UNIVERSITY OF CALIFORNIA PUBLICATIONS.

UNIVERSITY OF CALIFORNIA—COLLEGE OF AGRICULTURE.

AGRICULTURAL EXPERIMENT STATION.

LANDS OF THE COLORADO DELTA IN THE SALTON BASIN.

FIELD AND LABORATORY WORK

BY FRANK J. SNOW.

DISCUSSION

BY E. W. HILGARD AND G. W. SHAW.

BULLETIN No. 140.

(Berkeley, February, 1902.)

SACRAMENTO:

A. J. JOHNSTON, : : : : : SUPERINTENDENT STATE PRINTING.

1902.

BENJAMIN IDE WHEELER, Ph.D., LL.D., *President of the University.*

EXPERIMENT STATION STAFF.

E. W. HILGARD, Ph.D., LL.D., *Director and Chemist.*
E. J. WICKSON, M.A., *Horticulturist.*
W. A. SETCHELL, Ph.D., *Botanist.*
R. H. LOUGHRIDGE, Ph.D., *Agricultural Geologist and Physicist.* (*Alkali Investigations.*)
C. W. WOODWORTH, M.S., *Entomologist.*
M. E. JAFFA, M.S., *Assistant Chemist.* (*Foods, Soils, Fertilizers.*)
G. W. SHAW, M.A., Ph.D., *Assistant Chemist.* (*Soils, Sugars.*)
GEORGE E. COLBY, M.S., *Assistant Chemist.* (*Fruits, Waters, Insecticides.*)
J. BURTT DAVY, *Assistant Botanist.*
LEROY ANDERSON, M.S.A., *Dairy Husbandry.*
A. R. WARD, B.S.A., D.V.M., *Veterinarian, Bacteriologist.*
E. H. TWIGHT, B.Sc., Diplomé E.A.M., *Instructor in Viticulture.*
W. T. CLARKE, *Assistant Entomologist.*
C. H. SHINN, B.A., *Inspector of Stations.*
C. A. COLMORE, B.S., *Clerk to the Director.*

EMIL KELLNER, *Foreman of Central Station Grounds.*

JOHN TUOHY, *Patron*, JULIUS FORRER, *Foreman*,	Tulare Substation, Tulare.
R. C. RUST, *Patron*, JOHN H. BARBER, *Foreman*,	Foothill Substation, Jackson.
S. D. MERK, *Patron*, J. W. NEAL, *Foreman*,	Coast Range Substation, Paso Robles.
S. N. ANDROUS, *Patron*, J. W. MILLS, *Foreman*,	Southern California Substation, Pomona. Ontario.
V. C. RICHARDS, *Patron*, T. L. BOHLENDER, *in charge*,	Forestry Station, Chico.
ROY JONES, *Patron*, WM. SHUTT, *Foreman*,	Forestry Station, Santa Monica.

Bulletins and reports of this Station will be sent free to any citizen of the State, upon application.

NOTICE.

