feet quarter-inch plates, or 1,434,936 pounds, at 7 cents a pound	100,445

Excavation, 58,667 cubic yards cemented gravel, at $1 a yard	$58,667
Excavation, 125,000 cubic yards sand, at 20 cents a yard	25,000
5,210 cubic yards of concrete, under steel apron, at $10 a yard	52,100
18,792 cubic yards of concrete in toe wall, at $10 a yard	187,920
Diversion of river	10,000
Outlet, gates, tower, etc	20,000
Concrete core wall to be carried into east abutment	180,000
Engineering and contingencies, 15 per cent	209,331
Right of way	20,000
	1,624,731

Cost per acre-foot capacity, $8.74.

WATER STORAGE ON SALT RIVER.

CHARACTER OF DRAINAGE BASIN.

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:

Area of drainage basin of Salt River.

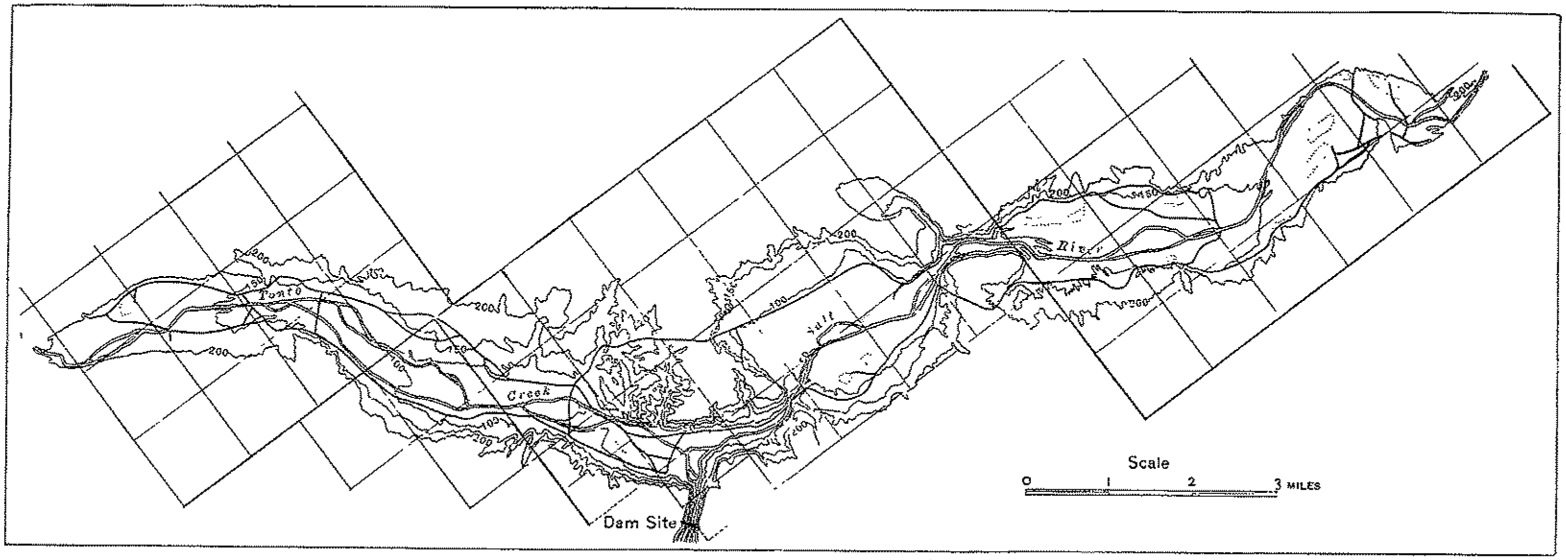
	Square miles.
Salt River at its mouth	12,700
Salt River at Arizona dam	12,260
Verde River near its mouth	6,000
Salt River above mouth of Verde	6,260
Salt River at dam site below Tonto Creek	5,756
Salt River between mouth of Verde and Tonto dam site	504

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 as 11,496 feet.

Rather peculiar conditions exist in Salt River Basin, which favor a large water supply relative to its drainage area. In a previous publication the writer has described these conditions, as follows:[a]

> The southern portion of the Territory may be again 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, Bonito 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.

[a] Irrigation near Phoenix, Ariz.: Water-Supply and Irrigation Paper, U. S. Geol. Survey, No. 2, p. 15.



OUTLINE OF SALT RIVER RESERVOIR SITE.

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 part, precipitation occurs. This influence continues until the wind passes the summit, where the process is reversed.

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 twenty 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 semitropic 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 this stream Salt River 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 reservoir sites 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.

WATER SUPPLY.

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 twenty-six 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.

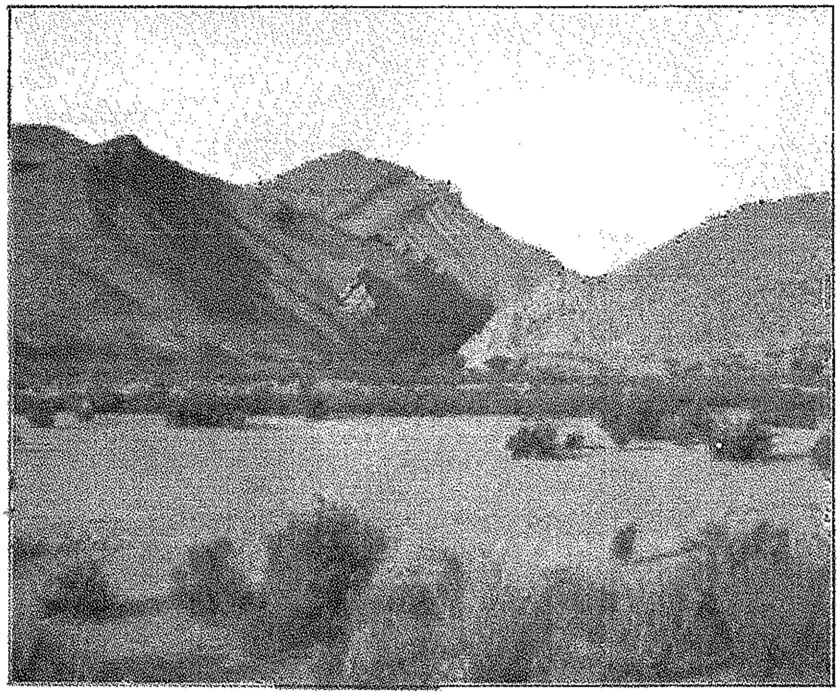
Precipitation, in inches, at Camp Apache.

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
1876	0.92	1.72	2.02	0.08	0.26	1.02	5.20	2.52	2.00	2.44	1.34	0.22	19.74
1877	.36	.94	.72	.96	1.15	.00	3.11	1.20	.99	.81	.19	2.07	12.50
1878	.18	1.35	2.41	1.77	.18	.79	8.76	9.33	.76	.00	1.94	1.14	28.61
1879	1.89	1.17	.03	.12	.00	.05	3.92	3.06	1.52	2.64	1.77	2.41	18.58
1880	1.31	.95	.80	.46	.00	.46	5.83	1.44	.55	.56	.03	2.38	14.77
1881	.20	1.17	2.45	1.53	.35	T.	5.63	8.31	5.41	4.68	.85	.54	31.12
1882	2.82	2.85	1.09	.91	.94	3.27	4.79	7.36	1.02	T.	2.34	.23	27.62
1883	.85	2.46	2.03	.22	.86	.02	5.46	4.26	.60	1.39	.02	3.48	21.65
1884	.68	3.43	4.44	1.67	1.31	2.35	.14	5.59	1.50	2.02	.82	5.52	29.47
1885	.52	1.00	2.05	.52	1.12	.82	2.60	3.16	.44	.38	1.56	1.41	15.58
1886	3.90	2.73	1.06	.91	.00	.19	1.90	4.75	3.16	1.66	.56	.24	21.06
1887	.59	2.16	.04	.81	.15	1.70	3.29	3.92	2.23	.55	1.83	.57	17.84
1888	1.42	1.83	2.92	.71	.71	T.	3.24	[1.00]	.32	1.23	2.63	2.88	18.89
1889	2.24	.88	1.85	.47	.00	.11	2.67	2.87	1.02	.46	.55	3.98	17.10
1890	2.26	2.40	.82	1.39	.00	.00	5.00	4.44	2.37	2.17	2.85	3.02	26.72
1891	1.65	4.10	.85	T.	.36	T.	2.72	1.22	1.81	.00	.00	.65	13.36
1892	.65	2.29	2.22	1.36	.36	.15	1.33	1.30	1.23	.55	.57	.69	12.76
1893	.28	1.10	2.45	.00	2.18	.00	2.57	3.43	2.65	.04	.28	.10	15.08
1894	1.24	.96	1.36	.19	.79	.00	1.27	5.01	1.32	2.47	.00	2.81	17.42
1895	1.89	.72	.02	T.	1.00	.01	.74	5.44	1.68	3.02	2.39	1.12	18.03
1896	.16	.33	.86	.34	.00	.52	4.31	4.36	1.84	2.42	.77	.68	16.09
1897	2.23	1.40	1.79	.24	.34	.37	1.20	2.07	3.41	1.30	.00	.57	14.92
1898	2.76	1.50	1.08	.50	2.70	2.60	4.33	3.59	.12	.00	.57	.80	20.55
1899	1.33	1.04	.17	.45	.00	1.90	4.55	.96	1.52	.82	.71	1.60	15.05
1900	.30	.29	1.15	1.75	.10	.00	.82	1.31	2.79	.77	4.86	T.	14.14
1901	2.87	2.60	1.20	.20	1.15	.00	3.38	1.45	.45	1.22	.65	1.80	16.97

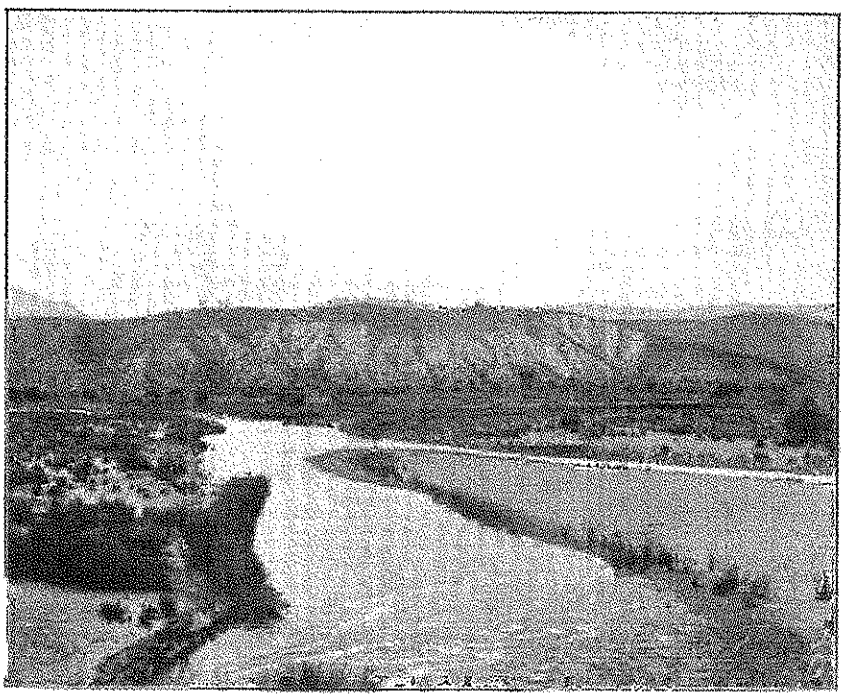
Measurements of the flow near the dam site below Tonto Creek were begun in February, 1901, and are still continued. Besides these there are records of flow of Salt River above the mouth of the Verde from April, 1897, to November 30, 1899, and of Salt River below the Verde for several previous years and for 1900. The measurements below the Verde are made in the various irrigation canals. 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:

Proportion of total flow of Salt and Verde rivers discharged by Salt River.

Month.	1897.	1898.	1899.	1901.	Mean.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	
January		0.587	0.520	0.615	0.574
February		.555	.541	.539	.545
March		.531	.660	.631	.607
April		.720	.740	.855	.772
May	0.813	.719	.862	.836	.808
June	.720	.647	.590	.728	.672
July	.575	.573	.564	.567	.570
August	.495	.503	.619	.425	.510
September	.419	.516	.469	.657	.515
October	.654	.494	.328		.492
November	.523	.522	.461		.502
December	.515	.504			



A. GORGE OF SALT RIVER LOOKING DOWNSTREAM.



B. SALT RIVER RESERVOIR SITE, LOOKING UPSTREAM.

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 this period direct observations were made by the Hudson Reservoir Company, and from April 20, 1897, to November 30, 1899, 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.

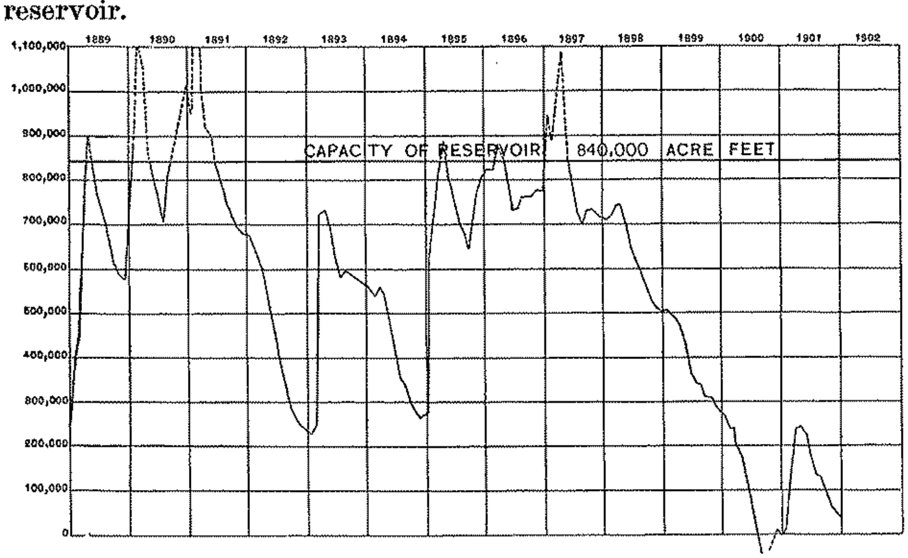


FIG. 2.—Fluctuations of Salt River reservoir, operated in connection with Verde River, under a duty of 660,000 acre-feet per annum.

The drainage area between the reservoir and the mouth of the Verde is nearly 10 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 the tables of discharges for the Verde, at McDowell, and Salt River at the reservoir site, were obtained. In reducing the discharge of Arizona dam to the required amounts, the following percentages were used:

Estimated monthly discharge at McDowell and Salt River reservoir sites, in percentage of total at Arizona dam.

Month.	Verde at McDowell.	Salt at reservoir site.	Month.	Verde at McDowell.	Salt at reservoir site.
January	0.42	0.52	August	0.49	0.46
February	.45	.50	September	.48	.46
March	.39	.56	October	.50	.44
April	.20	.72	November	.50	.45
May	.19	.76	December	.50	.45
June	.30	.63			
July	.42	.52	Mean	.40	.54

Estimated monthly discharge of Salt River at reservoir site.

[Drainage area, 5,756 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	Depth in inches.
1888.[a]						
August			161	9,902	.03	.03
September			161	9,580	.03	.03
October	154	132	146	8,957	.02	.02
November	2,592	191	379	22,545	.06	.07
December	19,570	249	3,014	185,367	.52	.58
The year				236,351		
1889.[a]						
January	12,976	866	2,092	190,185	.54	.62
February	1,970	767	1,303	72,289	.23	.24
March	18,925	1,995	4,897	301,178	.85	.98
April	4,002	1,797	2,862	170,289	.50	.56
May	1,356	473	790	48,562	.14	.16
June	387	224	296	17,618	.05	.06
July	682	174	257	15,871	.04	.05
August	347	179	192	11,797	.03	.03
September	539	179	240	14,260	.04	.04
October	310	140	194	11,906	.03	.03
November	283	239	259	15,422	.04	.04
December	11,417	251	2,561	157,360	.44	.51
The year	18,925	174	1,420	1,026,737	.24	3.32
1890.[a]						
January	8,190	716	2,591	159,324	.45	.52
February	71,644	523	5,049	280,192	.88	.92
March	9,648	1,437	3,596	221,139	.62	.71
April	1,495	986	1,325	78,826	.23	.26
May	1,040	479	695	42,720	.12	.13
June	423	250	322	19,155	.06	.07
July	453	206	272	16,758	.05	.08
August	3,538	512	1,787	109,906	.31	.36
September	1,695	334	1,076	64,018	.20	.22
October	3,285	331	1,218	70,502	.21	.24
November	13,727	345	2,123	126,297	.37	.41
December	13,665	500	2,817	173,218	.49	.56
The year	71,644	206	1,906	1,362,055	.33	4.46
1891.[a]						
January	8,906	551	1,777	109,254	.31	.36
February	150,000	413	19,408	1,077,834	3.37	3.47
March	4,968	753	2,768	170,204	.48	.55
April	2,182	1,654	1,922	114,390	.33	.37
May	2,243	1,461	1,834	112,761	.32	.37
June	1,132	587	842	50,083	.15	.17
July	502	312	388	23,884	.07	.08
August	346	236	261	16,066	.04	.05

[a] Obtained by taking proportional part of the discharge of Salt River at Arizona dam.

