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[The letters in parentheses preceding the titles are those used to designate the papers for advance publication]

ILLUSTRATIONS

QUALITY OF WATER OF THE COLORADO RIVER IN 1928–1930

By C. S. Howard

SAMPLES

This report gives the results obtained in the continuation of a study of the Colorado River begun in 1925.[1] The analyses represent composites of daily samples collected by the observers at the gaging stations on the Colorado River at Cisco, Utah, and Lees Ferry and Grand Canyon, Ariz.; on the Green River at Green River, Utah; and on the San Juan River near Bluff, Utah. Analyses are given for samples collected about once a month from the Williams River at Planet, Ariz. The Arizona stations are operated under the direction of W. E. Dickinson, district engineer of the Geological Survey at Tucson, Ariz., and the Utah stations under the direction of A. B. Purton, district engineer of the Geological Survey at Salt Lake City, Utah. The average discharges given in Table 3 were calculated from data furnished by these district engineers. Complete discharge data for this period will be published in the regular series of water-supply papers.

The samples were collected at Cisco by Dan Granell, A. J. Clark, and B. M. Tanner; at Lees Ferry by O. R. Clark, J. S. Gatewood, and M. B. Scott; at Grand Canyon by Charles Wells, D. H. Barber, and D. D. Lewis; at Green River by H. T. Howland and F. N. Hansen; on the San Juan River by J. A. Allis, N. D. Nevills, and J. E. Ringwood; and on the Williams River by H. S. Leak. The points at which samples were taken are shown in Figure 18.

All the samples were collected in 4-ounce bottles and were sent to the laboratory in Washington for analysis. As a rule a single bottle was filled each day. It is believed that the samples truly represented the river as to its content of dissolved mineral matter.

METHODS OF ANALYSIS

The analyses were made by the methods regularly used in the United States Geological Survey.[2] The 4-ounce samples were allowed

[1] Collins, W. D., and Howard, C. S., Quality of water of Colorado River in 1925–26: U. S. Geol. Survey Water-Supply Paper 596, pp. 33–43, 1928. Howard, C. S., Quality of water of the Colorado River in 1926–1928: U. S. Geol. Survey Water-Supply Paper 636, pp. 1–14, 1929.

[2] Collins, W. D., Notes on practical water analysis: U. S. Geol. Survey Water-Supply Paper 496, pp. 235–261, 1928.

to stand in the laboratory until the suspended matter settled, leaving the liquid above apparently free from even traces of silt. The clear liquid was drawn off through a siphon without disturbing the sediment and was collected in flasks to make three composite samples each month.

For most of the samples the weight of the suspended material in each bottle was determined. The suspended matter was washed into an evaporating dish with distilled water and dried on a steam bath.

FIGURE 18.—Map of the Colorado River drainage basin, showing sampling points

Correction was made for the weight of the soluble salts in the original water (usually 5 to 8 cubic centimeters) transferred to the evaporating dish with the suspended matter. The quantities of suspended matter reported for composite samples are averages of the determinations for the daily samples.

COMPOSITION OF WATER OF COLORADO RIVER AND TRIBUTARIES

Table 3 gives analyses of samples collected from the Colorado River and some of its tributaries during the period of two years. The dates show the number of daily samples in each composite. The

plan was to have a single bottle filled each day except for the Williams River, for which a set of eight bottles was filled about once a month. Some of the samples were lost in transit, and a few that contained hydrogen sulphide when received were rejected.

The results for dissolved solids are sums of the constituents determined, with the bicarbonate divided by 2.03 to obtain the equivalent carbonate. The total hardness is the calcium carbonate equivalent to the calcium and magnesium together. The noncarbonate hardness is the total hardness minus the quantity of calcium carbonate equivalent to the bicarbonate. The mean discharge is that for the period represented by each composite analysis. The quantity of dissolved solids in tons per day is obtained by multiplying the dissolved solids in parts per million by the discharge in second-feet and the factor 0.002697.

The average of the 36 analyses for a year at each of the stations is given in the table as Nos. 37, 75, 113, 151, 189, and 227. These analyses represent accurately the composition of water that would be contained in a vessel or reservoir that had received equal quantities of water from the river each day for the sampling period.

The weighted averages for each station are given as Nos. 38, 76, 114, 152, 190, and 228. The quantities of the individual constituents in each analysis were multiplied by the mean discharge for the period represented by the analysis, and the sum of the 36 products for each constituent was divided by the sum of the discharges to obtain the weighted averages. These analyses represent approximately the composition of water that would be found in a reservoir containing all the water passing the given station during the year, after thorough mixing in the reservoir. Because the composite samples for analysis were made from equal daily samples, the analyses themselves do not represent accurately the water that would be found in a reservoir containing the whole flow of the river covered by the individual analyses. The error due to this effect is not great, but its tendency is to make the weighted average show more dissolved material than would be found in the water of a reservoir storing the whole flow of the river for a year. The weighted average shows less concentrated water than that represented by the average of the 36 individual analyses, because at times of high discharge the rivers carry the smallest amount of dissolved solids in parts per million.

TABLE 1.—*Weighted averages of analyses from Colorado River and certain tributaries for the year ending September 30, 1930*

[Analytical results in parts per million]

	Green River at Green River, Utah	San Juan River at Goodridge, Utah	Colorado River at Cisco, Utah	Colorado River at Lees Ferry, Ariz.	Colorado River at Grand Canyon, Ariz.
Silica (SiO_2)	14	16	14	15	16
Iron (Fe)	.12	.10	.14	.17	.11
Calcium (Ca)	59	75	73	76	81
Magnesium (Mg)	23	17	28	25	26
Sodium (Na)	56	50	80	74	85
Potassium (K)	3.8	3.5	4.4	4.3	5.0
Bicarbonate (HCO_3)	179	159	156	167	184
Sulphate (SO_4)	177	214	254	247	252
Chloride (Cl)	26	11	55	44	62
Nitrate (NO_3)	1.2	1.7	6.1	2.5	3.4
Residue on evaporation	464	483	619	597	645
Hardness as $CaCO_3$ (calculated):					
Total	240	257	298	295	311
Noncarbonate	93	127	169	157	160
Mean discharge—second-feet	6,290	2,380	8,420	18,000	18,500
Dissolved solids—tons per day	7,630	2,990	13,500	27,800	31,100

The weighted averages for the different stations given in Table 1 show a general similarity in composition of the waters at the different stations. The increase of about 50 parts per million of dissolved material shown for the Colorado River between Lees Ferry and Grand Canyon is made up largely of sodium, chloride, and bicarbonate.