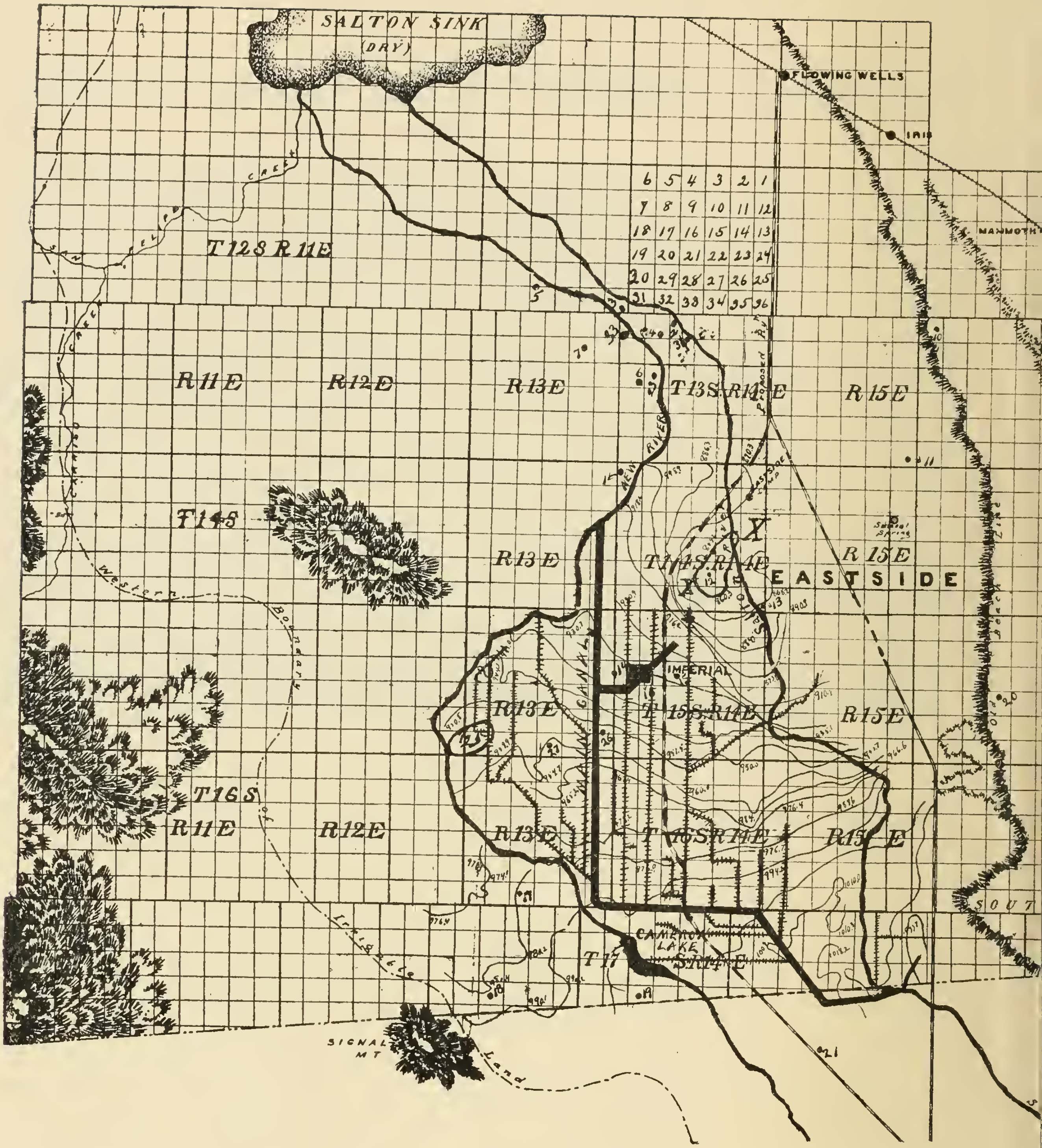
Attention is called to the fact that certain errors occur in Table I, page 7, of Bulletin 140 of this Station. The errors have been corrected in the following reprint, and you are requested to insert it in the proper place in the said bulletin.

TABLE I. Preliminary Results of Alkali Leachings.