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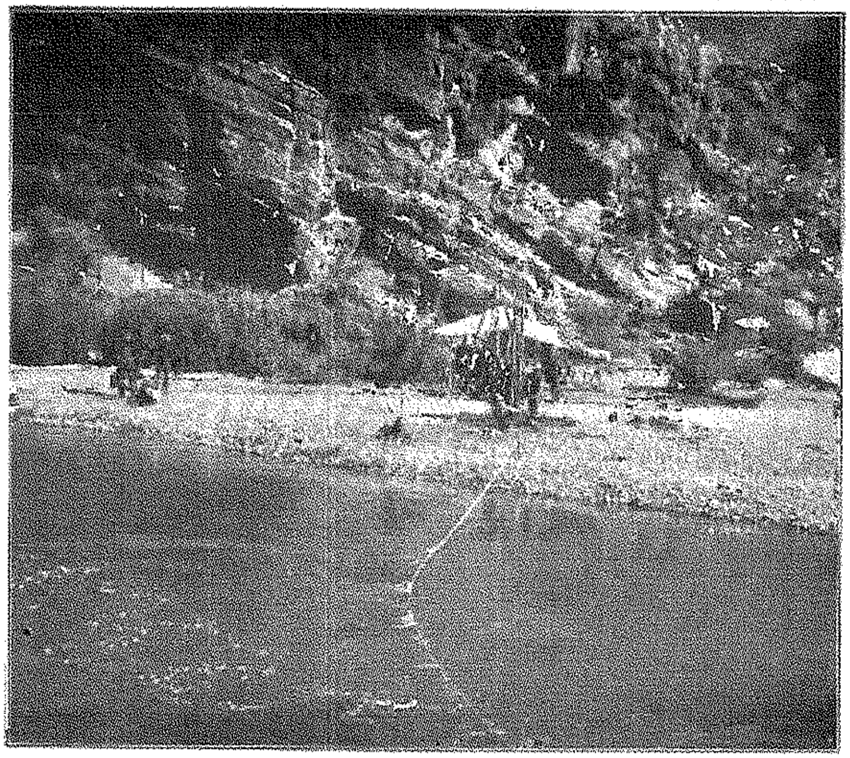
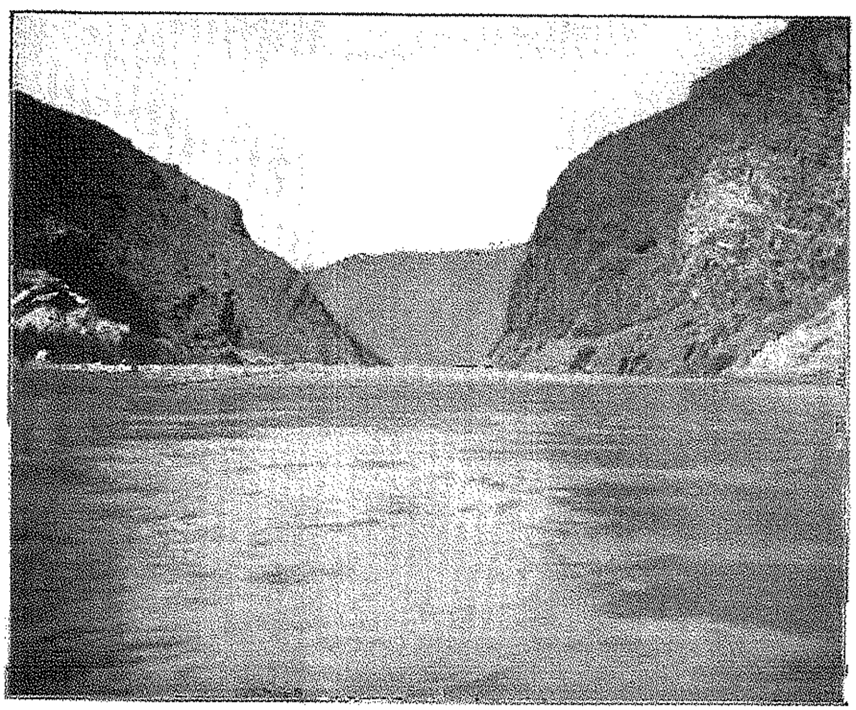


A. DRILLING PARTY ON SALT RIVER, LINE A OF BORINGS.



B. SALT RIVER DAM SITE, LOOKING DOWNSTREAM.

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Estimated monthly discharge of Salt River at reservoir site—Continued.

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	Depth in inches.
1891.[a]						
September	605	220	378	22,500	.07	.08
October	273	203	227	13,933	.04	.05
November	283	207	230	13,710	.04	.04
December	311	264	295	14,151	.05	.06
The year	150,000	203	2,529	1,738,770	.44	5.65
1892.						
January	445	318	352	21,614	.06	.07
February[b]	234	204	221	12,274	.04	.04
March[b]	268	206	230	14,118	.04	.04
April[b]	450	268	315	18,765	.05	.06
May[b]	760	185	365	22,431	.06	.07
June[b]	157	76	110	6,523	.02	.02
July	267	168	189	11,606	.03	.03
August	259	152	186	11,427	.03	.03
September	180	150	157	9,361	.03	.03
October	770	144	196	12,066	.03	.03
November	392	203	231	13,736	.04	.04
December	266	236	253	14,578	.04	.05
The year	770	76	234	168,499	.04	.51
1893.						
January	286	286	286	17,585	.05	.06
February	5,312	275	747	41,459	.13	.13
March	207,208	331	7,734	475,523	1.34	1.54
April	1,782	508	1,043	62,079	.18	.20
May	1,520	257	602	37,010	.14	.16
June	222	93	143	8,509	.02	.02
July	592	145	279	17,138	.05	.06
August	1,164	219	753	46,301	.13	.15
September	1,116	272	508	30,218	.09	.10
October	655	242	331	20,345	.05	.06
November	305	252	266	15,852	.04	.04
December	293	281	283	17,404	.05	.06
The year	207,208	93	1,081	789,423	.18	2.58
1894.						
January	327	286	303	18,609	.05	.06
February	316	263	288	15,995	.05	.05
March	1,430	294	760	46,761	.13	.15
April	968	342	610	36,673	.10	.11
May	356	241	271	16,636	.05	.06
June	280	139	166	9,897	.03	.03
July	276	82	148	9,081	.02	.02
August	866	131	412	25,343	.07	.08
September	685	133	280	16,642	.05	.06
October	628	107	213	13,094	.04	.05
November	272	186	207	12,290	.03	.03
December	738	209	397	24,432	.07	.08
The year	1,430	82	338	245,453	.06	.78
1895.						
January[c]	46,806	744	5,390	331,358	.93	1.07
February[c]	3,697	368	1,373	76,239	.24	.25
March[c]	3,173	1,253	1,738	106,838	.30	.35
April[c]	2,704	961	1,711	105,144	.30	.33
May[c]	940	480	673	41,356	.12	.14
June[c]	475	193	309	18,372	.05	.06
July[d]	353	120	160	9,816	.03	.03
August[d]	1,022	209	440	27,168	.08	.09
September[d]	499	166	242	14,425	.04	.04
October[d]	7,194	279	857	52,675	.15	.17
November[d]	3,994	309	764	45,467	.13	.15
December[d]	995	430	603	37,104	.10	.12
The year	46,806	120	1,188	865,962	.20	2.80

[a] Obtained by taking proportional part of the discharge of Salt River at Arizona dam.
[b] Approximate; filled in from minimum discharge recorded in same months for 1900.
[c] Results obtained by taking from the published discharge of Salt River at McDowell (Eighteenth Ann. Rept., Pt. IV, p. 298) that percentage of the whole that represents the discharge of the Salt between the mouth of the Verde and the reservoir site.
[d] Results obtained by taking proportional part of the discharge of Salt River at Arizona dam. Mr. Trott's figures used in computation.

Estimated monthly discharge of Salt River at reservoir site—Continued.

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	Depth in inches.
1896.[a]						
January	547	416	447	27,497	.08	.09
February	479	339	393	22,572	.07	.07
March	1,769	428	844	51,925	.15	.17
April	1,487	636	941	55,986	.16	.18
May	669	352	485	29,861	.08	.09
June	292	150	204	12,245	.03	.03
July	5,528	111	779	47,928	.13	.15
August	4,997	256	797	49,017	.14	.16
September	4,280	241	534	31,752	.09	.10
October	555	265	398	24,484	.07	.08
November	672	300	443	26,375	.08	.09
December	400	293	317	19,479	.05	.05
The year	5,528	111	548	399,121	.08	1.26
1897.						
January[a]	19,422	312	2,647	162,777	.46	.53
February[a]	2,494	543	970	53,871	.17	.18
March[a]	5,762	1,013	2,160	132,808	.38	.44
April	9,743	1,136	4,281	254,787	.74	.83
May[b]	1,910	608	1,114	68,461	.19	.22
June[b]	591	180	358	21,305	.06	.07
July[b]	285	78	175	10,173	.03	.03
August[b]	755	157	410	25,176	.07	.08
September[b]	1,269	398	673	40,049	.11	.12
October[b]	1,010	228	549	33,755	.09	.10
November[b]	290	257	273	16,225	.05	.06
December[b]	292	251	270	16,590	.05	.06
The year	19,422	78	1,157	835,977	.20	2.72
1898.[c]						
January	1,077	240	338	20,808	.06	.07
February	743	473	587	32,511	.10	.10
March	858	509	688	42,261	.12	.14
April	1,036	496	757	45,000	.13	.14
May	704	261	448	27,513	.08	.09
June	351	182	237	14,112	.04	.04
July	800	166	408	25,085	.07	.08
August	1,211	130	385	23,658	.06	.07
September	868	106	338	20,136	.06	.07
October	180	106	156	9,538	.03	.03
November	232	182	202	12,041	.03	.03
December	402	232	300	18,401	.05	.06
The year	1,211	106	404	291,064	.07	.92
1899.[c]						
January	762	249	356	21,906	.06	.07
February	461	332	386	21,421	.06	.06
March	617	404	480	29,499	.08	.09
April	575	437	536	32,025	.09	.10
May	475	204	308	18,926	.05	.06
June	493	161	204	12,119	.03	.03
July	1,410	155	444	27,282	.08	.09
August	3,325	166	671	41,240	.11	.13
September	1,228	165	298	17,675	.05	.06
October	738	158	253	15,548	.04	.05
November	215	157	203	12,040	.03	.03
December[d]	203	142	195	12,009	.03	.03
The year	3,325	142	361	261,690	.06	.80
1900.[e]						
January	242	222	234	14,388	.04	.05
February	234	204	221	12,274	.04	.04
March	268	206	230	14,118	.04	.05
April	450	268	315	18,765	.05	.06
May	760	185	365	22,431	.06	.07

[a] Mr. Trotts's figures used in these computations. Results obtained by taking proportional parts of the discharge of Salt River at Arizona dam.

[b] Results obtained by taking from the discharge registered at McDowell that percentage which represents the discharge of the river between McDowell and the reservoir site.

[c] Results obtained by taking from the discharge registered at McDowell that part of percentage that represents the discharge of the river between McDowell and reservoir site.

[d] Trott's figures.

[e] Computations made from Mr. F. P. Trott's figures.

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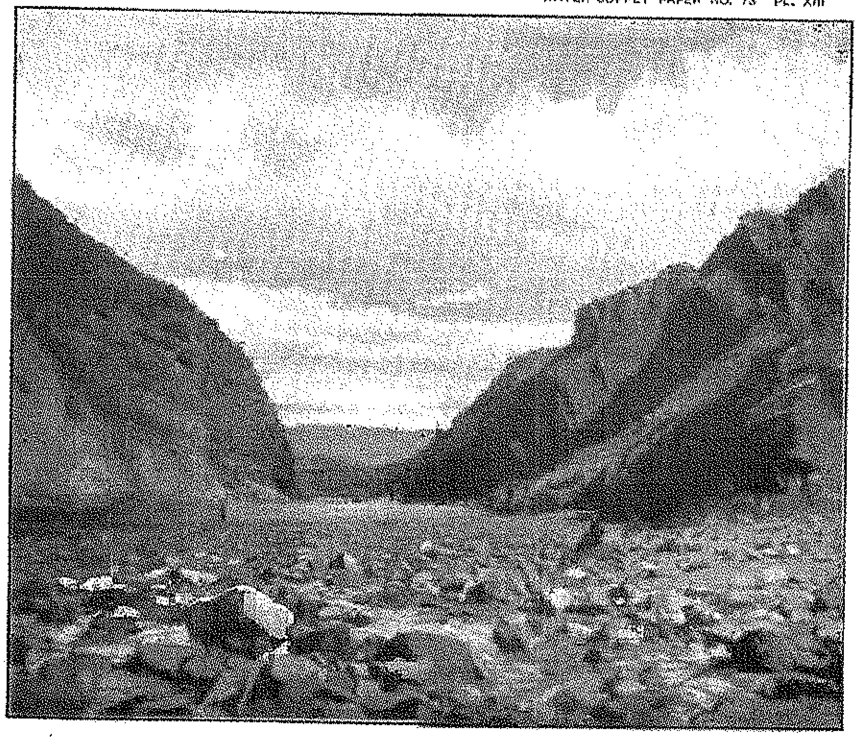
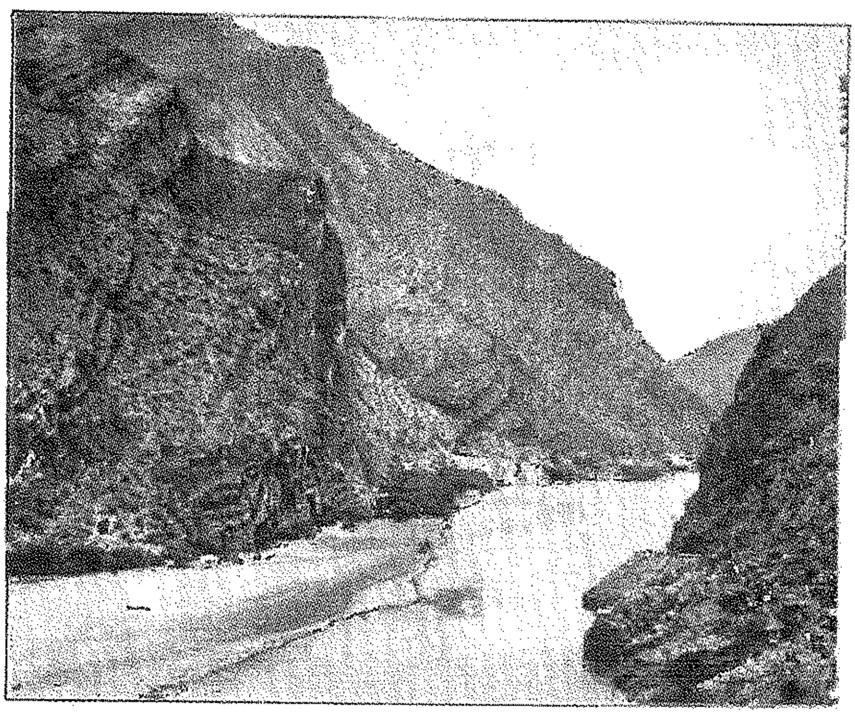


A. SALT RIVER DAM SITE, LOOKING UPSTREAM.



B. SOUTH ABUTMENT OF SALT RIVER DAM, LOOKING DOWNSTREAM.

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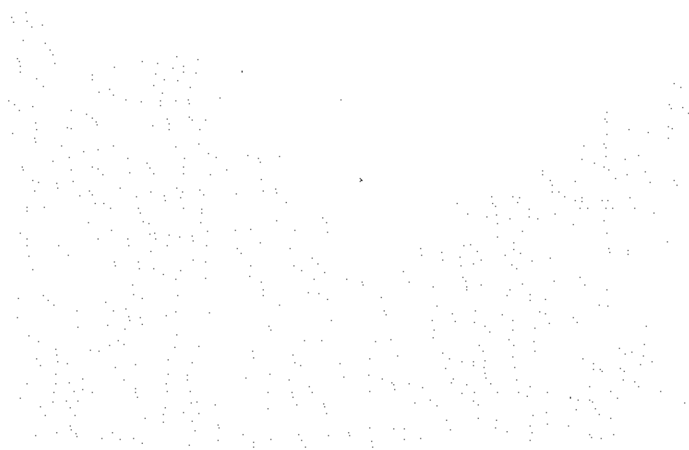


Estimated monthly discharge of Salt River at reservoir site—Continued.