The quantity of dissolved solids carried by the Colorado River at Lees Ferry is slightly greater than the sum of the quantities carried by the three tributaries above Lees Ferry. This difference is shown graphically in Figure 19, where the quantities of each constituent are represented in ton equivalents of the average daily load.

Weighted averages for the Grand Canyon station for each of the five years and for the whole period are given in Table 2. It will be seen that the average daily load of dissolved solids is not directly related to the mean discharge and that the maximum and minimum results for the average residue on evaporation do not occur in the same years as the maximum and minimum discharge.

TABLE 2.—*Weighted averages of analyses from Colorado River at Grand Canyon for the five years ending September 30, 1930*

[Analytical results in parts per million]

	Oct. 9, 1925, to Sept. 30, 1926	Oct. 1, 1926, to Sept. 30, 1927	Oct. 1, 1927, to Sept. 30, 1928	Oct. 1, 1928, to Sept. 30, 1929	Oct. 1, 1929, to Sept. 30, 1930	5-year period 1925–1930
Silica (SiO_2)	19	17	17	18	16	17
Iron (Fe)	.31	.24	.15	.23	.11	.22
Calcium (Ca)	66	77	66	74	81	73
Magnesium (Mg)	21	22	22	23	26	23
Sodium (Na)	75	77	65	73	85	74
Potassium (K)	5.7	5.5	4.3	6.2	5.0	5.4
Bicarbonate (HCO_3)	159	162	162	164	184	165
Sulphate (SO_4)	201	235	187	229	252	220
Chloride (Cl)	56	53	48	48	62	53
Nitrate (NO_3)	1.6	2.4	2.4	2.5	3.4	2.4
Residue on evaporation	546	586	509	579	645	571
Hardness as $CaCO_3$ (calculated):						
Total	251	285	254	281	311	274
Noncarbonate	121	152	121	146	160	139
Mean discharge—second-feet	19,900	23,800	22,200	26,800	18,500	21,800
Dissolved solids—tons per day	28,100	36,600	29,400	40,100	31,100	33,100

The analyses for the Williams River show bicarbonate as the principal acid constituent; in the Colorado, Green, and San Juan Rivers sulphate is the principal acid constituent. The discharge of the Williams River is so small that the chemical composition of the Colorado River at Yuma below the Williams is practically the same as at Topock, which is above the Williams.[3]

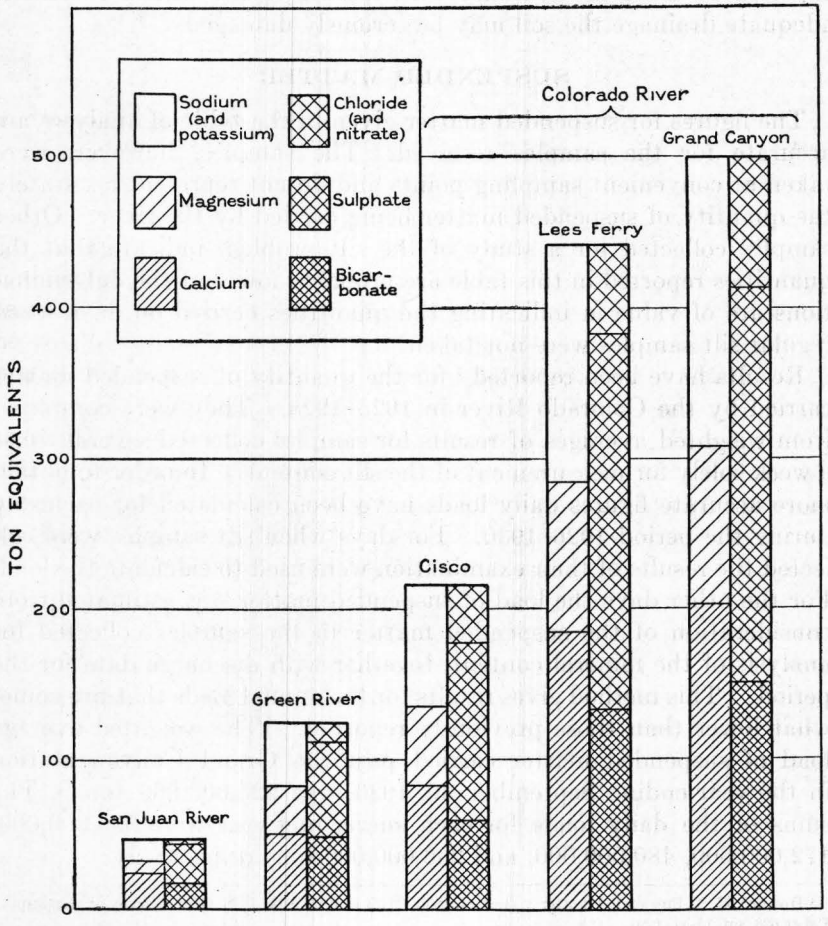

FIGURE 19.—Average daily load of dissolved matter carried by the Colorado River and its principal tributaries

UTILIZATION OF THE WATER OF COLORADO RIVER AND ITS TRIBUTARIES

The water of the Colorado River and its tributaries is nearly always turbid but when clarified is satisfactory for drinking. The water is suitable for all ordinary domestic uses but is harder than is usually

[3] Howard, C. S., Quality of water of the Colorado River in 1926–1928: U. S. Geol. Survey Water-Supply Paper 636, pp. 4–5, Table 2, 1930.

considered satisfactory for public supplies. Water from the Green River at Green River, Utah, and from the Colorado River at Cisco, Utah, is used in locomotives after treatment.

The usefulness of the water of the Colorado and its tributaries for irrigation is wholly dependent on the drainage of the irrigated land. With good drainage and liberal use of the water no trouble should be experienced from the ordinary constituents of the water. Without adequate drainage the soil may be seriously damaged.

SUSPENDED MATTER

The figures for suspended matter given in the table of analyses are accurate for the samples received. The samples, however, were taken at convenient sampling points and do not represent accurately the quantity of suspended matter being carried by the river. Other samples collected for a study of the silt problem indicate that the quantities reported in this table are probably low, but the determinations are of value in indicating the quantities carried on days when regular silt samples were not taken.

Results have been reported [4] for the quantity of suspended matter carried by the Colorado River in 1925–1928. They were computed from weighted averages of results for samples collected several times a week solely for measurement of the silt content. In order to obtain more accurate figures daily loads have been calculated for each day during the period 1926–1930. For days when silt samples were collected the results of their examination were used to calculate the load. For the other days the load of suspended matter was estimated from consideration of the suspended matter in the samples collected for analysis of the mineral content, together with discharge data for the period. This method gives results for the annual loads that are somewhat lower than those previously reported.[5] The weighted average load of suspended matter carried past the Grand Canyon station in the year ending September 30, 1926, was 225,000,000 tons. The sums of the daily loads for each succeeding year were 396,000,000, 172,000,000, 480,000,000, and 236,000,000 tons respectively.