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	Depth in inches.
1900.[a]						
June	157	76	110	6,523	.02	.02
July	130	45	64	3,933	.01	.01
August	521	63	142	8,711	.02	.02
September	290	88	116	6,898	.02	.02
October	359	95	161	9,902	.03	.03
November	2,222	146	387	23,055	.06	.07
December	245	184	202	12,396	.03	.03
The year	2,222	45	212	153,394	.035	.47
1901.						
January[a]	1,735	201	454	27,945	.08	.09
February[b]	4,172	928	2,414	134,047	.42	.44
March[b]	3,468	740	1,423	87,472	.25	.29
April[b]	1,562	620	1,050	62,442	.18	.20
May[b]	1,267	462	735	45,203	.13	.15
June[b]	508	147	288	17,262	.05	.06
July[b]	3,556	71	346	21,296	.06	.07
August[b]	2,221	207	529	32,504	.09	.10
September[b]	670	123	309	17,907	.05	.06
October[b]	215	117	152	9,334	.03	.03
November[b]	215	183	189	10,629	.03	.03
December[b]	195	183	190	11,663	.03	.03
The year	4,172	71	672	477,704	.11	1.55
1902.						
January	238	170	186	11,423	.03	.03
February	220	184	194	10,852	.03	.03

[a] Computations made from Mr. F. P. Trott's figures.
[b] Computations made from observations by United States Geological Survey.

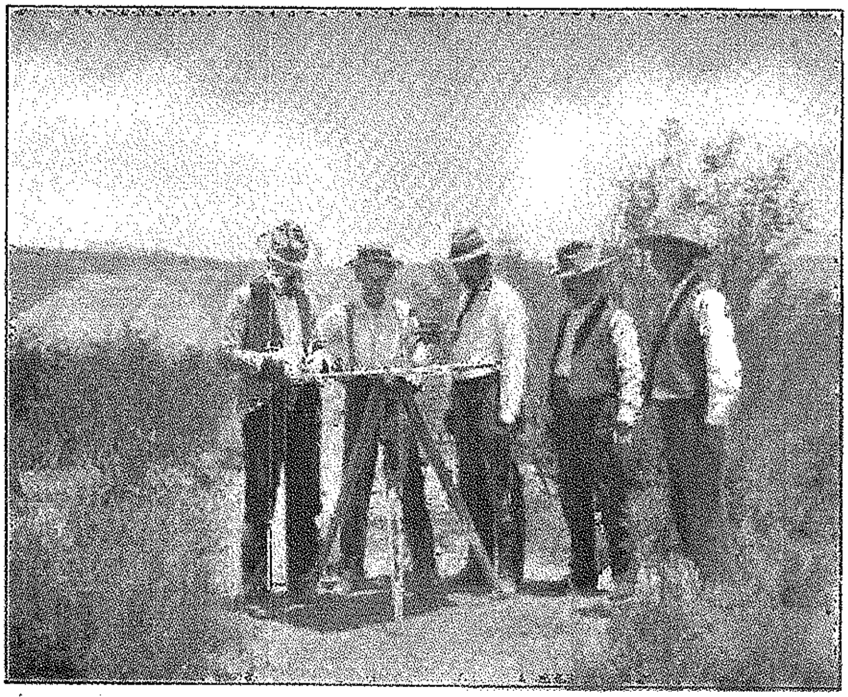
History of Salt River Reservoir, operated from 1889 to 1901, in connection with the unregulated Verde River, with annual use of 660,000 acre-feet.

[Capacity of reservoir, 840,745 acre-feet. Annual use, 660,000 acre-feet.]

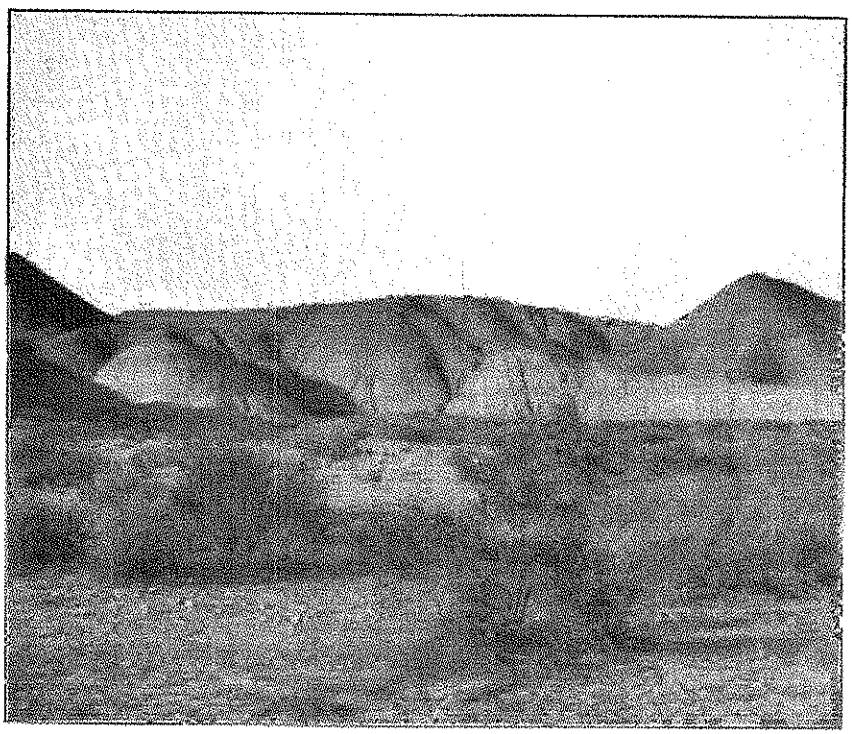
Month.	Per cent annual.	Water required for irrigation and other use.	Furnished by Verde.	Required from reservoir.	Depth of evaporation.	Area exposed to evaporation.	Loss by evaporation.	Total evaporation and use.	Inflow.	Balance in reservoir.	Overflow.
1889.		*Acre-ft.*	*Acre-ft.*	*Acre-ft.*	*Feet.*	*Acre-ft.*	*Acre-ft.*	*Acre-ft.*	*Acre-ft.*	*Acre-ft.*	*Acre-ft.*
January	6	39,600	153,611	0	0.25	6,874	1,718	1,718	190,185	{200,000 {388,467	--------
February	7	46,200	65,059	0	.34	8,676	2,950	2,950	72,289	457,806	--------
March	8	52,800	209,747	0	.50	10,895	5,448	5,448	301,178	753,536	--------
April	9	59,400	47,302	12,098	.58	12,361	7,169	19,267	170,289	840,745	63,813
May	11	72,600	12,141	60,459	.83	13,398	11,120	75,330	48,562	813,977	--------
June	11	72,600	8,390	64,210	.92	12,950	11,914	76,124	17,618	755,471	--------
July	10	66,000	12,819	53,181	1.00	12,403	12,403	65,584	15,871	705,758	--------
August	10	66,000	12,556	53,444	1.08	11,821	12,767	66,210	11,797	651,345	--------
September	9	59,400	14,880	44,520	.83	11,231	9,332	53,841	14,260	611,764	--------
October	7	46,200	13,530	32,670	.50	10,796	5,398	38,068	11,906	585,602	--------
November	6	39,600	17,136	22,464	.42	10,596	4,450	26,914	15,422	574,110	--------
December	6	39,600	174,845	0	.33	11,433	3,773	3,773	157,360	727,697	--------
1890.											
January	6	39,600	128,685	0	.25	13,233	3,308	3,308	159,324	840,745	42,968
February	7	46,200	252,172	0	.34	13,459	4,576	4,576	280,192	840,745	275,616
March	8	52.800	153,967	0	.50	13,459	6,729	6,729	221,139	840,745	214,410
April	9	59,400	21,896	37,504	.58	13,459	7,806	45,310	78,826	840,745	33,516
May	11	72,600	10,680	61,920	.83	13,362	10,190	72,110	42,720	811,355	--------
June	11	72,600	9,121	63,479	.92	12,935	11,900	75,379	19,155	755,131	--------
July	10	66,000	13,535	52,465	1.00	12,408	12,408	64,873	16,758	707,016	--------
August	10	66,000	117,074	0	1.08	12,659	13,671	13,671	109,906	803,251	--------
September	9	59,400	66,802	0	.83	13,404	11,125	11,125	64,018	840,745	15,399
October	7	46,200	80,116	0	.50	13,459	6,729	6,729	70,502	840,745	63,773
November	6	39,600	140,331	0	.42	13,459	5,652	5,652	126,297	840,745	120,645
December	6	39,600	192,464	0	.33	13,459	4,440	4,440	173,218	840,745	168,778

History of Salt River Reservoir, operated from 1889 to 1901, etc.—Continued.

Month.	Per cent annual.	Water required for irrigation and other use.	Furnished by Verde.	Required from reservoir.	Depth of evaporation.	Area exposed to evaporation.	Loss by evaporation.	Total evaporation and use.	Inflow.	Balance in reservoir.	Overflow.
1891.		*Acre-ft.*	*Acre-ft.*	*Acre-ft*	*Feet.*	*Acre-ft.*	*Acre-ft.*	*Acre-ft.*	*Acre-ft.*	*Acre-ft.*	*Acre-ft.*
January	6	39,600	88,244	0	.25	13,459	3,365	3,365	109,204	840,745	105,839
February	7	46,200	970,051	0	.34	13,459	4,576	4,576	1,077,834	840,745	1,073,258
March	8	52,800	118,535	0	.50	13,459	6,730	6,730	170,204	840,745	163,474
April	9	59,400	31,775	27,625	.58	13,459	7,806	35,431	114,390	840,745	78,959
May	11	72,600	28,190	44,410	.83	13,459	11,170	55,580	112,761	840,745	57,161
June	11	72,600	23,849	48,751	.92	13,459	12,382	61,133	50,083	829,695	--------
July	10	66,000	19,291	46,709	1.00	13,231	13,231	59,940	23,884	793,639	--------
August	10	66,000	17,113	48,887	1.08	12,814	13,839	62,726	16,066	746,977	--------
September	9	59,400	23,478	35,922	.83	12,438	10,323	46,245	22,500	719,232	--------
October	7	46,200	15,833	30,367	.50	12,138	6,069	36,436	13,933	696,729	--------
November	6	39,600	15,233	24,367	.42	11,840	4,973	29,340	13,710	681,099	--------
December	6	39,600	20,168	19,432	.33	11,744	3,875	23,307	14,151	674,943	--------
1892.											
January	6	39,600	17,458	22,142	.25	11,698	2,925	25,067	21,614	671,490	--------
February	7	46,200	11,746	34,454	.34	11,525	3,918	38,372	12,274	645,392	--------
March	8	52,800	7,087	45,713	.50	11,151	5,575	51,288	14,118	608,222	--------
April	9	59,400	4,604	54,796	.58	10,684	6,197	60,992	18,765	565,995	--------
May	11	72,600	5,935	66,665	.83	10,183	8,452	58,213	22,431	507,782	--------
June	11	72,600	3,588	69,012	.92	9,282	8,549	77,561	6,523	436,744	--------
July	10	66,000	9,374	56,626	1.00	8,518	8,518	65,144	11,606	383,206	--------
August	10	66,000	12,172	53,828	1.08	7,792	8,415	62,243	11,427	332,210	--------
September	9	59,400	9,768	49,632	.83	7,098	5,891	55,523	9,361	286,048	--------
October	7	46,200	13,712	32,488	.50	6,621	3,310	35,798	12,066	262,316	--------
November	6	39,600	15,263	24,337	.42	6,300	2,646	26,983	13,736	249,069	--------
December	6	39,600	17,309	22,291	.33	6,202	2,046	24,337	14,578	239,310	--------
1893.											
January	6	39,600	14,204	25,396	.25	6,061	1,515	26,911	17,585	229,984	--------
February	7	46,200	25,502	20,698	.34	6,133	2,085	22,783	41,459	248,660	--------
March	8	52,800	331,168	0	.50	9,533	4,767	4,767	475,523	719,416	--------
April	9	59,400	17,244	42,156	.58	12,328	7,150	49,306	62,079	732,189	--------
May	11	72,600	9,252	63,348	.83	12,223	10,145	73,493	37,010	695,706	--------
June	11	72,600	4,052	68,548	.92	11,589	10,662	79,210	8,509	625,005	--------
July	10	66,000	13,842	52,158	1.00	10,825	10,825	62,983	17,138	579,160	--------
August	10	66,000	49,321	16,679	1.08	10,297	11,120	27,800	46,301	597,661	--------
September	9	59,400	31,532	27,868	.83	12,168	10,099	37,967	30,218	589,912	--------
October	7	46,200	23,120	23,080	.50	10,666	5,333	28,413	20,345	581,844	--------
November	6	39,600	17,613	21,987	.42	10,561	4,435	26,422	15,852	571,274	--------
December	6	39,600	19,388	20,212	.33	10,464	3,453	23,665	17,404	565,013	--------
1894.											
January	6	39,600	15,030	24,570	.25	10,347	2,587	27,157	18,609	556,465	--------
February	7	46,200	14,395	31,805	.34	10,234	3,480	35,285	15,995	537,175	--------
March	8	52,800	32,565	20,235	.50	10,254	5,127	25,362	46,761	558,574	--------
April	9	59,400	10,187	49,213	.58	10,279	6,162	55,375	36,673	539,872	--------
May	11	72,600	4,159	68,441	.83	9,860	8,184	76,625	16,636	479,883	--------
June	11	72,600	4,713	67,887	.92	9,040	8,317	76,204	9,897	413,579	--------
July	10	66,000	7,334	58,666	1.00	8,173	8,173	66,839	9,081	355,821	--------
August	10	66,000	26,966	39,034	1.08	7,510	8,111	47,145	25,343	334,019	--------
September	9	59,400	17,365	42,035	.83	7,052	5,853	47,888	16,642	302,773	--------
October	7	46,200	14,880	31,320	.50	6,855	3,427	34,747	13,094	281,120	--------
November	6	39,600	13,656	25,944	.42	6,601	2,772	28,716	12,290	264,694	--------
December	6	39,600	27,147	12,453	.33	6,554	2,162	14,615	24,432	274,511	--------
1895.											
January	6	39,600	248,225	0	.25	9,039	2,260	2,260	352,508	624,759	--------
February	7	46,200	93,747	0	.34	11,579	3,937	3,937	80,251	701,073	--------
March	8	52,800	228,734	0	.50	12,611	6,305	6,305	112,461	807,229	--------
April	9	59,400	30,591	28,809	.58	13,459	7,806	36,615	110,678	840,745	40,547
May	11	72,600	15,864	56,736	.83	13,392	11,115	67,851	43,533	816,427	--------
June	11	72,600	9,104	63,496	.92	12,987	11,948	75,444	19,339	760,422	--------
July	10	66,000	8,916	57,084	1.00	12,417	12,417	69,501	12,543	703,464	--------
August	10	66,000	22,074	43,926	1.08	11,828	12,774	56,700	35,909	682,673	--------
September	9	59,400	10,473	48,927	.83	11,617	9,642	58,569	19,577	643,681	--------
October	7	46,200	20,630	25,570	.50	11,772	5,886	31,456	99,856	712,081	--------
November	6	39,600	27,550	12,050	.42	12,607	5,253	17,303	81,878	776,656	--------
December	6	39,600	24,042	15,558	.33	13,006	4,292	19,850	54,601	811,407	--------
1896.											
January	6	39,600	25,382	14,218	.25	13,235	3,309	17,527	28,900	822,780	--------
February	7	46,200	22,577	23,623	.34	13,296	4,520	28,143	27,380	822,017	--------
March	8	52,800	40,798	12,002	.50	13,459	6,780	18,782	72,863	840,745	35,353
April	9	59,400	21,776	37,624	.58	13,459	7,806	45,430	57,061	840,745	11,631
May	11	72,600	9,430	63,170	.83	13,277	11,020	74,190	27,424	793,979	--------
June	11	72,600	7,133	65,467	.92	12,719	11,701	77,168	13,328	730,139	--------
July	10	66,000	44,241	21,759	1.00	12,425	12,425	34,184	39,292	735,247	--------



A. MARICOPA COUNTY WATER-STORAGE COMMISSIONERS INSPECTING PLANE-TABLE WORK.



B. CLAY HILLS, NORTH EDGE OF RESERVOIR SITE.

History of Salt River Reservoir, operated from 1889 to 1901, etc.—Continued.

Month.	Per cent annual.	Water required for irrigation and other use.	Furnished by Verde.	Required from reservoir.	Depth of evaporation.	Area exposed to evaporation.	Loss by evaporation.	Total evaporation and use.	Inflow.	Balance in reservoir.	Overflow.
		Acre-ft.	*Acre-ft.*	*Acre-ft.*	*Feet.*	*Acre-ft.*	*Acre-ft.*	*Acre-ft.*	*Acre-ft.*	*Acre-ft.*	*Acre-ft.*
1896.											
August	10	66,000	57,541	8,459	1.08	12,593	13,600	22,059	49,017	762,205	....
September	9	59,400	37,273	22,127	.83	12,710	10,549	32,676	31,752	761,281	....
October	7	46,200	31,161	15,039	.50	12,700	6,350	21,389	24,484	764,376	....
November	6	39,600	32,226	7,374	.42	12,780	5,367	12,741	26,375	778,010	....
December	6	39,600	23,808	15,792	.33	12,840	4,237	20,029	19,479	777,460	....
1897.											
January	6	39,600	150,258	0	.25	13,459	3,365	3,365	162,777	840,745	96,127
February	7	46,200	53,871	0	.34	13,459	4,576	4,576	53,871	840,745	49,295
March	8	52,800	104,350	0	.50	13,459	6,730	6,730	132,808	840,745	126,078
April	9	59,400	99,084	0	.58	13,459	7,806	7,806	254,787	840,745	246,981
May	11	72,600	20,143	52,457	.83	13,459	11,170	63,627	68,461	840,745	5,034
June	11	72,600	10,524	62,076	.92	13,248	12,188	74,264	21,305	787,786	....
July	10	66,000	8,643	57,357	1.00	12,681	12,681	70,038	10,173	727,921	523,515
August	10	66,000	28,318	37,682	1.08	12,249	13,229	50,910	25,176	702,187	....
September	9	59,400	61,584	0	.83	12,225	10,171	10,171	40,049	732,065	....
October	7	46,200	21,154	25,046	.50	12,400	6,200	31,246	33,755	734,574	....
November	6	39,600	16,443	23,157	.42	12,345	5,185	28,342	16,225	722,457	....
December	6	39,600	17,290	22,310	.33	12,228	4,035	26,345	16,590	712,702	....
1898.											
January	6	39,600	16,884	22,716	.25	12,156	3,039	25,755	20,808	707,755	....
February	7	46,200	29,357	16,843	.34	12,190	4,145	20,628	32,511	719,638	....
March	8	52,800	41,547	11,253	.50	12,387	6,198	17,451	42,261	744,448	....
April	9	59,400	22,894	36,506	.58	12,524	7,364	43,870	45,000	745,578	....
May	11	72,600	12,762	59,838	.83	12,328	10,231	70,069	27,513	703,022	....
June	11	72,600	9,333	63,267	.92	11,744	10,804	74,071	14,112	643,162	....
July	10	66,000	21,462	44,538	1.00	11,153	11,153	55,688	25,085	612,560	....
August	10	66,000	25,840	40,160	1.08	10,845	11,713	51,873	23,658	584,345	....
September	9	59,400	21,397	38,003	.83	10,528	8,738	46,741	26,136	557,740	....
October	7	46,200	10,999	35,201	.50	10,194	5,097	40,298	9,538	526,980	....
November	6	39,600	12,236	27,364	.42	9,928	4,170	31,534	12,041	507,487	....
December	6	39,600	19,399	20,201	.83	9,780	3,227	23,428	18,401	502,460	....
1899.											
January	6	39,600	22,919	16,681	.25	9,763	2,441	19,122	21,906	505,244	....
February	7	46,200	20,232	25,968	.34	9,741	3,312	29,279	21,421	497,386	....
March	8	52,800	17,539	35,261	.50	9,645	4,823	40,084	29,499	486,801	....
April	9	59,400	14,983	44,417	.58	9,341	5,418	49,835	32,025	468,991	....
May	11	72,600	10,342	62,258	.83	8,990	7,462	69,720	18,726	418,197	....
June	11	72,600	9,967	62,633	.92	7,873	7,243	69,876	12,119	360,440	....
July	10	66,000	24,183	41,817	1.00	7,667	7,667	49,484	27,282	338,238	....
August	10	66,000	28,856	37,144	1.08	7,481	8,079	45,223	41,240	334,255	....
September	9	59,400	22,371	37,029	.83	7,259	6,025	43,054	17,675	308,876	....
October	7	46,200	34,749	11,451	.50	7,082	3,541	14,992	15,548	309,432	....
November	6	39,600	13,874	25,726	.42	6,973	2,929	28,755	12,040	292,817	....
December	6	39,600	14,677	24,923	.33	6,602	2,178	27,101	12,009	277,765	....
1900.											
January	6	39,600	13,281	26,319	.25	6,568	1,642	27,961	14,388	264,192	....
February	7	46,200	12,273	32,927	.34	6,320	2,149	36,076	12,274	240,390	....
March	8	52,800	11,092	41,708	.50	5,935	2,967	44,675	14,118	209,833	....
April	9	59,400	7,298	52,102	.58	5,404	3,134	55,236	18,765	173,362	....
May	11	72,600	7,083	65,517	.83	4,450	3,693	69,210	22,431	126,583	....
June	11	72,600	3,840	68,760	.92	3,477	3,199	71,959	6,523	61,147	....
July	10	66,000	3,630	62,370	1.00	1,440	1,440	63,810	3,933	1,270	....
August	10	66,000	10,226	55,774	1.08	0	0	0	8,711	....	−45,793
September	9	59,400	8,097	51,303	.83	0	0	0	6,898	....	−44,405
October	7	46,200	12,602	33,598	.50	0	0	0	9,902	....	−23,696
November	6	39,600	28,178	11,422	.42	401	168	11,590	23,055	11,465	....
December	6	39,600	15,150	24,450	.33	382	126	24,576	12,396	....	− 715
1901.											
January	6	39,600	28,704	10,896	.25	549	137	11,033	27,945	16,912	....
February	7	46,200	103,249	0	.34	3,112	1,058	1,058	134,047	149,901	....
March	8	52,800	63,688	0	.50	5,417	2,709	2,709	87,472	234,664	....
April	9	59,400	10,938	48,462	.58	6,151	3,568	52,030	62,442	245,076	....
May	11	72,600	8,606	63,994	.83	6,065	5,034	69,028	45,203	221,251	....
June	11	72,600	6,222	66,378	.92	5,465	5,027	71,405	17,262	167,108	....
July	10	66,000	12,916	53,084	1.00	4,436	4,436	57,520	21,296	131,884	....
August	10	66,000	38,561	27,439	1.08	4,130	4,460	31,899	32,504	132,489	....
September	9	59,400	5,514	53,886	.83	3,780	3,137	57,023	17,907	93,373	....
October	7	46,200	8,210	37,990	.50	3,004	1,502	39,492	9,334	63,215	....
November	6	39,600	15,238	24,362	.42	2,290	962	25,363	10,629	48,481	....
December	6	39,600	16,485	23,115	.33	1,761	581	23,696	11,663	36,346	....

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 ten 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 around; 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.

SALT RIVER RESERVOIR.

BORINGS.

Borings were made to bed rock at 31 points in the canyon, on four different lines. The first trial was made near the upper end of the canyon near the site selected by the Hudson Reservoir Company. Five holes were here drilled to rock, the depth in two of them being 44 and 64.5 feet. These results are shown in fig. 3. Another site was then selected about 1,600 feet downstream, and conditions were so much more favorable that a more thorough exploration was made, and the greatest depth being less than half that found above, the lower site was decided upon. Fig. 4 shows profiles of these borings. Following is a complete list of the borings.

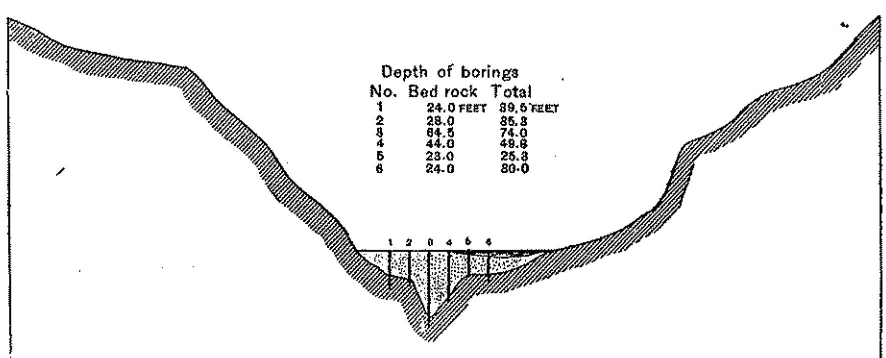
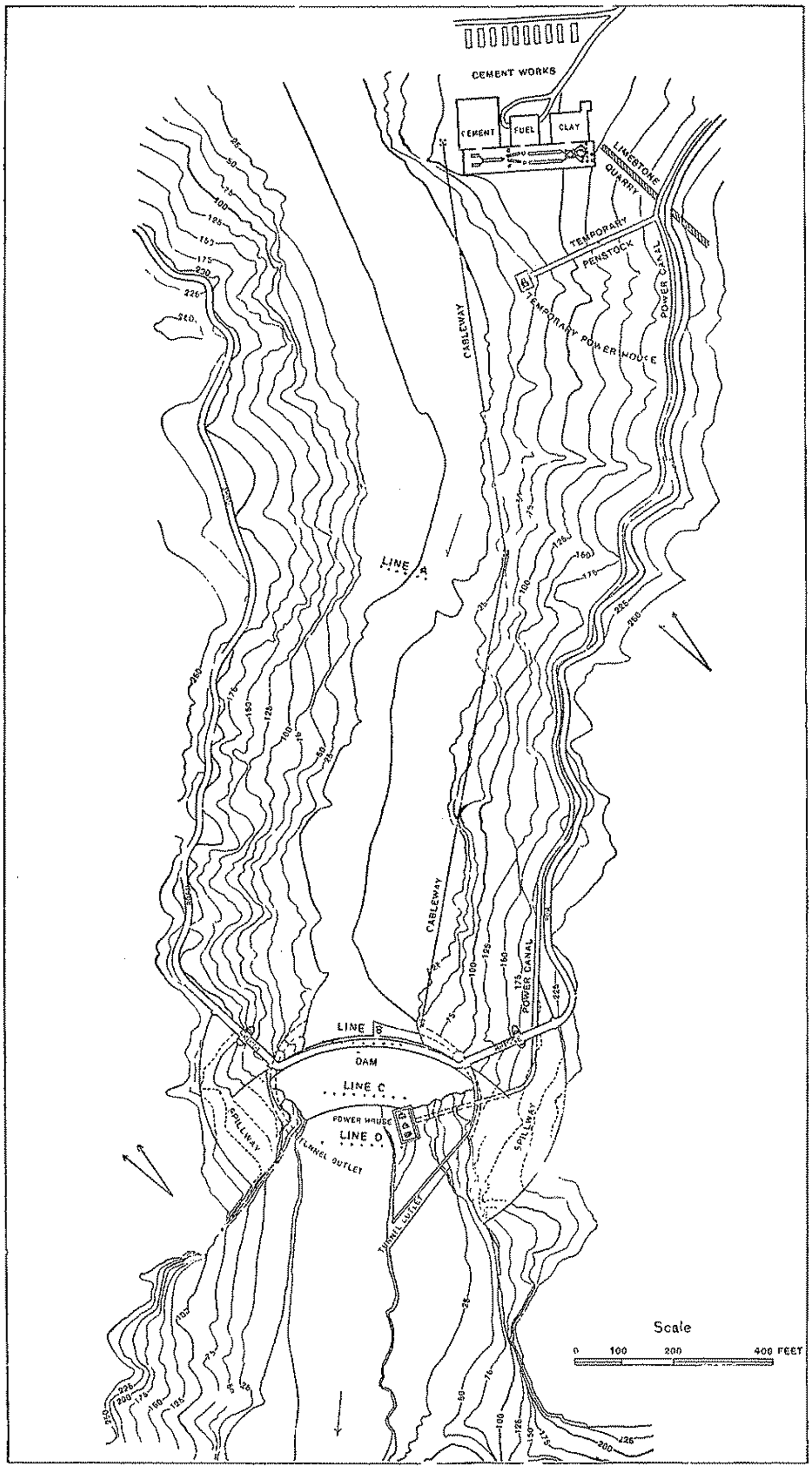


FIG. 3.—Profile of borings at Hudson Reservoir Company's dam site.



PLAN OF DAM, POWER PLANT, AND CEMENT FACTORY.

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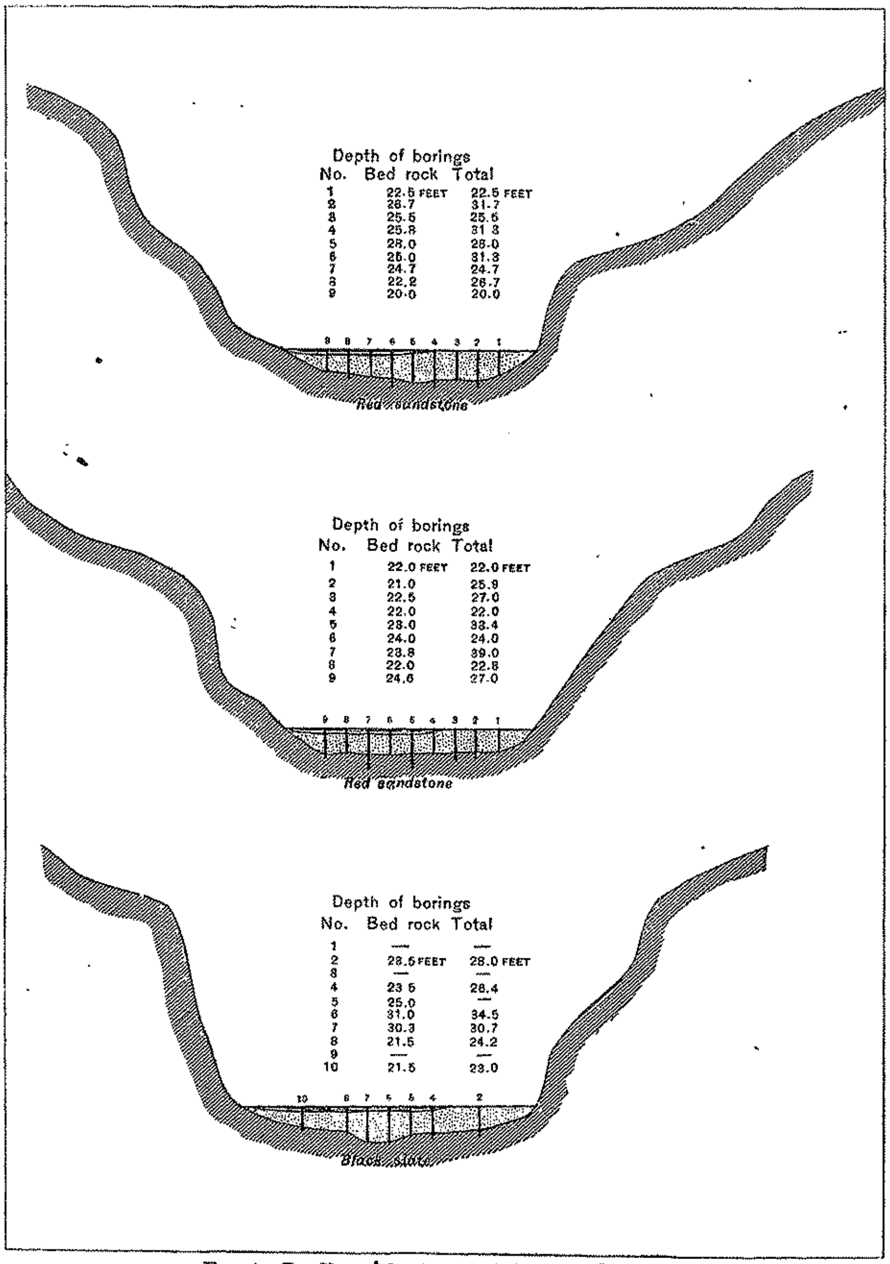


FIG. 4.—Profiles of borings at Salt River dam site.