[4] Howard, C. S., Suspended matter in the Colorado River in 1925–1928: U. S. Geol. Survey Water-Supply Paper 636, pp. 15–44, 1930.

[5] Idem, p. 24.

ANALYSES

TABLE 3.—*Analyses of water from Colorado River and certain tributaries*

[C. S. Howard, S. K. Love, W. L. Lamar, K. T. Williams, and T. Judson, analysts. Analytical results in parts per million]

Colorado River at Grand Canyon, Ariz.

No.	Date of collection	Analyst	Suspended matter	Residue on evaporation	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulphate (SO_4)	Chloride (Cl)	Nitrate (NO_3)	Dissolved solids	Hardness as $CaCO_3$ (calculated)		Mean discharge (second-feet)	Dissolved solids (tons per day)
																Total	Non-carbonate		
	1928																		
1	Oct. 1–5, 8–10	S. K. L.	2,070	1,398	18	0.06	142	59	209	6.6	215	612	164	16	1,333	597	421	6,200	22,300
2	Oct. 11–20	do	20,000	1,586	15	.07	208	56	196	7.7	206	798	128	5.4	1,516	750	581	14,000	57,200
3	Oct. 21–31	do	8,800	1,253	16	.07	151	45	166	9.6	198	585	112	5.5	1,188	562	400	9,160	29,300
4	Nov. 1–10	do	10,100	1,103	16	.06	125	41	159	8.3	201	494	109	7.2	1,059	481	316	11,900	34,000
5	Nov. 11–20	do	2,600	1,134	20	.09	121	46	173	5.1	216	492	121	10	1,095	491	314	9,250	27,300
6	Nov. 21–30	do	1,660	1,091	18	.08	112	45	168	5.4	219	453	124	8.3	1,042	464	285	8,550	24,000
7	Dec. 1, 3–10	do	1,230	1,090	15	.07	111	48	170	5.0	222	443	136	8.6	1,046	474	292	8,380	23,600
8	Dec. 11–20	do	770	1,142	16	.07	112	50	182	5.1	235	452	153	7.5	1,093	485	293	5,740	16,900
9	Dec. 21–31	do	320	1,416	18	.05	134	59	235	5.9	276	533	220	13	1,354	577	351	3,940	14,400
	1929																		
10	Jan. 1–2, 4–10	do	480	1,326	18	.06	131	57	210	5.6	276	500	190	12	1,260	561	335	5,770	19,600
11	Jan. 11–17	do	230	1,251	18	.06	125	54	197	5.0	279	452	184	11	1,183	534	305	5,120	16,300
12	Jan. 21–22, 24–31	do	460	1,154	22	.12	114	50	186	4.3	250	429	167	12	1,108	490	285	6,120	18,300
13	Feb. 1–10	do	1,090	1,063	20	.12	108	46	161	4.3	233	391	150	12	1,007	459	268	7,360	20,000
14	Feb. 11–19	do	610	1,100	19	.08	108	45	175	4.3	227	403	165	11	1,049	454	269	5,630	15,900
15	Feb. 20–28	do	570	1,166	20	.10	113	49	181	4.5	238	434	165	13	1,097	483	288	6,430	19,000
16	Mar. 1–10	do	1,790	1,090	12	.14	107	46	175	3.5	224	413	158	10	1,035	456	273	8,280	23,100
17	Mar. 11–20	do	20,600	900	11	.20	104	33	125	6.1	190	392	79	9.0	853	395	240	23,700	54,500
18	Mar. 21–31	C. S. H.	6,900	856	15	.13	98	32	126	6.4	200	341	88	5.2	810	376	212	14,500	31,700
19	Apr. 1–10	do	16,700	698	13	.13	89	25	95	5.3	193	265	70	2.1	660	325	167	29,200	52,000
20	Apr. 11–20	T. J.	8,700	581	14	.10	71	24	78	6.1	182	218	56	2.7	560	276	127	23,500	35,500
21	Apr. 21–30	S. K. L.	9,000	466	18	.16	59	20	59	7.7	172	162	36	.40	447	230	89	36,500	44,000
22	May 1–10	do	5,400	463	14	.10	58	21	53	5.0	172	160	38	2.9	437	231	90	31,700	37,400
23	May 11–20	S. K. L., C. S. H.	7,100	332	12	.31	48	16	37	6.6	155	102	22	1.2	322	186	59	62,900	54,600
24	May 22–31	do	9,400	272	11	.33	42	13	27	4.6	136	77	15	1.8	259	158	47	92,800	64,800
25	June 1–10	C. S. H.	5,400	270	17	.12	42	12	27	5.6	132	77	14	1.3	261	154	46	84,100	59,200
26	June 11, 13–20	do	3,500	230	14	.18	36	12	20	7.0	117	63	15	1.2	226	139	43	86,400	52,700
27	June 21–30	do	2,090	249	13	.29	40	12	23	4.5	125	72	18	.78	245	149	47	67,700	44,700
28	July 1–10	do	1,530	289	22	.24	42	13	31	3.5	121	86	23	1.0	281	158	59	45,600	34,600

TABLE 3.—*Analyses of water from Colorado River and certain tributaries*—Continued

Colorado River at Grand Canyon, Ariz.—Continued

No.	Date of collection	Analyst	Suspended matter	Residue on evaporation	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulphate (SO_4)	Chloride (Cl)	Nitrate (NO_3)	Dissolved solids	Hardness as $CaCO_3$ (calculated)		Mean discharge (second feet)	Dissolved solids (tons per day)
																Total	Non-carbonate		
	1929																		
29	July 11-20	C. S. H	3,500	426	22	0.60	61	18	48	5.6	147	151	37	0.21	416	226	106	26,800	30,100
30	July 21-31	do	24,000	658	17	.51	80	23	91	8.5	164	272	61	.18	634	294	160	31,200	53,300
31	Aug. 1-3, 5, 6, 9, 10	do	51,000	1,014	39	.37	142	35	104	14	202	503	43	1.1	981	498	333	51,900	137,000
32	Aug. 11-13, 15-20	do	26,000	747	20	.23	96	23	102	4.5	186	327	44	.80	709	334	182	33,600	64,200
33	Aug. 21-31	do	4,100	710	18	.17	96	26	95	3.4	178	291	68	1.2	686	347	201	13,700	25,400
34	Sept. 1, 2, 4-10	do	33,000	911	37	.05	119	35	107	8.3	194	426	66	.60	895	441	282	26,400	63,700
35	Sept. 11-20	S. K. L	14,400	814	20	.30	106	29	94	5.3	175	368	50	1.6	760	384	241	25,900	53,100
36	Sept. 21, 23-30	do	35,000	805	22	.38	104	26	99	5.3	191	354	50	1.3	756	367	220	33,200	67,700
37	Average of analyses 1-36		9,400	863	18	.17	99	35	122	5.9	196	350	93	5.5	824	389	229	-------	-------
38	Weighted average of analyses 1-36		11,900	579	18	.23	74	23	73	6.2	164	229	48	2.5	555	281	146	26,800	40,100