Borings at Salt River dam site.

No.	Bed rock.	Total depth.	Character of rock.
Line A, Hudson Reservoir Company site.	*Feet.*	*Feet.*	
1	24.0	39.5	Red sandstone.
2	28.0	35.3	Sandstone.
3	64.5	74.0	Coarse, soft white sandstone.
4	44.0	49.8	Broken quartzite.
5	23.0	25.3	Do.
6	24.0	30.0	Do.

Borings at Salt River dam site—Continued.

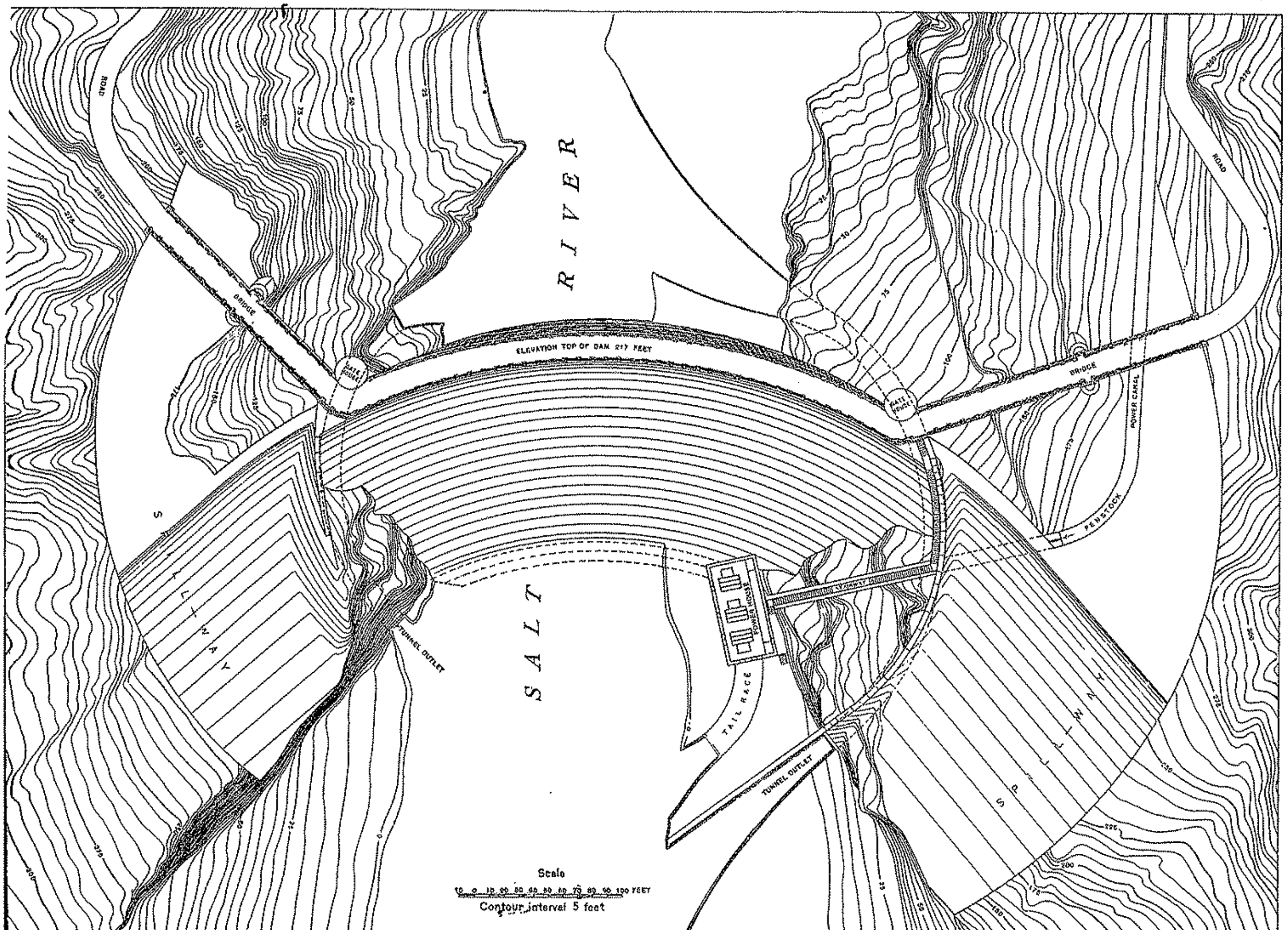
No.	Bed rock.	Total depth.	Character of rock.
Line B, 1,600 feet below line A.	*Feet.*	*Feet.*	
1	22.5	22.5	Red sandstone.
2	26.7	31.7	Do.
3	25.5	25.5	Do.
4	25.8	31.3	Do.
5	28.0	28.0	Do.
6	25.0	31.3	Do.
7	24.7	24.7	Do.
8	22.2	26.7	Do.
9	20.0	20.0	Do.
Line C, 100 feet below line B.			
1	22.0	22.0	Red sandstone.
2	21.0	25.9	Do.
3	22.5	27.0	Do.
4	22.0	22.0	Do.
5	23.0	33.4	Do.
6	24.0	24.0	Do.
7	23.8	39.0	Do.
8	22.0	22.8	Do.
9	24.6	27.0	Do.
Line D, 100 feet below line C.			
1			
2	23.5	28.0	Black slate.
3			
4	23.5	26.4	Black slate.
5	25.0		Do.
6	31.0	34.5	Do.
7	30.3	30.7	Do.
8	21.5	24.2	Do.
9			Do.
10	21.5	23.0	Do.

CAPACITY OF RESERVOIR.

The capacity of the reservoir was determined by a plane-table 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:

Capacity of Salt River reservoir.

Height above low water.	Area.	Capacity of section.	Total capacity.
Feet.	*Acres.*	*Acre-feet.*	*Acre-feet.*
10	24	120	120
20	128	760	880
30	224	1,760	2,640
40	401	3,125	5,765
50	694	5,475	11,240
60	1,085	8,895	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	5,536	49,635	198,880
130	6,394	59,650	258,530
140	7,293	68,435	326,965
150	8,411	78,520	405,485
160	9,664	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



PLAN OF SALT RIVER DAM.

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 dam is determined by the supply of water available for storage.

PLANS FOR THE DAM.

The gorge on Salt River is an especially favorable site for a masonry dam, and the most permanent, conservative, and secure form of high dam that is known to engineering science can be constructed. The formation is sedimentary, with the strata inclined at an angle of about 30° to the horizonal, 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. Building stone of the same material is at hand, and above the site. As elsewhere set forth, good Portland cement can be made in the vicinity. 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 a large margin of safety is provided, as the structure can not slide without shearing the masonry. In addition to these precautions the dam planned is to be built in the form of a circular arch, greatly increasing 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 can not 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.

Structure.	Material.	Pressure per square foot.	Authority.
		Tons.	
Bridge, Pont-y-Prydd, Wales	Limestone rubble, lime mortar.	20.7	I. O. Baker.
Brooklyn Bridge	Granite masonry	39.5	Duryea & Mayer.
Washington Monument, in wind.	Cut marble	25.4	Col. T. L. Casey.
St. Louis Bridge, before completion.	Cut limestone	38.0	History St. Louis Bridge, p. 370.
South Street Bridge, Philadelphia.	do	15.7	Trans. Am. Soc. C. E., Vol. VII, p. 305.
Rookery Building, Chicago	Cut granite	30.0	I. O. Baker.
Bear Valley dam	Granite rubble	40.0	J. D. Schuyler.
All Saints' Church, Angers	Forneaux stone	43.0	J. T. Fanning, p. 403.
Chapter House, Elgin	Red sandstone	20.0	Do.
St. Paul's, London	Portland limestone	19.7	Do.
St. Peter's, Rome	Calcareous tufa	16.7	Do.
Various arch bridges	Cut masonry	60.0	Do.
Quaker Bridge dam (projected).	Rubble masonry	15.0	Rep. Aqueduct Com., p. 55.
Almanza dam (300 years old)	do	14.3	Edward Wegman, p. 24.

Various experimental tests.

Material crushed.	Pressure per square foot.	Authority.
	Tons.	
Concrete prisms cut from Vrynwy dam	181	Sir Andrew Clark.
Granite ashlar, with mortar 1:2	583	Austrian Society E. & A.
Sandstone rubble, mortar 1:2	255	Do.
Sandstone rubble, mortar 1:3½	184	Do.
Gravel concrete 1:2:3	128	Do.
Gravel concrete 1:3:5	66	Do.

Two cubes of 1 cubic inch each were cut from briquets of neat cement, manufactured from materials obtained near the site. These were tested at the United States Navy-Yard, in Washington.

Sample No. 1 crushed at 6,690 pounds, or 482 tons per square foot.

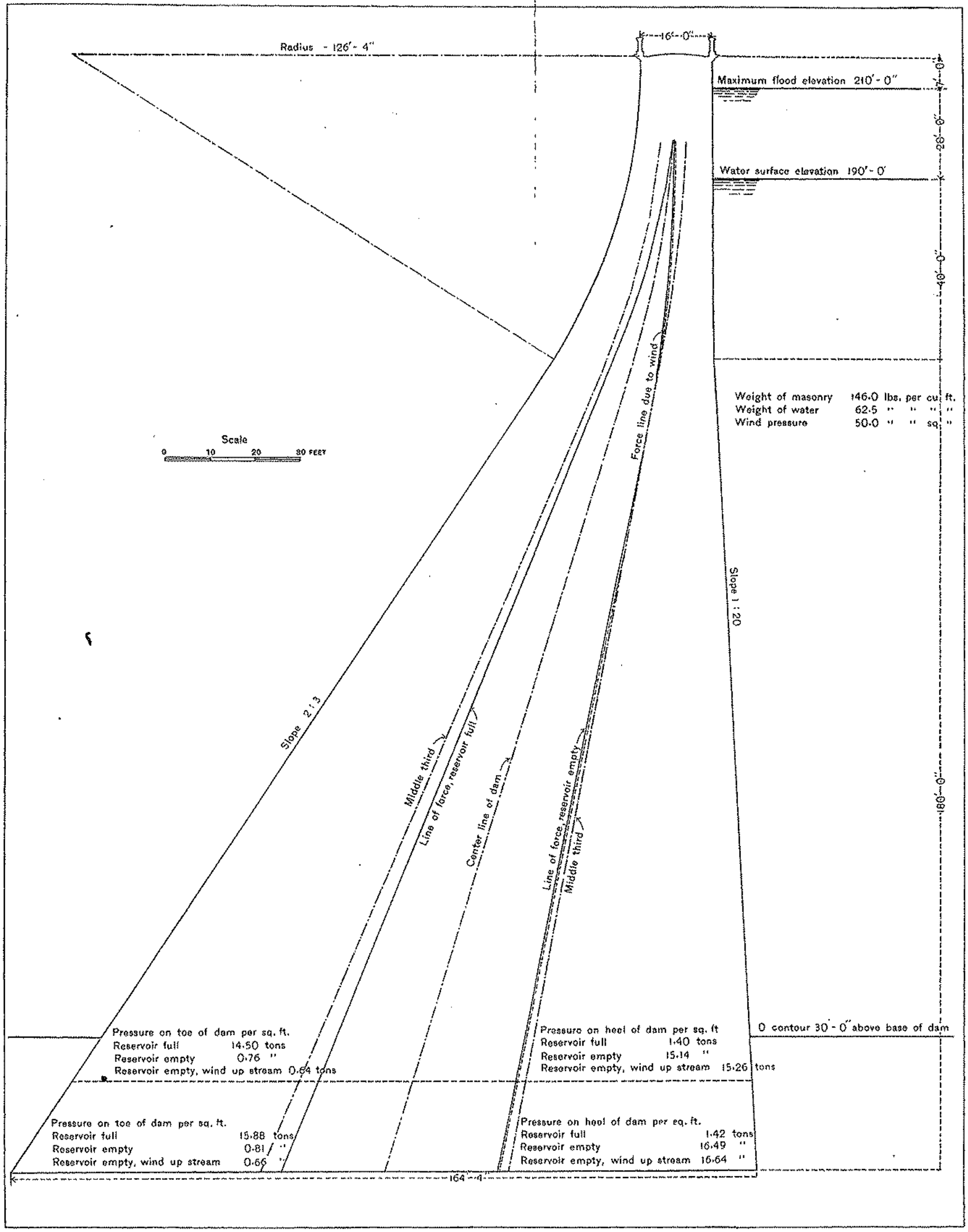
Sample No. 2 crushed at 8,840 pounds, or 636 tons per square foot.

Two cubes with edges of 2 inches were cut from samples of the rock to be used in Salt River dam, and crushed in the testing machine at the United States 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 1,800 tons per square foot. These results are so high that the strength of the rock is entirely eliminated from the discussion.

Test No. 4, in the above table, made by the Austrian Society, is very nearly representative of the masonry to be used in the proposed



MAXIMUM SECTION OF SALT RIVER DAM, SHOWING FORCE LINES.

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Salt River dam. A coefficient of safety of 10 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:

At the 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 tons per square foot.

At the 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 afterwards repaired and the foundation reenforced. 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.

At the Puentes dam in Spain the central portion of the 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.

The dam at Austin, Tex., 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 instead of solid rock.

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

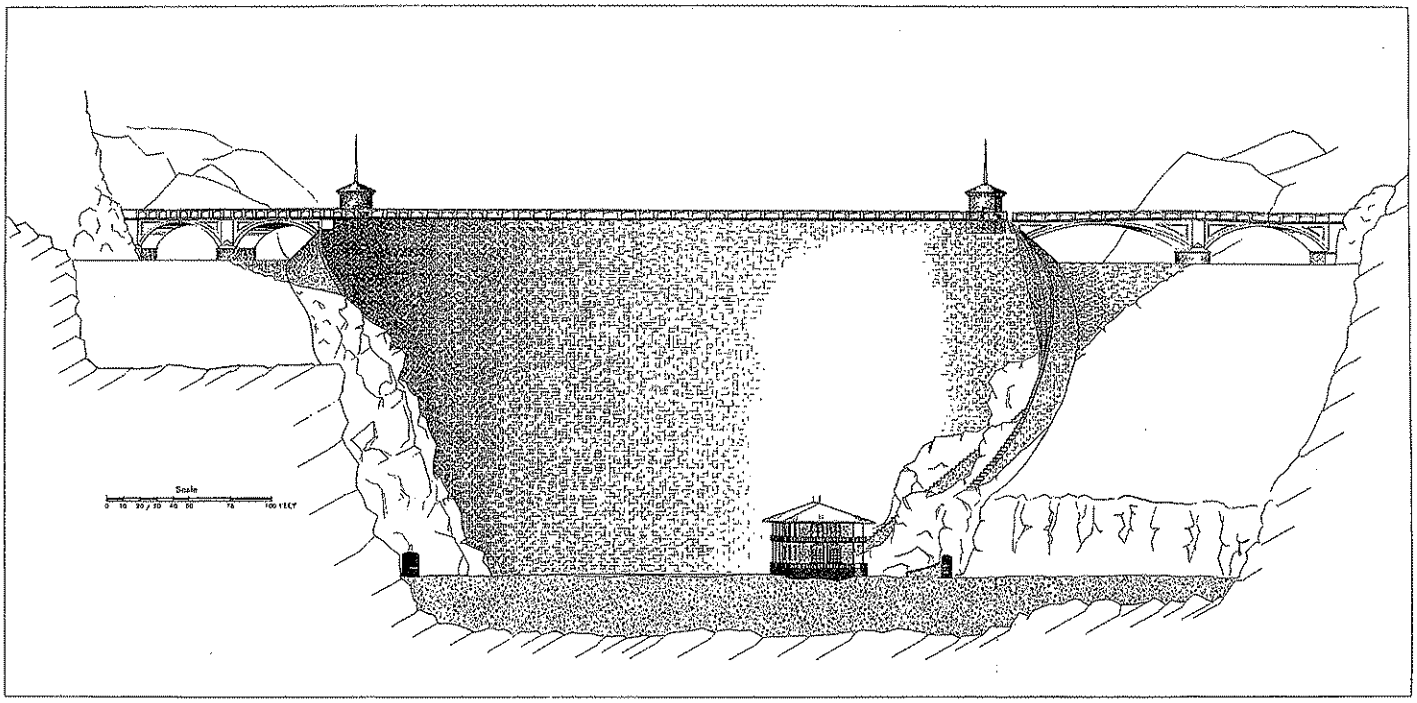
The proposed dam is designed to be 217 feet above low water in the river at the dam site and to store water at a maximum depth of 190 feet, the total height of dam above lowest foundation being about 247 feet. Spillways 20 feet deep will be excavated in the solid rock sides of the canyon and the rock 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 spillways, 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 States Geological Survey. The following are the results of this test:

Specific gravities of two specimens of sandstone.

I. Determined on lumps.
   A. In ordinary distilled water as quickly as possible.
      No. 1.—Specific gravity, 2.42 at room temperature.
      No. 2.—Specific gravity, 2.47 at room temperature.
   B. After soaking in distilled water 24 hours.
      No. 1.—Specific gravity, 2.44 at room temperature.
      No. 2.—Specific gravity, 2.49 at room temperature.
   C. After standing in distilled water under the air pump for 24 hours.
      No. 1.—Specific gravity, 2.50 at room temperature.
      No. 2.—Specific gravity, 2.52 at room temperature.
II. Determined on the powdered samples.
      No. 1.—Specific gravity, 2.583 at 21.5 C., compared with water of same temperature.
      No. 2.—Specific gravity, 2.611 at 17.5 C., compared with water of same temperature.

Tests for crushing were also made and are given on page 36.

The rock is to be used in as large pieces 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 130 pounds, the masonry will weigh, as nearly as can be estimated, 146 pounds to the 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 nonelastic. Any elasticity it may have will tend to relieve this pressure. The maximum possible pressure, 16.64 tons, occurs at the heel when the reservoir is empty, with a strong wind blowing upstream.



ELEVATION OF SALT RIVER DAM.

The table on p. 36 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 bed rock, the piling to be reenforced 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 1 foot higher than the top of the outlet channel for three-fourths of its length, about 50 feet of the southern end of the embankment being left at an elevation 6 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 downstream over the completed portion of the foundation, discharging into the stream bed at least 300 feet downstream 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 8 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 can not be driven deep enough to cut off the underflow, 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, bowlders, 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 in 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 cement grout. Throughout the length of the foundations a trench 6 feet wide and 6 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 can not 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 1 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 1 foot, with the stone of the underlying course. The stretchers must not be less than 3 feet long, nor less than 2 feet in any other dimension. The headers must not be less than 6 feet in length nor less than 2 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 the stones in the body of the dam must be nowhere less than 4 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 stone and the smallest 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 1 part of Portland cement, 2 parts of good sharp sand; and all concrete used in this portion of the dam shall consist of 1 part cement, 2 parts sand, and 3 parts of broken stone graded to such size as will pass through a screen with meshes 2 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 1 part Portland cement to 3 parts of sand, and concrete of 1 part Portland cement, 3 parts sand, and 4 parts broken stone of a size to pass through a screen with meshes 2 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 pre-

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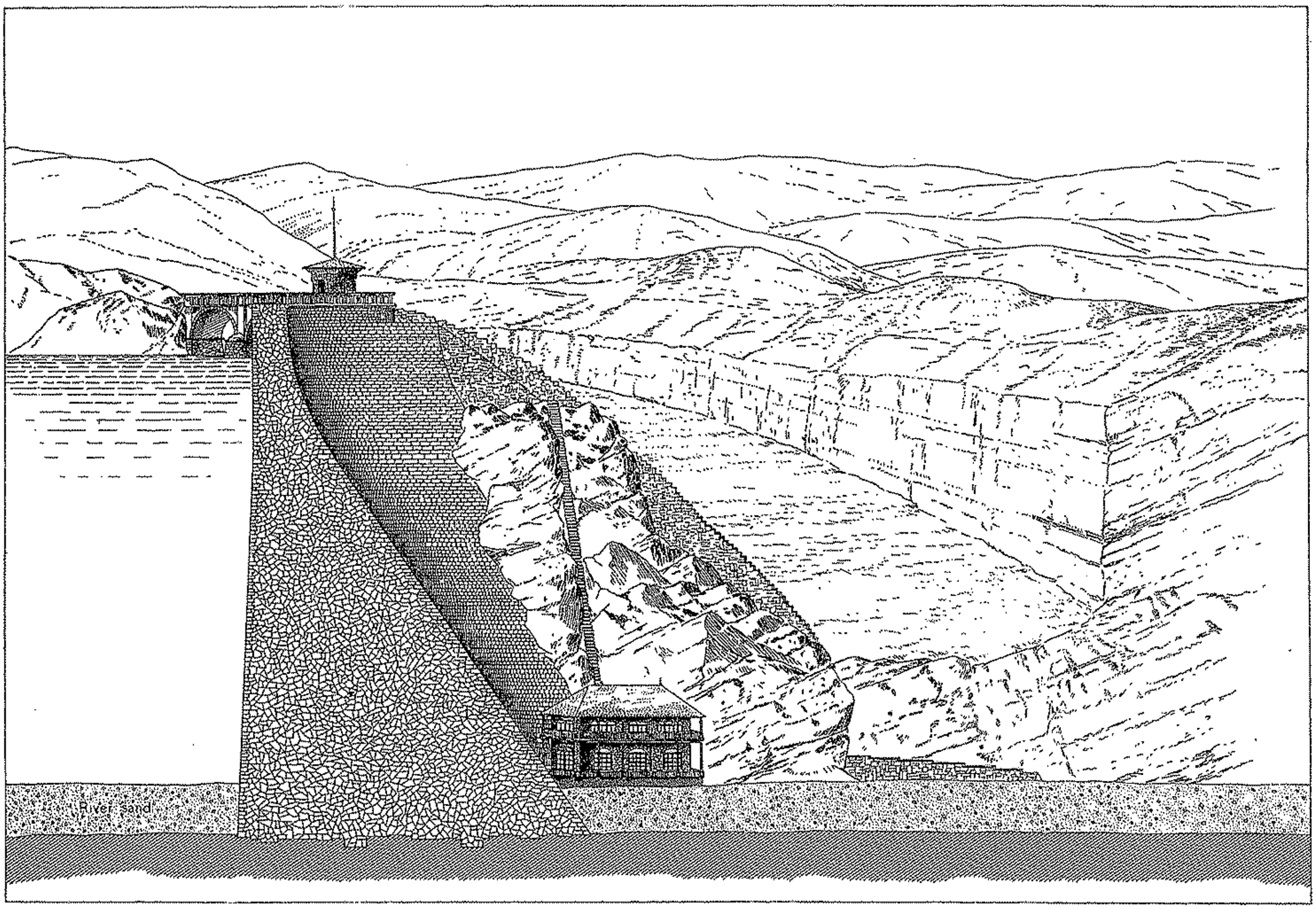

SECTION OF DAM AND ELEVATION OF SPILLWAY AND POWER HOUSE.

vious to the completion of the masonry in which it is placed. No cement shall be used until at least sixty 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.

Date.	Sediment.	Total volume.
1901.	*Per cent.*	*Acre-feet.*
January	0.00026	9.27
February 1–15	.00053	34.42
February 16–28	.00012	8.28
March	.000099	9.53
April 1–18	.0000021	.06
April 19 to May 26	No sediment.	.00
May 27–31	.005895	28.74
June	No sediment.	.00
July	.003924	83.58
August	.004128	134.16
September	.0013323	23.85
October	.000054	5.04
November	.000058	.65
December	No sediment.	.00
Total for the year		337.58

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 eight hundred years to fill the reservoir if none were drawn off. It would probably be one hundred 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 usually be found in the lower layers of water, and it will therefore contribute to the maintenance of 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 part of the reservoir, which in this case is 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 more than a century.

SPILLWAY PROVISION.

The greatest flood ever known in Salt River Valley occurred in February, 1891. It is described in the Twelfth Annual Report of the United States Geological Survey, and has been referred to on page 20 of this report. The maximum discharge of this flood was estimated at the almost incredible volume of 300,000 cubic feet per second. A freshet of less magnitude, but still very large, occurred in 1890. There is abundant evidence that there had been no flood approaching these in magnitude for a very long time. The drainage area from which this flood was drawn was considerably more than double the area tributary to the proposed Salt River reservoir, but the latter having more than the average precipitation, it is credited with 54 per cent of the total discharge under the discussion of "Water-supply" on page 26. A smaller drainage basin is, moreover, liable to a relatively higher flood discharge than a larger one, though the floods are of shorter duration. From the above considerations it is estimated that the maximum flood wave possible at Salt River reservoir is 220,000 cubic

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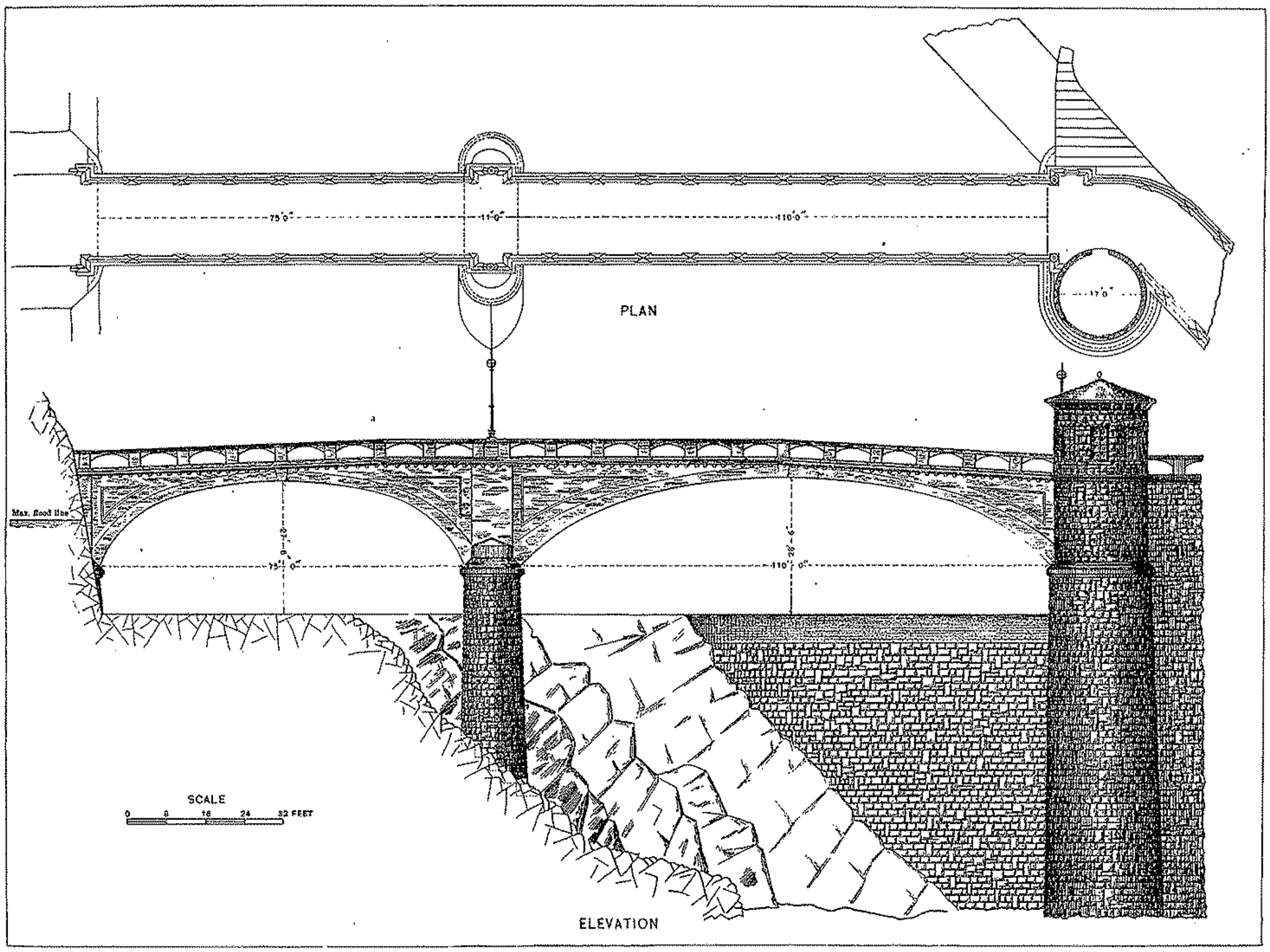

ELEVATION OF BRIDGE, SPILLWAY, AND GATE TOWER.

feet per second, reaching this amount by a rapid increase in volume, and declining somewhat less suddenly from the maximum to the normal discharge. On this assumption an examination has been made of the effect of such a flood upon the reservoir. It is assumed that the reservoir is full up to the bottom of the spillway, and that a great flood occurs, with a mean discharge for the first hour of 120,000 cubic feet per second, and increases its discharge 10,000 cubic feet per second during each hour for eleven hours, at the end of which time it has reached its maximum wave of 220,000 cubic feet per second. The discharge then decreases in an arithmetical progression for twenty hours, at the rate of 5,000 second-feet per hour, reaching a discharge of 120,000 second feet as a mean for the thirty-first hour.

This spillway as planned has a total length of 350 feet, and its bottom is 27 feet below the top of the dam. Its discharge capacity is computed from the formula $Q=H^{\frac{3}{2}}\,1220=3.5\,LH^{\frac{3}{2}}$.

Effect of maximum flood on Salt River reservoir, with spillway 350 feet long, 190 feet above river bed.

[$Q=H^{\frac{3}{2}}\,1220$.]

Hour.	Inflow.		Outflow.		Net rise.	Elevation.
	Second-feet.	Acre-feet.	Second-feet.	Acre-feet.		
					Feet.	*Feet.*
1	120,000	9,920	12,920	1,065	0.82	190.82
2	130,000	10,740	14,380	1,185	.87	191.69
3	140,000	11,570	16,560	1,365	.92	192.61
4	150,000	12,390	19,430	1,600	.97	193.58
5	160,000	13,320	22,920	1,890	1.01	194.59
6	170,000	14,040	27,190	2,245	1.03	195.62
7	180,000	14,870	31,600	2,610	1.06	196.68
8	190,000	15,690	36,730	3,035	1.08	197.76
9	200,000	16,520	42,360	3,500	1.10	198.86
10	210,000	17,350	48,460	4,000	1.11	199.97
11	220,000	18,170	54,980	4,540	1.12	201.09
12	215,000	17,760	61,590	5,085	1.03	202.12
13	210,000	17,350	67,940	5,610	.94	203.06
14	205,000	16,930	73,960	6,110	.86	203.92
15	200,000	16,520	79,620	6,575	.78	204.70
16	195,000	16,170	84,900	7,010	.71	205.41
17	190,000	15,690	89,790	7,415	.64	206.05
18	185,000	15,280	94,270	7,785	.57	206.62
19	180,000	14,870	98,340	8,120	.51	207.13
20	175,000	14,450	102,740	8,485	.45	207.58
21	170,000	14,040	105,300	8,695	.40	207.98
22	165,000	13,630	108,200	8,935	.35	208.33
23	160,000	13,220	110,810	9,150	.30	208.63
24	155,000	12,830	113,040	9,335	.26	208.89
25	150,000	12,390	114,920	9,490	.21	209.10
26	145,000	11,980	116,460	9,620	.17	209.27
27	140,000	11,570	117,630	9,720	.13	209.40
28	135,000	11,150	118,610	9,795	.10	209.50
29	130,000	10,740	119,250	9,850	.06	209.56
30	125,000	10,320	119,620	9,880	.03	209.59
31	120,000	9,920	119,760	9,892	.00	209.59
Capacity of spillway			123,120	10,170		210.00

At the end of the thirty-first hour the surface of the water has reached an elevation of 209.6 feet, or 7.4 feet below the top of the dam, and from that point begins to decline, the spillway having at this elevation a discharge of 119,760 cubic feet per second. The above-assumed flood wave might, therefore, be considerably exceeded without flowing over the dam, and therefore the spillway provisions as planned are considered ample for all possible requirements. It should be noted, however, that the dam would not be injured nor endangered by a very considerable flow over the top.

OUTLET WORKS.