Colorado River near Cisco, Utah

	1929																		
39	Oct. 1-3, 5-10	S. K. L	350	789	14	0.06	82	38	98	4.8	160	340	61	6.5	723	361	230	7,310	14,300
40	Oct. 11-15, 17-20	do	1,490	839	16	.19	90	39	103	3.8	167	364	62	6.5	767	385	248	7,240	15,000
41	Oct. 21-31	do	350	945	16	.08	95	49	127	3.7	185	423	82	11	898	438	287	5,250	12,700
42	Nov. 1-10	do	114	1,013	14	.08	100	50	135	3.2	192	445	85	12	939	455	298	5,090	12,900
43	Nov. 11-20	do	121	1,081	13	.06	106	51	152	6.6	207	463	104	10	1,008	474	305	4,610	12,500
44	Nov. 21-30	do	94	1,071	15	.08	109	52	151	5.0	219	461	104	13	1,018	486	306	4,120	11,300
45	Dec. 1-10	do	163	1,075	15	.06	107	52	155	5.1	215	468	107	14	1,029	481	305	3,920	10,900
46	Dec. 11-12, 16-20	do	53	1,074	14	.08	109	50	159	5.3	215	469	110	13	1,035	478	301	3,570	9,970
47	Dec. 21-31	do	97	1,386	14	.08	127	61	215	6.1	246	544	180	16	1,284	568	366	2,760	9,560
	1930																		
48	Jan. 1-10	W. L. L	135	1,242	13	.07	115	56	186	7.0	226	498	152	12	1,150	517	332	2,720	7,790
49	Jan. 11-13, 18-20	do	152	1,277	17	.07	118	60	193	9.3	227	525	156	13	1,203	541	355	2,400	8,440
50	Jan. 21-31	do	112	1,263	14	.08	116	56	189	7.4	228	493	151	14	1,153	520	333	1,990	6,190
51	Feb. 1-10	do	880	1,137	15	.09	105	51	168	6.4	213	447	134	12	1,043	472	297	3,390	9,540

52	Feb. 11–19	do	450	1,092	13	.04	100	50	172	6.7	201	473	122	11	1,047	455	290	3,800	10,700
53	Feb. 20–28	do	1,320	1,131	10	.05	101	52	178	6.1	202	509	109	10	1,075	466	300	4,010	11,600
54	Mar. 1–10	do	740	1,202	10	.05	111	53	191	6.7	214	521	140	10	1,148	495	320	3,230	10,000
55	Mar. 11–20	do	3,000	1,122	10	.11	102	52	174	3.5	[a] 208	472	133	11	1,060	468	298	3,290	9,410
56	Mar. 21–31	do	215	1,017	6.4	.05	99	46	153	8.2	205	407	123	9.1	953	436	268	3,350	8,610
57	Apr. 1–8, 10	do	1,380	897	13	.08	89	41	130	6.6	200	348	106	8.2	840	391	227	7,320	16,600
58	Apr. 11–20	do	3,100	347	13	.08	54	15	35	5.6	160	109	24	4.1	339	196	65	18,600	17,100
59	Apr. 21–30	do	2,490	331	13	.09	51	14	35	5.6	140	116	25	3.0	332	185	70	20,400	18,300
60	May 1–10	do	1,430	340	13	.09	48	15	37	4.6	128	114	28	3.4	326	182	77	16,400	14,400
61	May 11–20	do	950	508	14	.06	61	23	63	5.0	140	201	45	5.6	487	247	132	10,800	14,200
62	May 21–31	C. S. H.	2,900	336	17	.38	49	17	30	4.0	130	113	23	2.4	320	192	86	22,600	19,500
63	June 1–10	K. T. W.	1,380	278	14	.40	41	13	28	3.0	104	100	20	2.4	273	156	71	29,100	21,400
64	June 11–20	do	1,020	257	11	.08	43	11	25	2.4	118	84	17	2.1	254	153	56	30,500	20,900
65	June 21–30	do	780	360	11	.08	53	16	41	2.6	124	136	27	3.6	351	198	96	18,500	17,500
66	July 1–3, 5–10	do	350	563	13	.02	63	25	78	3.5	127	233	59	6.5	544	260	156	7,530	11,000
67	July 11–20	do	3,800	785	15	.12	91	34	105	4.8	159	346	72	8.0	754	367	237	6,830	13,900
68	July 21–23, 25–31	do	1,800	853	13	.06	98	38	110	3.8	174	378	70	9.0	806	401	258	6,890	15,000
69	Aug. 1–10	do	14,000	875	20	.20	114	34	107	5.1	186	405	56	3.9	837	424	272	9,760	22,000
70	Aug. 11–20	do	13,800	784	14	.10	114	32	91	4.6	204	361	48	3.1	768	416	249	11,500	23,800
71	Aug. 21–31	do	820	905	14	.06	98	43	130	4.0	177	414	84	11	885	421	276	4,720	11,300
72	Sept. 2–6, 8–10	do	1,330	1,296	14	.06	128	59	204	5.1	196	598	147	21	1,273	562	401	3,480	11,900
73	Sept. 11–20	do	33	1,332	14	.06	134	64	193	4.8	194	653	119	20	1,297	597	439	3,220	11,300
74	Sept. 21–30	do	3,800	1,531	15	.08	158	68	225	4.2	222	743	138	26	1,487	674	492	3,450	13,800
75	Average of analyses 39–74		1,800	898	14	.10	94	41	127	5.1	184	383	90	9.6	853	403	253		
76	Weighted average of analyses 39–74		2,320	619	14	.14	73	28	80	4.4	156	254	55	6.1	593	298	169	8,420	13,500

Colorado River at Lees Ferry, Ariz.