For the purpose of facilitating the discharge of sediment from the reservoir, and also to furnish the maximum reenforcement 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 3½ 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 12,800 pounds per square foot on the gates, or a total on each gate of about 390 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 inclosed 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 reenforced on each side by a 12-inch **I** beam, and the whole is inclosed by a thin steel skin, to minimize the tendency to produce vibrations. The beams 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

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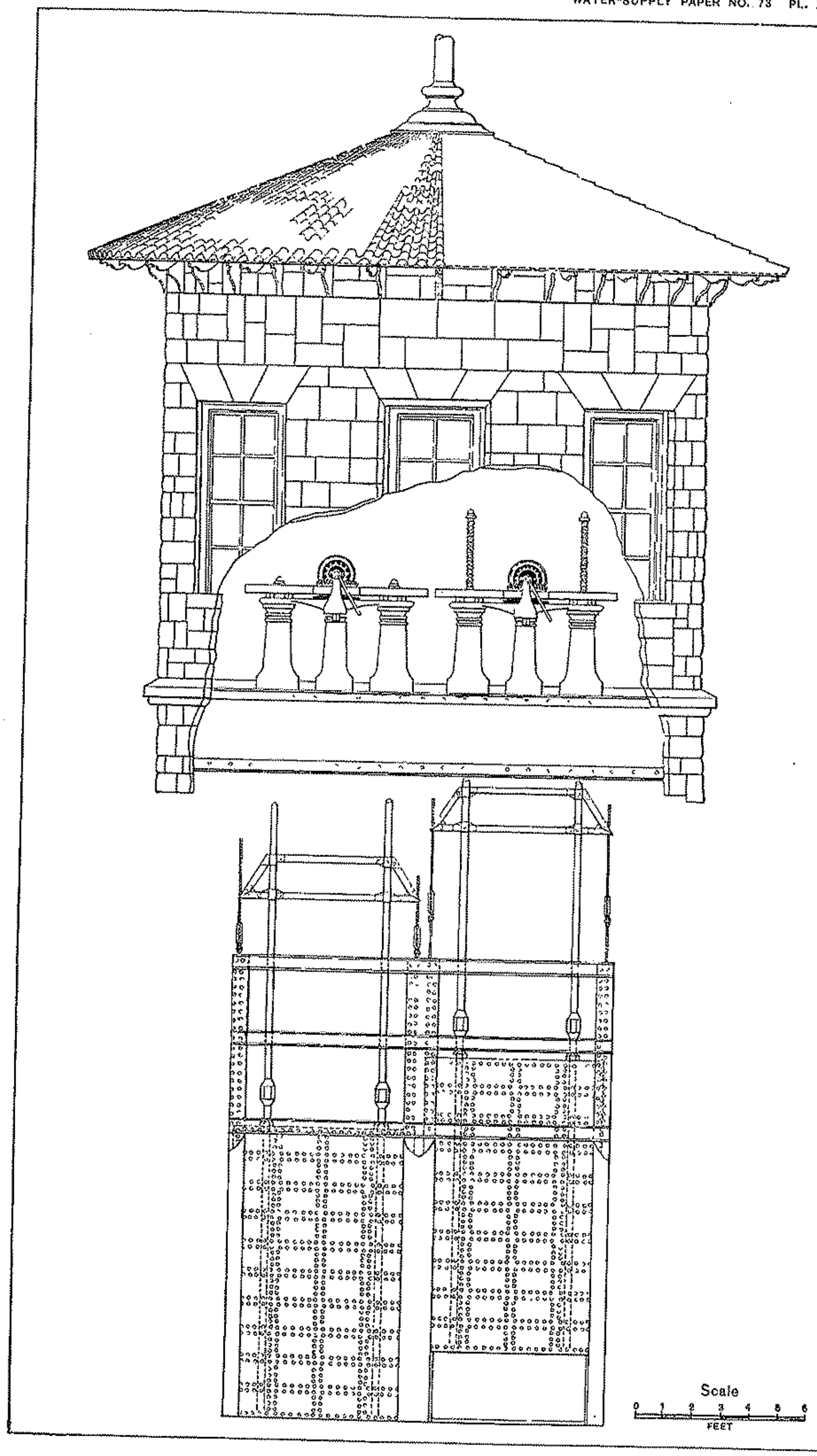


ELEVATION OF TOWER, GATES, AND GATE LIFTS.

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 7 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 3-inch, double-extra heavy steel drivepipe, and will work in guides, as shown in Pl. XXI. 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 on Pl. XXII.

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 horsepower 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 haul.

The best means for 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 8 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 0.0006.

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 permanence. The adopted flume section is a rectangular box, 4 feet deep and 7 feet 8 inches wide inside, built of 2-inch redwood plank, supported by frame of native pine. Sawmills 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. The details of flume construction are shown on Pl. XXIII.

There are to be two tunnels on the line, one 15,000 and one 18,000 feet in length. Both are to be 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 horsepower after deducting seepage, friction, and losses in water wheels, electric plant, etc. It is designed to use 900 horsepower at the dam and 300 horsepower at the cement mill.

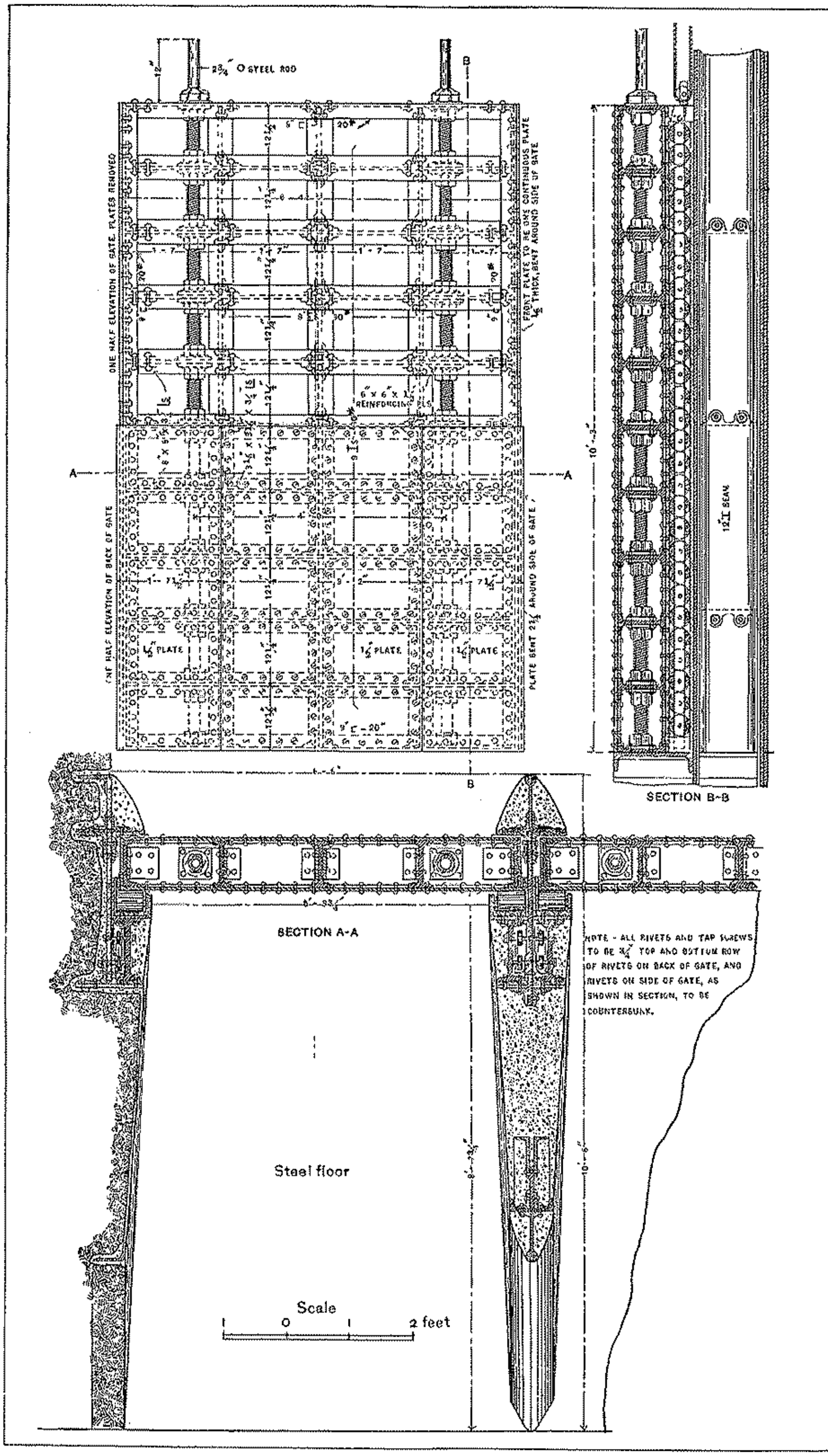
The power plant will consist of three units of 300 kilowatts each, one of which will be temporarily installed near the cement mill, to be used there in making cement and in drilling for the outlet tunnels, dam foundations, etc., before the permanent plant is installed, until it is desired to store water above the 25-foot contour of the reservoir, at which time the manufacture of cement should have been completed, when this unit will be placed alongside the other two below the dam. The two units placed below the dam will be at first protected by a temporary power house, until the foundation of the dam at that point is brought up to the level of the ground, when the stone power house will be built.

The windows of the power house will be 10 feet above the bed of the river, and the tailrace of the power house will be provided with a gate by which, if it ever becomes necessary, backwater from the discharge of the spillways can be prevented from entering the power house. At such times, perhaps once in twenty or thirty years, it may become necessary to close down the power plant for a few hours.

The following approximate estimate of the cost of the power installation has been prepared:

Estimated cost of power plant.

Diversion works:		
Dam	$10,000	
1,000 feet of flume	2,325	
75,200 feet of canal	58,975	
3,300 feet of tunnel, at $6	19,800	
		$91,100



ELEVATION AND SECTION OF OUTLET GATES.

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Water wheels, etc.:		
9 wheels, shafts, nozzles, housings, etc	$7,350	
3 pairs couplings for attaching dynamos	555	
270 feet 52-inch pipe for penstock	1,600	
Receiver and 9 branches	1,555	
Freight on 140,000 pounds, at 3 cents	4,200	
Power house	10,000	
		$25,260
Electric plant:		
3 300-kilowatt dynamos and exciters	24,000	
Transformers and motors	35,000	
Transmission lines	1,000	
Freight and installation	12,000	
		72,000
Total cost of power plant		188,360

The power plant as planned is about what is necessary in the construction of the dam and the manufacture of cement. It contemplates the use of the entire flow of the Salt River at minimum stages, and hence is the maximum that can be made available at full head for use at all times. After the construction of the reservoir this power can be utilized for other purposes, but if constantly required will consume water from the reservoir during the winter months, when usually a sufficient supply for irrigation purposes can be obtained from the unregulated flow of the Verde River. If, however, the power is used exclusively for pumping water for irrigation, it will not be required during the season of high water on the Verde. When this supply becomes insufficient, it will be necessary to start the pumping plants and to draw water from the reservoir, which can be utilized at such times, both for power and irrigation; hence, if used exclusively for pumping, none will be wasted.

There are other power possibilities in this reservoir site by arranging to draw all irrigation water from the reservoir under a considerable head through turbines which can be used to develop power for pumping purposes. Such development, however, will be of a very different character from the works already planned. The water will be drawn under a variable head, and at times of extreme scarcity, when the reservoir may run nearly or quite empty, and when irrigation water is most needed, the head will be diminished and the water to be drawn will be insufficient or entirely lacking at times when the power for pumping is most needed, unless the duty of the reservoir is diminished to a sufficient extent to prevent this. It is probable, however, that such a utilization of the power could be profitably made. A decision on this point rests on the equation between the cost of necessary plant and the value of necessary storage capacity on the one side as against the value of the water pumped on the other side. There is, however, a limit to the availability of underground waters which can not be definitely known until an extensive trial is made by pumping on the large reservoir of water which seems to be stored underground in Salt River Valley. The problem, however, is an attractive one, and deserves extensive study in connection with the utilization of Salt River reservoir.

CEMENT MANUFACTURE.

The natural topographic conditions of this site are very favorable for the construction of a masonry dam of the most conservative and permanent design yet devised. This form of construction, however, is rendered very expensive by the remoteness and difficulty of access to the site. There is a wagon haul of over 40 miles across mountainous country from the end of the railroad, which is a branch road with light traffic and high rates. It is estimated that cement would cost at the dam site about $9 per barrel. As over 100,000 barrels of cement would be required for the dam, such a price is a most serious handicap to the project, and presents a strong temptation to adopt a rock-fill type of structure which would be immensely cheaper. However, before deciding this important point, it was thought best to investigate the possibility of manufacturing cement in the vicinity, and, with this object, search was made in Tonto Basin for materials suitable for the purpose. Eight samples of rock and clay were sent in for analysis to E. A. Duryee, superintendent of the cement works at Colton, Cal. The analyses were as follows:

Analyses of rocks and clays from Tonto dam site.

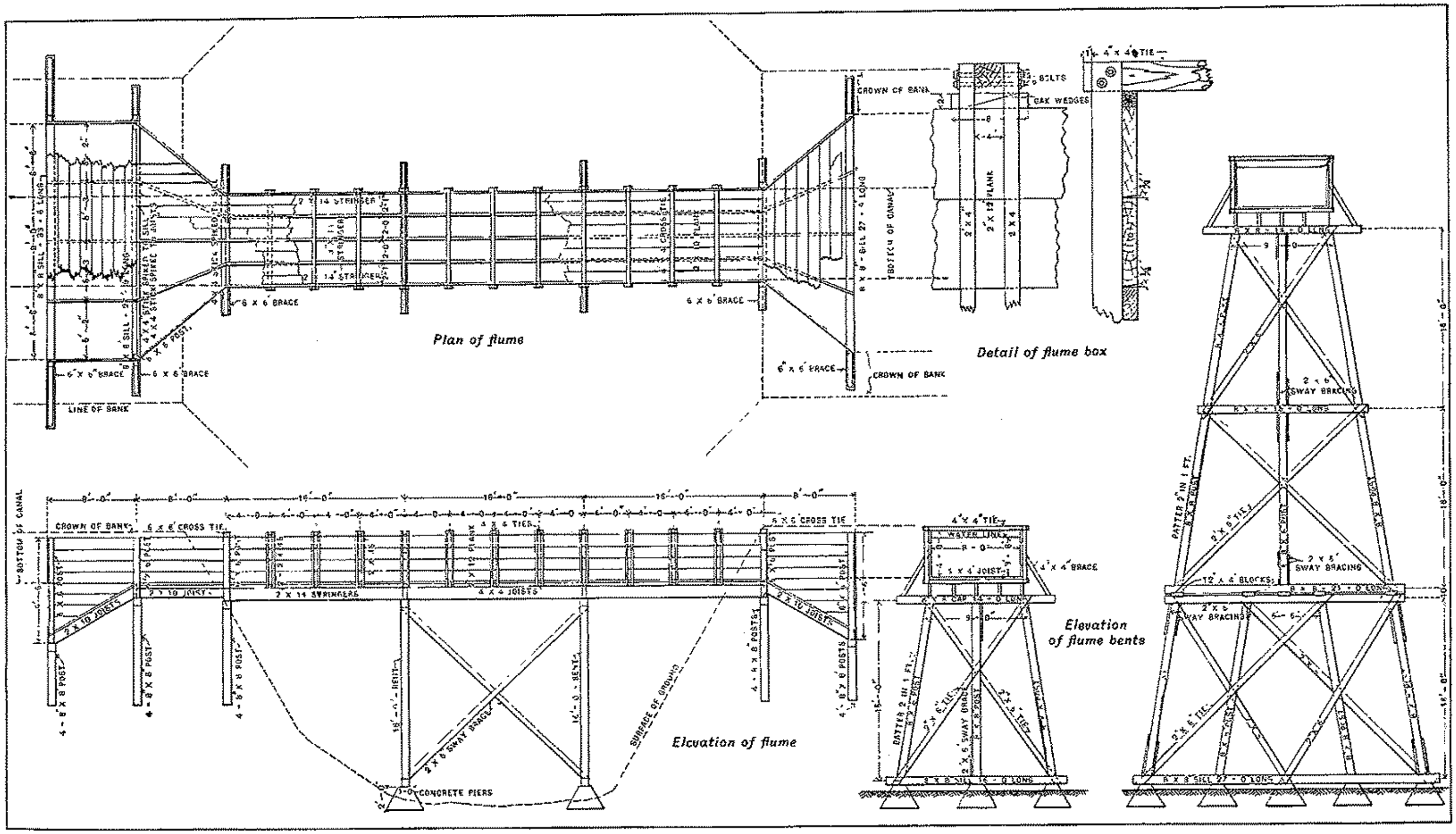
Constituent.	No. 1.	No. 2.	No. 4.	No. 6.	No. 7.	No. 8.
Moisture	-------	2.80	11.25	20.10	13.40	-------
Silica	-------	50.60	55.70	51.00	51.90	67.90
Alumina and ferric oxide	0.20	15.80	20.50	16.70	23.70	18.00
Magnesia	.60	4.072	-------	4.576	.97	.972
Calcium carbonate	95.80	16.60	11.80	6.048	10.90	.00
Insoluble residue	3.30	-------	-------	-------	-------	-------
Total	99.90	89.872	99.25	98.424	100.87	86.872

No. 1. Limestone near dam site; very abundant and convenient.
No. 2. Calcareous shale near dam site; ledge 1 foot thick; expensive to quarry.
No. 3. Shale near dam site; ledge 4 inches thick; expensive to quarry.
No. 4. Clay 1 mile from dam site; abundant.
No. 5. Shale near dam site; ledge 3 inches thick; expensive to quarry.
No. 6. Clay from Sallie May Canyon, 8 miles from dam site.
No. 7. Clay from hills, 3 miles north of dam site; very abundant.
No. 8. Shale from canyon below dam site; ledge 2 feet thick.