	1929																		
77	Oct. 1–10	S. K. L.	3,500	615	12	0.07	79	26	73	4.3	160	272	31	4.0	580	304	173	17,300	27,100
78	Oct. 11–20	do	3,000	714	12	.06	85	31	89	3.5	171	312	46	5.2	668	340	199	15,700	28,300
79	Oct. 21–31	do	2,240	760	11	.06	89	34	98	3.4	174	334	56	5.2	716	362	219	12,200	23,600
80	Nov. 1–10	do	1,020	864	9.6	.10	96	38	108	6.7	195	363	69	5.8	792	396	236	10,200	21,800
81	Nov. 11–20	do	920	903	12	.18	97	41	119	5.4	200	381	76	6.2	836	411	247	9,820	22,100
82	Nov. 21–30	do	700	954	12	.20	103	44	127	5.9	211	401	86	5.5	888	438	265	8,090	19,400
83	Dec. 1–10	do	750	1,014	14	.12	108	47	134	8.2	220	428	96	8.2	952	463	282	7,870	20,200
84	Dec. 11–20	do	600	982	14	.13	103	45	133	5.1	217	403	95	7.8	913	442	264	8,000	19,700
85	Dec. 21–31	do	350	966	14	.12	100	45	136	4.6	220	392	100	7.5	908	434	254	5,550	13,600
	1930																		
86	Jan. 1–10	W. L. L.	280	1,174	10	.08	123	52	167	8.8	249	478	135	10	1,107	521	317	5,340	15,900
87	Jan. 11–20	do	214	1,076	10	.10	113	48	156	8.2	242	430	126	8.8	1,019	479	281	5,400	14,800
88	Jan. 21–31	do	194	1,185	9.0	.09	125	53	174	8.2	262	472	138	8.3	1,117	530	315	3,740	11,200
89	Feb. 1–10	do	590	1,087	11	.06	113	47	158	3.2	245	435	127	8.3	1,023	475	274	6,360	17,500
90	Feb. 11–19	do	1,120	931	7.0	.07	101	41	130	3.2	215	381	100	6.7	876	421	244	8,040	19,000

[a] Includes equivalent of small quantity of carbonate (CO_3).

TABLE 3.—*Analyses of water from Colorado River and certain tributaries*—Continued

Colorado River at Lees Ferry, Ariz.—Continued

No.	Date of collection	Analyst	Suspended matter	Residue on evaporation	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulphate (SO_4)	Chloride (Cl)	Nitrate (NO_3)	Dissolved solids	Hardness as $CaCO_3$ (calculated)		Mean discharge (second-feet)	Dissolved solids (tons per day)
																Total	Non-carbonate		
	1930																		
91	Feb. 20-28	W. L. L	2,600	960	7.0	0.07	105	40	135	4.8	205	418	92	6.7	910	426	258	11,900	29,200
92	Mar. 1-10	do	1,700	938	9.8	.10	95	41	137	6.6	205	402	90	4.1	887	406	238	9,610	23,000
93	Mar. 11-20	do	1,040	933	4.4	.05	99	43	142	6.9	210	405	105	5.1	914	424	252	8,190	20,200
94	Mar. 21-31	do	1,770	912	10	.06	93	41	127	9.1	206	373	90	4.5	849	401	232	9,900	22,700
95	Apr. 1-10	do	1,520	797	8.6	.06	84	36	110	6.4	198	323	78	3.5	747	358	195	10,100	20,300
96	Apr. 11-12, 14-20	C. S. H	6,900	492	24	.41	63	23	66	3.5	180	176	41	.54	486	252	104	37,500	49,200
97	Apr. 21-30	do	4,400	349	19	.17	52	18	38	4.6	161	115	24	.48	351	204	72	38,300	36,000
98	May 1-10	K. T. W	3,300	304	16	.24	47	14	32	3.5	145	97	20	1.2	302	175	56	38,300	31,200
99	May 11-20	do	1,360	375	14	.08	53	18	42	3.8	150	133	28	2.2	368	206	83	24,200	24,000
100	May 21-31	do	2,030	383	14	.14	53	18	46	3.7	149	142	29	1.8	381	206	84	33,800	34,700
101	June 1-10	do	4,900	294	15	.10	48	13	29	2.9	139	96	16	.60	289	173	59	56,800	44,300
102	June 11-20	do	330	261	14	.16	41	12	26	2.7	121	84	16	1.0	256	152	52	57,500	39,700
103	June 21-30	do	2,500	317	18	.21	47	14	34	3.2	129	115	20	.55	315	175	69	40,300	34,200
104	July 1-10	do	530	374	13	.12	51	17	44	3.4	130	138	32	2.0	365	197	91	18,300	18,000
105	July 11-20	do	9,300	645	19	.54	83	27	80	4.3	178	264	51	.40	617	318	172	15,600	26,000
106	July 20-31	do	13,500	776	19	.39	100	28	99	4.5	175	361	47	.20	745	365	221	17,800	35,800
107	Aug. 1-10	do	20,500	932	20	.18	126	32	107	4.6	178	453	50	.20	881	446	300	20,500	48,700
108	Aug. 11-20	do	44,000	1,087	21	.13	156	36	114	5.3	191	560	38	.20	1,025	538	381	34,700	95,900
109	Aug. 21-31	do	9,100	662	16	.30	85	25	86	5.6	188	286	41	1.0	638	315	161	16,800	28,900
110	Sept. 1-10	do	5,500	756	23	.25	94	30	97	6.4	174	339	55	3.3	734	358	215	11,000	21,800
111	Sept. 11-20	do	6,500	1,120	12	.08	141	42	144	6.2	189	543	81	8.2	1,071	525	370	8,460	24,400
112	Sept. 21-30	do	1,760	1,076	13	.10	120	46	148	6.4	186	498	93	17	1,033	489	336	6,810	19,000
113	Average of analyses 77-112		4,500	778	14	.15	91	34	102	5.2	188	328	67	4.5	738	365	210	------	------
114	Weighted average of analyses 77-112		6,100	597	15	.17	76	25	74	4.3	167	247	44	2.5	571	295	157	18,000	27,800

	1929																		
115	Oct. 1, 4–10	S. K. L.	4,600	670	19	0.25	82	26	85	5.1	168	267	60	4.4	632	312	174	17,900	30,500
116	Oct. 11–20	do	3,900	760	21	.13	88	32	103	3.8	184	303	71	7.2	720	351	200	15,900	30,900
117	Oct. 21–31	do	3,200	813	37	.14	94	35	111	4.3	188	334	81	5.5	795	378	224	12,700	27,200
118	Nov. 1, 3–10	do	1,180	883	17	.20	95	40	122	7.6	202	352	94	6.9	824	402	236	10,700	23,800
119	Nov. 11–20	do	880	934	18	.08	101	42	134	6.2	218	378	103	6.1	896	425	246	10,200	24,700
120	Nov. 21–30	do	620	979	15	.08	105	45	147	5.4	228	402	118	5.6	955	447	260	8,580	22,100
121	Dec. 1, 2, 4–10	do	620	1,047	15	.08	112	47	154	10	240	424	130	6.1	1,016	473	276	8,170	22,400
122	Dec. 11–19	do	620	1,038	16	.08	105	46	149	9.1	233	399	126	7.4	972	451	260	8,290	21,700
123	Dec. 22–31	W. L. L.	330	1,046	16	.10	105	45	161	8.8	240	377	144	7.0	982	447	250	6,120	16,200
	1930																		
124	Jan. 1, 3–10	do	217	1,234	15	.10	124	53	198	9.3	268	457	184	9.6	1,182	527	308	5,500	17,500
125	Jan. 12–20	do	220	1,137	11	.09	114	50	178	8.5	261	409	172	7.1	1,078	490	276	5,940	17,300
126	Jan. 21–24	do	217	1,169	18	.05	119	50	185	9.0	268	423	176	8.0	1,120	502	283	4,160	12,600
127	Feb. 2, 4–10	do	340	1,145	16	.04	115	50	177	8.2	257	429	158	9.2	1,089	492	282	6,370	18,700
128	Feb. 11–19	do	790	1,006	12	.05	106	44	158	6.7	236	375	134	7.1	959	445	252	8,130	21,000
129	Feb. 20–28	do	2,700	978	13	.04	105	42	148	5.1	210	399	113	5.6	934	435	263	11,700	29,500
130	Mar. 1–3, 5–8, 10	do	1,980	963	7.2	.12	95	40	152	5.8	202	394	116	6.2	916	402	236	10,300	25,400
131	Mar. 11–20	do	1,200	1,027	14	.05	101	44	161	6.9	224	394	136	5.6	973	433	249	8,570	22,500
132	Mar. 21–31	do	3,100	963	12	.06	99	40	148	7.0	234	360	122	5.0	908	412	220	10,900	26,700
133	Apr. 1–3, 6–10	do	2,360	836	12	.11	86	35	124	6.9	215	302	106	4.0	782	358	182	10,500	22,100
134	Apr. 11–13, 15–20	do	10,900	554	8.2	.12	69	23	71	6.7	187	199	51	3.1	523	267	114	36,800	51,900
135	Apr. 21–28, 30	C. S. H.	5,900	382	16	.12	57	18	40	4.5	177	113	32	1.6	369	216	71	37,000	36,800
136	May 1, 3, 5–10	do	4,900	346	14	.07	53	16	30	5.0	172	97	29	1.0	330	198	57	39,000	34,700
137	May 11–20	K. T. W.	2,110	385	14	.08	54	17	48	3.8	158	127	38	3.3	383	205	75	24,900	25,700
138	May 21–31	do	2,900	420	15	.24	56	19	52	4.2	155	147	40	3.0	413	218	91	33,500	37,300
139	June 1–8, 10	do	6,600	349	17	.09	59	15	35	3.5	174	104	23	3.0	345	209	66	56,400	52,500
140	June 11–20	do	3,600	289	16	.08	48	12	31	3.2	143	86	22	2.2	291	169	52	56,900	44,700
141	June 21–25, 27–30	do	2,600	328	14	.10	50	14	36	3.5	139	107	27	2.0	322	182	68	41,800	36,300
142	July 2, 4–10	do	720	410	19	.10	52	18	56	3.2	138	141	49	2.8	409	204	91	19,400	21,400
143	July 11–20	do	22,700	783	17	.14	101	27	110	6.6	194	324	80	.50	762	363	204	17,800	36,600
144	July 21–27, 29–31	do	18,700	819	18	.06	106	28	110	6.6	192	365	64	2.2	794	380	222	19,300	41,300
145	Aug. 1–10	do	33,000	989	23	.14	132	34	121	4.6	204	463	64	.80	943	469	302	22,600	57,500
146	Aug. 11–20	do	58,000	1,102	20	.08	155	35	126	5.3	203	557	50	.20	1,049	531	364	38,000	108,000
147	Aug. 21–31	do	12,200	689	19	.18	85	26	104	4.2	200	285	58	1.0	681	319	155	17,800	32,700
148	Sept. 1–10	do	6,300	801	21	.16	96	30	120	4.6	190	336	83	5.1	789	363	207	11,100	23,600
149	Sept. 11–12, 14–20	do	9,200	1,216	19	.20	153	44	166	5.3	205	568	114	8.2	1,179	563	395	8,920	28,500
150	Sept. 21–30	do	1,600	1,000	13	.08	118	44	166	4.3	209	458	130	18	1,054	475	304	6,760	19,200
151	Average of analyses 115–150		6,400	821	16	.11	94	34	117	5.9	203	324	92	5.0	788	375	209	-------	-------
152	Weighted average of analyses 115–150		9,300	645	16	.11	81	26	85	5.0	184	252	62	3.4	622	311	160	18,500	31,100

TABLE 3.—*Analyses of water from Colorado River and certain tributaries*—Continued