The shales, and especially samples 3 and 5, being expensive to quarry and grind, were intended for use only in case the clays should, upon analysis, prove to be unsuitable for the purpose intended.

Everything considered, samples 1 and 7 appeared to be the most favorable for the purpose, and accordingly a quantity of No. 7 and No. 1 were shipped to Colton for an experimental burn. The following is quoted from Mr. Duryee's report:

The clay and limestone were ground separately and then mixed in the proportions of 6.18 pounds limestone and 2.25 pounds clay, making a raw mixture that



DETAILS OF FLUME CONSTRUCTION.

tested 43 per cent lime. As the limestone was very hard and therefore more difficult to make into cement than a softer material, fluorspar to the amount of 1½ ounces, or 1 per cent, was added. The materials were also ground quite fine, but no finer than is the practice in some cement works, viz:

	Per cent.
Passed a sieve of 50 meshes to the linear inch	99.9
Passed a sieve of 100 meshes to the linear inch	99.75
Passed a sieve of 200 meshes to the linear inch	71.75

The raw mixture was made into briquets, and these, after being dried, were burned in a gasoline furnace. They burned to a good hard clinker of a good color, which yielded a cement of good color.

Analysis of the cement.

Lime	63.56
Alumina and ferric oxide	10.40
Silica	22.85
Magnesia	.71

Alkalies not determined.

Tensile tests of the neat cement briquets.

	Pounds per square inch.
7 days (1 day in air, 6 in water)	410
14 days (1 day in air, then in water till broken)	690
28 days (1 day in air, then in water till broken)	775

Chemical analyses of Nos. 1 and 7 were also made in the laboratory of the Geological Survey, to test the uniformity of the deposits. These samples differ slightly from the samples sent to Mr. Duryee, but still are eminently suitable for the purpose. The following are the results found in the Survey laboratory:

Analysis of limestone from Salt River, Arizona.

CaO	55.56
MgO	.10
Fe_2O_3 and Al_2O_3	.20
SiO_2	.51
CO_2(cal)	43.77
Total	100.14

Analysis of clay No. 7, from Salt River, Arizona.

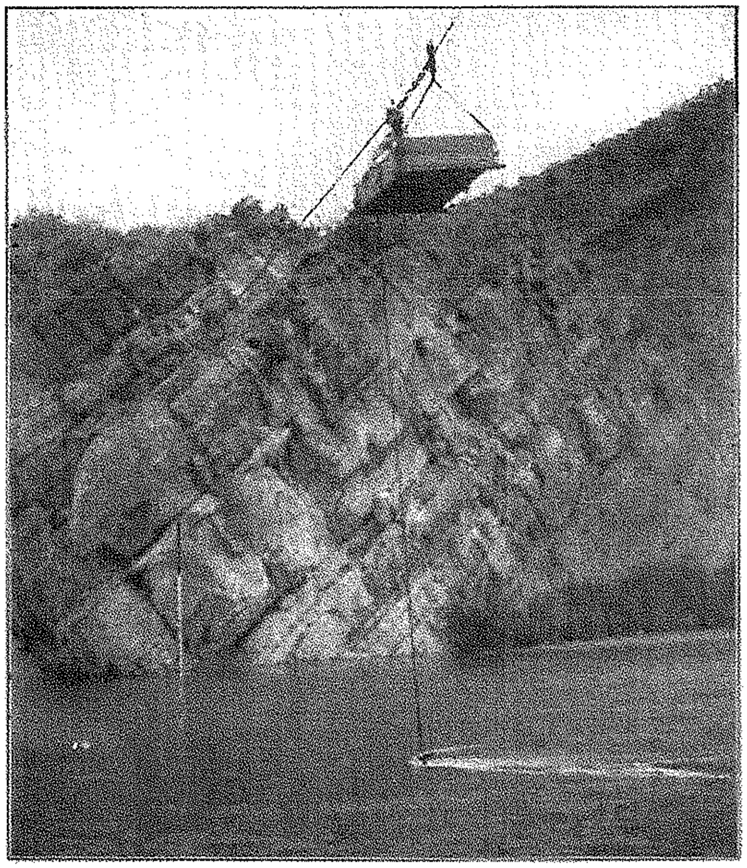
Chlorine	.20
Silica	50.51
Fe_2O_3	5.03
Al_2O_3 and P_2O_5	14.63
TiO_2	.66
MnO	.03
CaO	6.77
MgO	3.00
K_2O	3.06
Na_2O	2.18
Loss at red heat	13.30
Total	99.37

Altogether these results are very gratifying, and prove beyond question the existence of convenient and abundant materials from which cement can be made. The greatest difficulty is the scarcity of fuel. There is considerable wood in the reservoir site, mainly cottonwood and mesquite, which it will be desirable to clear out of the reservoir in any event. Wood is not suitable for burning cement clinker by modern methods, but if made into charcoal and then ground to powder would answer, or oil may be imported for the purpose from California. A large amount of power is required for grinding the rock and the clinker, and a still larger amount will be necessary in the construction of the dam, for excavating to foundation, quarrying and handling the rock, mixing and handling mortar, etc. If steam power were used for all these purposes the small amount of wood at hand would soon be exhausted, and it would be necessary to haul wood a long distance, or to import coal, either of which would be very expensive. Water power can be developed by diverting water from Salt River above the reservoir site, carrying it in a canal above the proposed lake and dropping it through a penstock just below the dam. By such means an ample supply of power can be obtained, available through the construction period and afterwards also, if desired. The chief expense attached to this development will be the construction of the canal for conveying water from the diversion site to the dam site. But as the power will be valuable for other purposes its cost is not entirely chargeable to the dam, and everything considered, this is by far the cheapest manner of obtaining the large amount of power required. This is treated more in detail under the proper heading, page 45.

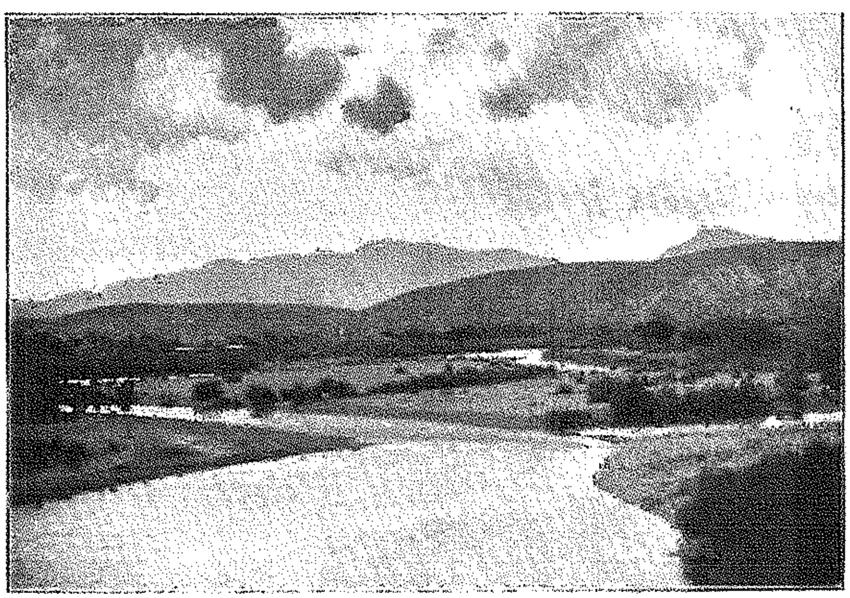
The estimated cost of the cement plant, with modern machinery capable of producing 300 barrels per day, as furnished by Mr. E. A. Duryee, is as follows:

Approximate cost of a rotary process 2-kiln Portland cement plant of a daily capacity of 300 barrels.

Crusher	$2,000
Mill for disintegrating clay	500
Rotary clay dryer	1,500
Elevators and conveyors for raw materials	1,000
Storage bins for raw materials	1,000
Mills for grinding raw materials	10,000
Two rotary kiln-linings and stacks	15,000
Mills for grinding cement	10,000
300-horsepower electric motors and step-down transformers	9,000
Conveyors and elevators for cement	1,500
Cost of grading and erecting machinery	10,000
Shafting and pulleys, belts, and setting up same	5,000
Buildings and bins for cement	10,000
Office, laboratory, and equipment of same	1,500
Freight	10,000
Plans, specifications, and superintendence	3,000
Total	91,000



A. GAGING STATION ON SALT RIVER, HEAD OF CANYON, BELOW MOUTH OF TONTO CREEK.



B. VIEW UP TONTO CREEK FROM THE GORGE.

With such a mill, and using charcoal for burning cement, the cost of manufacture would be approximately as follows, allowing for power only the proportion necessary for maintaining and operating the electric plant provided:

Cost per barrel of making cement at Salt River dam site, Tonto Basin.

Labor and superintendence	$0.70
Raw materials	.30
Fuel for burning	.90
Power (maintenance and operation only)	.05
Repairs and sundries	.05
Total	2.00

ROADS AND BRIDGES.

The road from Globe to Payson passes through the reservoir almost its entire length. In case of the construction of the dam this road would be submerged, and it will be necessary to provide a new one around the reservoir. If it were deflected to the east it would be thrown into exceedingly rough mountain country, where the construction would be very expensive and the road beset by heavy grades. By passing to the west of the reservoir it would be necessary to use the dam as a viaduct and to build bridges across the spillways. There would not be a great amount of road construction, and this plan would be far cheaper and furnish a much better road than could be built east of the reservoir. The road to the dam site would be necessary in the construction of the dam, and some sort of passageway over the spillways would be necessary in operating the gates.

In view of the contemplated manufacture of cement near the dam and the high cost of steel delivered at the site, it has been decided to build the bridges of the Melan arch type—that is, a light steel skeleton embedded in concrete. This will be about as cheap and far more substantial and permanent than a steel bridge, and more in keeping with the massive and permanent character of the dam. Each bridge is designed to abut at one end on the dam and the other end on the solid rock of the hill, and will have one pier. The spans of each bridge will be 110 feet and 75 feet in the clear. The general design is shown in Pl. XX. They are both similar to bridges that have been in successful use for years and involve no new or untried features.

DAMAGES.

The surveys show about 740 acres of cultivated land that will be submerged by the reservoir. The improvements on these lands consist mainly of small frame or adobe houses, fences, and irrigation ditches. It is thought that an average value of $50 per acre for these lands should be ample to include all improvements. About 4,400 acres of unimproved land is also in private hands, and has little or no value. Allowing $1.25 per acre for such lands, we have a total for damages of $42,500.

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The balance of the reservoir site—about 9,000 acres—is public land, the control of which is in litigation, and will not be included in this estimate.

COST.

The following estimates are based upon the data at hand in April, 1902, and are subject to modification:

Estimated cost of Salt River storage dam.

[247 feet above foundation; 190 feet available storage. Capacity, 840,000 acre-feet.]

257,420 cubic yards rubble masonry, exclusive of power and cement, at $3.50 a yard	$900,970
Cement plant	91,000
Power plant, house, and canal	188,360
Manufacture of 150,000 barrels Portland cement, at $2 a barrel	300,000
Excavation of foundation and river diversion	50,000
Outlet tunnels and lining	31,450
Gates and machinery	11,600
Outlet towers, shafts, and houses	9,000
Viaducts across spillways	26,000
Roads	15,000
Engineering and contingencies, 15 per cent	243,507
Total cost of structures	1,866,887
Damage to private lands	42,500
	1,908,387

Cost per acre-foot, $2.27.

The cost of dam 20 feet lower, storing 600,000 acre-feet, would be practically the same for all items except the masonry and cement, which would be about 20 per cent less, making the total cost about $1,680,000, or $2.75 per acre-foot capacity.

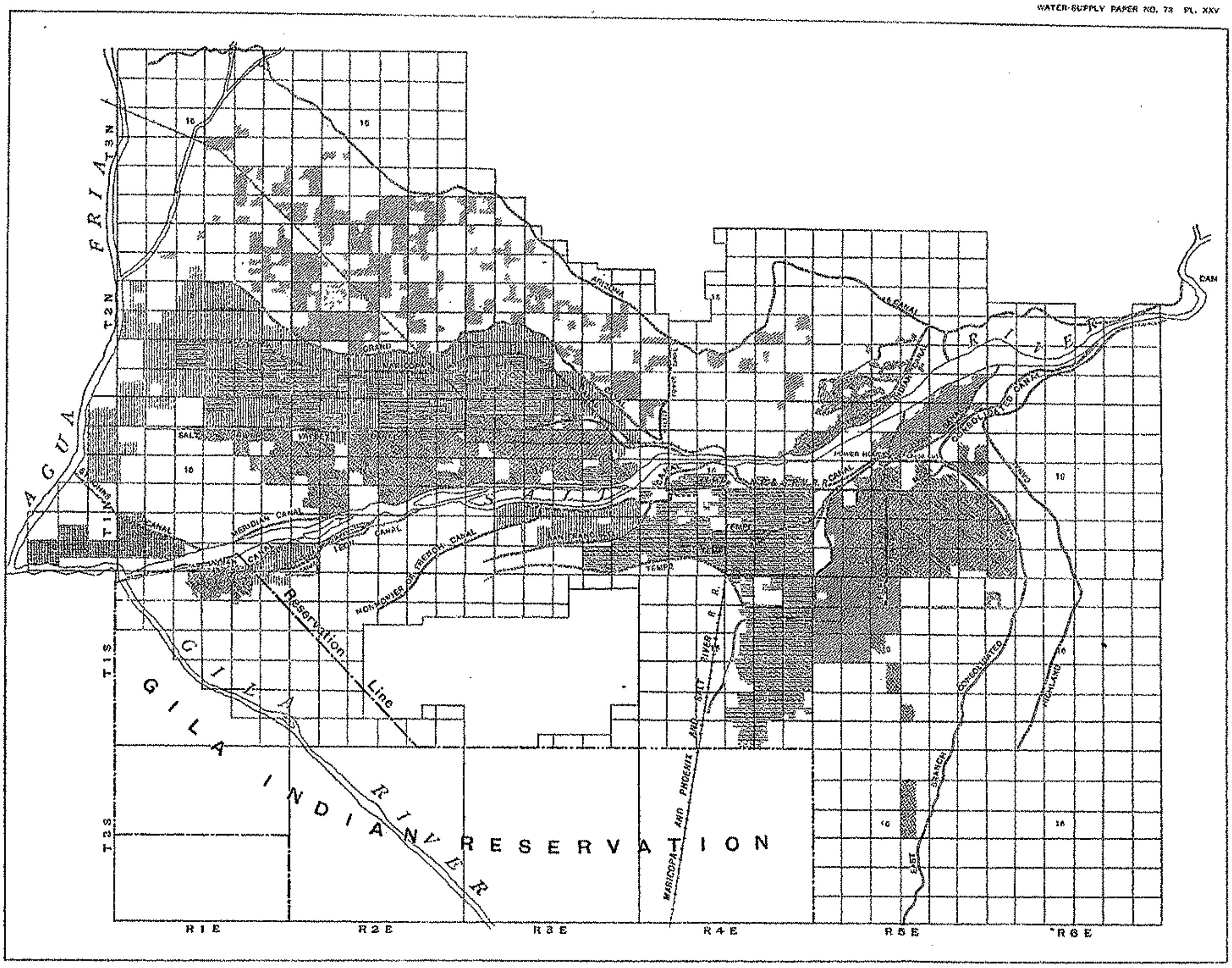
ACKNOWLEDGMENTS.

Generous assistance and valuable suggestions relative to the studies of the problems discussed in this report have been received from numerous sources.

Especial mention is due to the work of Mr. C. R. Olberg, who as principal assistant has performed the major portion of the voluminous computations and most of the detailed designing connected with the structures adopted for the Salt River reservoir, and has displayed in this work a commendable degree of skill and conscientious care.

Thanks are due to Mr. W. H. Code for the benefit of his valuable experience in pumping water by electric power for irrigation and for his advice regarding the relative quantities of water consumed in the various months of the year.

Acknowledgments are also due to Mr. F. P. Trott for valuable information concerning the water supply and for surveys on the McDowell reservoir site, the latter being made at considerable expense to him and freely furnished in the public interest.



MAP OF SALT RIVER VALLEY, SHOWING CANALS AND IRRIGATED LANDS.

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