Green River at Green River, Utah

No.	Date of collection	Analyst	Suspended matter	Residue on evaporation	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulphate (SO_4)	Chloride (Cl)	Nitrate (NO_3)	Dissolved solids	Hardness as $CaCO_3$ (calculated)		Mean discharge (second-feet)	Dissolved solids (tons per day)
																Total	Non-carbonate		
	1929																		
153	Oct. 1-10	S. K. L.	2,800	619	17	0.14	67	29	82	4.2	190	255	36	1.5	585	286	131	4,520	7,130
154	Oct. 11-20	do	2,460	585	19	.11	64	31	76	3.7	194	238	34	1.6	563	287	128	4,400	6,680
155	Oct. 21-31	do	1,080	607	14	.16	67	34	82	3.4	201	253	39	1.6	593	307	142	3,610	5,770
15b	Nov. 1-10	do	640	646	13	.06	69	35	83	3.4	213	262	43	1.5	615	316	142	3,370	5,590
157	Nov. 11, 13-20	do	460	701	8.0	.08	75	37	93	5.1	223	285	48	1.8	663	339	157	2,930	5,240
158	Nov. 21-30	do	420	742	14	.06	81	40	104	3.7	255	304	51	2.0	725	366	158	2,080	4,070
159	Dec. 1-9	do	330	720	12	.06	80	39	99	4.5	254	286	52	1.8	699	360	152	2,560	4,820
160	Dec. 11-20	do	440	656	11	.08	73	35	90	4.0	234	262	46	2.2	639	326	134	2,580	4,450
161	Dec. 21-31	do	189	766	12	.08	81	40	97	8.3	246	304	52	1.9	717	366	165	1,350	2,610
	1930																		
162	Jan. 1-10	W. L. L.	207	816	12	.07	89	43	104	5.9	[a]265	308	62	2.0	756	399	182	1,570	3,200
163	Jan. 11-14, 19-20	do	153	800	14	.04	87	41	102	5.6	[a]265	310	60	2.2	752	386	169	1,140	2,300
164	Jan. 21-31	do	340	816	11	.09	89	43	105	6.4	273	315	62	2.2	768	399	175	1,070	2,220
165	Feb. 1-10	do	1,470	728	10	.08	82	38	91	6.1	[a]257	275	54	1.8	685	361	150	3,060	5,650
166	Feb. 11-19	do	910	665	11	.03	72	34	93	3.8	218	271	48	2.1	642	319	141	3,840	6,650
167	Feb. 20-28	do	3,000	688	9.2	.06	70	34	101	3.4	199	300	44	2.4	662	314	151	5,710	10,200
168	Mar. 1-10	do	1,060	676	7.0	.07	68	34	94	6.1	204	304	46	1.8	661	309	142	3,680	6,560
169	Mar. 11-20	do	1,710	720	4.6	.05	77	38	101	4.5	228	299	50	1.6	688	348	162	3,550	6,590
170	Mar. 21, 23-31	do	2,250	630	14	.08	69	32	88	4.5	205	264	41	1.3	615	304	136	4,650	7,710
171	Apr. 1-10	do	2,230	655	13	.06	70	34	91	4.2	210	269	43	1.4	629	314	142	4,350	7,380
172	Apr. 11-20	do	6,600	388	15	.09	52	19	44	4.3	194	130	19	.61	380	208	49	13,500	13,800
173	Apr. 21-30	do	4,600	365	9.8	.06	57	18	35	4.3	176	124	16	1.8	353	216	72	12,900	12,300
174	May 1-10	do	2,470	273	9.8	.07	43	15	24	3.0	153	78	13	1.0	262	169	44	14,100	9,960
175	May 11-20	do	1,250	320	11	.10	45	17	34	4.2	154	110	17	.74	315	182	56	9,490	8,060
176	May 21-31	K. T. W.	8,800	321	14	.11	46	17	36	3.7	164	102	18	.80	318	185	50	11,900	10,200
177	June 1-10	do	3,300	239	17	.48	37	13	21	2.9	130	68	12	1.2	237	146	39	19,500	12,500
178	June 11-20	do	2,900	258	14	.08	40	13	25	2.1	139	75	10	1.0	249	153	39	19,300	13,000
179	June 21-30	do	1,540	249	13	.08	39	13	24	2.2	129	73	12	1.2	241	151	45	13,600	8,840
180	July 1-3, 5-10	do	420	303	14	.04	44	15	32	3.8	155	91	18	.80	295	172	44	6,240	4,960
181	July 11-20	do	7,500	447	18	.08	57	21	56	4.2	180	168	25	.90	439	229	81	5,470	6,480
182	July 21-31	do	2,900	444	17	.04	59	21	54	2.7	187	156	26	1.8	430	234	80	5,160	5,980
183	Aug. 1-9	do	20,200	881	20	.13	116	38	98	4.2	217	420	32	.20	835	446	268	5,270	11,900
184	Aug. 11-20	do	29,000	763	19	.08	93	30	99	4.3	216	340	34	.40	726	356	178	12,800	25,100
185	Aug. 21-31	do	6,200	461	14	.24	59	19	63	5.0	184	172	27	.40	450	225	75	6,760	8,200

186	Sept. 2–10	do	6,900	627	17	.28	79	27	79	4.8	184	271	34	.20	603	308	157	4,780	7,770
187	Sept. 11–20	do	1,590	544	11	.16	65	26	72	4.8	189	212	38	2.1	524	269	114	2,960	4,180
188	Sept. 21–30	do	6,200	701	11	.14	79	31	96	5.3	191	310	43	.80	670	325	168	3,650	6,590
189	Average of analyses 153–188		3,700	578	13	.10	68	29	74	4.4	202	230	36	1.4	555	288	123		
190	Weighted averages of analyses 153–188		5,100	464	14	.12	59	23	56	3.8	179	177	26	1.2	448	240	93	6,290	7,630

San Juan River at Goodridge, near Bluff, Utah

	1929																		
191	Oct. 1–10	S. K. L	16,200	361	20	0.14	60	13	35	2.9	129	154	8.0	1.7	358	203	97	2,990	2,890
192	Oct. 11–20	do	11,200	473	16	.10	73	17	49	2.7	139	215	10	2.9	454	252	138	2,170	2,660
193	Oct. 21–31	do	10,100	513	14	.09	79	18	49	5.4	154	230	13	2.3	487	271	145	1,500	1,970
194	Nov. 1–9	do	6,300	591	13	.25	88	23	56	5.9	161	272	15	2.3	555	314	182	1,250	1,870
195	Nov. 11–15, 17–20	do	6,500	613	12	.31	90	25	59	5.9	168	282	18	.83	576	328	190	1,070	1,660
196	Nov. 21–30	do	10,100	630	9.0	.16	94	25	62	5.3	171	296	17	3.5	596	338	197	881	1,420
197	Dec. 2–10	do	6,300	724	15	.15	102	29	75	3.4	180	346	20	4.7	684	374	226	864	1,590
198	Dec. 11–20	do	6,800	741	13	.10	102	31	72	6.0	180	355	20	5.1	693	382	234	776	1,450
199	Dec. 21–30	do	1,920	895	13	.08	124	36	94	3.5	224	425	26	5.1	837	458	274	403	910
	1930																		
200	Jan. 1, 4–10	W. L. L	5,500	684	8.2	.12	101	26	68	5.0	168	334	22	2.8	650	359	221	555	973
201	Jan. 11–18, 20	do	3,100	823	6.0	.07	118	31	85	5.3	200	399	26	3.3	772	422	258	484	1,010
202	Jan. 21–31	do	4,200	896	11	.08	128	35	92	4.5	220	432	26	5.1	842	464	283	399	906
203	Feb. 1, 2, 4–10	do	6,000	741	17	.07	91	31	82	2.6	137	377	24	2.7	695	355	242	763	1,430
204	Feb. 11–19	do	9,400	713	11	.07	93	28	79	3.2	147	362	21	3.8	673	347	227	1,550	2,810
205	Feb. 20–26, 28	do	11,400	803	8.8	.06	105	33	87	3.0	169	411	23	3.1	757	398	259	1,530	3,120
206	Mar. 1, 3–10	do	28,000	768	6.0	.07	103	33	81	4.2	[a] 169	384	22	2.5	716	393	253	924	1,780
207	Mar. 11–20	do	7,500	705	11	.06	97	30	74	4.6	171	348	22	2.3	673	366	225	1,210	2,200
208	Mar. 21–31	do	9,800	583	14	.10	87	24	55	4.6	175	270	14	2.0	557	316	172	1,570	2,360
209	Apr. 1–10	do	15,100	479	13	.05	74	20	40	4.2	164	211	11	1.5	456	267	132	2,790	3,430
210	Apr. 11–20	do	12,000	314	13	.05	54	12	26	4.0	142	118	6.0	1.2	304	184	68	4,810	3,940
211	Apr. 21–24, 26–29	K. T. W	12,600	301	17	.08	55	12	25	2.9	152	108	5.0	1.0	301	187	62	5,710	4,640
212	May 1–10	do	8,600	285	16	.08	50	11	24	2.6	132	104	5.0	1.4	279	170	62	4,200	3,160
213	May 12–20	do	10,000	347	14	.04	60	14	31	2.4	144	136	8.0	1.8	338	207	89	2,820	2,570
214	May 21–31	do	1,430	275	18	.08	49	10	23	2.6	136	93	6.0	1.2	270	164	52	6,020	4,380
215	June 1–10	do	2,900	276	16	.06	53	10	20	2.7	134	96	4.0	1.0	269	174	64	7,630	5,540
216	June 11–16, 18–20	do	7,000	206	13	.06	39	7.5	16	2.1	108	64	4.0	1.3	200	128	40	6,490	3,500
217	June 21–30	do	4,500	288	18	.04	51	9.2	23	3.2	122	106	7.0	1.5	279	165	65	3,030	2,280
218	July 1–10	do	2,010	335	18	.04	61	14	38	3.7	126	170	12	1.2	330	210	107	973	997
219	July 11–20	do	78,000	1,181	25	.07	182	37	119	6.6	259	606	22	.40	1,126	607	394	2,400	7,290
220	July 21–31	do	44,000	750	24	.16	107	20	95	4.2	210	353	14	1.4	722	350	177	4,260	8,300
221	Aug. 1–10	do	80,000	700	20	.10	97	20	92	4.2	213	320	14	.50	673	324	150	5,370	9,750
222	Aug. 11, 12, 14–20	do	48,000	673	19	.10	101	19	87	3.7	202	322	11	1.4	664	330	165	6,040	10,800
223	Aug. 21–31	do	5,500	538	21	.06	84	17	64	3.5	161	254	14	3.0	540	280	148	915	1,330
224	Sept. 1–4, 8–10	do	11,900	770	20	.08	114	26	91	4.0	175	398	21	2.8	763	.392	248	544	1,120

[a] Includes equivalent of small quantity of carbonate (CO_3).

TABLE 3.—*Analyses of water from Colorado River and certain tributaries*—Continued

San Juan River at Goodridge, near Bluff, Utah—Continued

No.	Date of collection	Analyst	Suspended matter	Residue on evaporation	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulphate (SO_4)	Chloride (Cl)	Nitrate (NO_3)	Dissolved solids	Hardness as $CaCO_3$ (calculated)		Mean discharge (second-feet)	Dissolved solids (tons per day)
																Total	Non-carbonate		
	1930																		
225	Sept. 11–20	K. T. W	4,300	756	21	0.12	106	27	90	4.0	169	385	22	4.8	743	376	237	405	81
226	Sept. 21–30	do	2,800	878	12	.10	123	31	105	3.2	185	454	26	12	857	435	283	355	821
227	Average of analyses 191–226		14,200	602	15	.10	89	22	63	3.9	167	283	16	2.7	576	314	177	-------	-------
228	Weighted average of analyses 191–226		19,300	483	16	.10	75	17	50	3.5	159	214	11	1.7	466	257	127	2,380	2,990

Williams River near Planet, Ariz.

	1929																		
229	Oct. 23	S. K. L	4	406	30	0.06	46	17	72	4.6	248	56	58	1.1	407	185	0	16	17
230	Nov. 17	do	19	452	34	.08	43	14	98	6.6	260	60	79	1.5	464	165	0	18	23
231	Dec. 21	do	11	439	35	.04	41	14	90	5.9	244	59	70	1.3	436	160	0	19	22
	1930																		
232	Jan. 13	W. L. L	-------	402	27	.09	46	15	69	7.5	252	55	56	1.2	401	176	0	18	20
233	Jan. 26	do	-------	444	27	.08	42	15	91	7.5	246	61	75	1.7	441	166	0	18	21
234	Feb. 9	do	-------	440	29	.08	40	14	92	9.3	[a] 236	60	74	1.4	436	157	0	17	20
235	Feb. 23	do	-------	434	30	.04	40	13	93	7.2	[a] 236	60	75	.64	435	153	0	18	21
236	Mar. 9	do	-------	430	28	.06	40	14	90	4.8	[a] 238	65	76	1.3	436	157	0	16	19
237	Mar. 20	do	7,500	273	31	.12	41	12	31	5.8	190	32	24	.38	271	152	0	784	571
238	Mar. 21	do	8,600	267	19	.12	42	11	30	4.6	192	29	22	.41	253	150	0	412	281
239	Mar. 23	do	2,170	388	31	.10	47	14	64	6.9	235	50	56	1.3	386	175	0	82	85
240	Apr. 26	do	-------	390	24	.06	47	15	68	6.6	249	58	54	.92	396	179	0	11	12
241	June 22	K. T. W	-------	562	54	.04	39	9.1	136	7.4	204	75	134	1.8	557	135	0	14	21
242	July 20	do	-------	457	38	.04	41	13	97	6.6	242	61	81	2.4	459	156	0	15	19
243	July 21	do	28,000	526	47	.22	60	22	100	6.6	427	11	73	5.4	536	240	0	16	23
244	Aug. 21	do	83	476	44	.06	41	15	99	5.8	242	60	84	2.0	470	164	0	12	15
245	Sept. 29	do	-------	430	33	.06	41	13	90	5.0	243	57	69	2.0	430	156	0	17	20

[a] Includes equivalent of small quantity of carbonate (CO_3).