Locality.	Percentages.				Pounds per Acre in 4 Feet.			
	Sulfates.	Carbonates.	Chlorids.	Total.	Sulfates.	Carbonates.	Chlorids.	Total.
1	.196	.013	.094	.303	31,360	2,080	15,040	48,480
2	.068	.010	.043	.121	10,880	1,600	6,880	19,360
3	.129	.012	.082	.223	20,640	1,920	13,120	35,680
4	.162	.007	.045	.214	25,920	1,120	7,200	34,240
5	.072	.010	.019	.101	11.520	1,600	3,040	16,160
6	.294	.008	.496	.798	47,040	1,280	79,360	127,680
7	.042	.009	.002	.053	6,720	1,440	320	8,480
8	.631	.013	.424	1.068	100,960	2,080	67,840	170,880
9	.179	.009	.162	.350	28,640	1,440	25,920	56,000
10	.207	.010	.027	.244	33,120	1,600	4,320	39,040
11	.173	.010	.056	.239	27,680	1,600	8,960	38,240
12	.172	.014	.044	.230	27,520	2,240	7,040	36,800
13	.141	.011	.164	.316	22,560	1,760	26,240	50,560
16	.142	.012	.137	.291	22,720	1,920	21,920	46,560
17	.080	.007	.035	.122	12,800	1,120	5,600	19,520
18	.056	.009	.001	.066	8,960	1,440	160	10,560
19	.129	.009	.005	.143	20,640	1,440	800	22,880
20	.152	.009	.154	.315	24,320	1,440	24,640	50,400
					484,000	29,120	318,400	831,520
Average in 4 feet					26,888	1,612	17,688	46,195
Minimum in 4 feet					6,720	1,120	160	8,480
Maximum in 4 feet					100,960	2,240	79,360	170,880

It will be observed that this preliminary examination indicates the average total alkali in the first four feet of soil to be about $1\frac{1}{7}$ per cent, or 46,000 pounds per acre; about three-eighths of which is common salt and about three-fifths glauber salt. Further, the enormous variation from 8480 to 170,880 pounds of soluble salts per acre—from a soil which will not injure citrus fruits to one that would be repugnant to all but the hardiest of alkali plants—shows that the land is quite "spotted," some localities being too highly charged with alkali to admit of any successful agricultural operations, while others do not exceed in amount the salts found in some of the better agricultural regions of the State. This condition suggested forcibly the need of a detailed local examination of the region.

TABLE OF CONTENTS.



SALTON SINK
(DRY)
FLOWING WELLS
IRIS
MAMMOTH
T12S R11E
R11E
R12E
R13E
T13S R14E
R15E
T14S
R13E
T14S R14E
R15E
EASTSIDE
IMPERIAL
R13E
T15S R14E
R15E
T16S
R11E
R12E
R13E
T16S R14E
R15E
NEW RIVER
CANAL
CAMERON LAKE
T17
SR14E
SIGNAL MT
SOUT

MAP

OF THE

SOUTHERN PART

OF

SALTON BASIN

SAN DIEGO COUNTY

CALIFORNIA

LANDS OF SALTON BASIN, SOUTHERN CALIFORNIA.

The Salton Basin, in the southeastern portion of the Colorado Desert, within the State of California, is a depression about 290 feet below sea level at its lowest point, where thick saline deposits have given rise to important enterprises in mining common salt. While the northern portion of this basin is largely covered with drifting sand, surrounding many tracts that, with irrigation, produce (as at Indio) abundant and early crops, the southern portion, here being considered, is to a considerable extent covered with alluvial deposits originally derived from the Colorado River; as is clearly indicated by their nature, as well as by the fact that at times of exceptional high water (such as occurred in 1890) the river overflows into the basin through two channels, named respectively the Salton and New rivers. In the year mentioned, the overflow was so copious as to flood the salt deposits, and for nearly a year there was a lake where doubtless originally the waters of the Gulf of California received the entire flow of the Colorado. The alluvial deposits of the river finally cut off the upper end of the Gulf, so that now a large area of alluvial country, or delta, extends between the Salton Basin and the present head of the Gulf. The part of this delta which slopes toward the north into the Salton Basin forms the subject of the present discussion. The subjoined map, reduced from sheets furnished by the "Imperial Land Company," will serve to elucidate the general features of the region, a portion of which has been surveyed in sufficient detail to give the contour lines indicating the slope, which, as will be noted, is considerable enough to render both irrigation and drainage easy; in general, toward a depression designated as Mesquit Lake, which can also serve as a back-water reservoir from Salton River and the main canal. To the eye, however, most of the country appears as a level plain, except where the channels of the streams form breaks. Its natural vegetation is very scanty; mesquit is found scattered over the plains, with locally some poplars on the lower ground; also low shrubby and herbaceous, partly saline, growth. On the higher ground vegetation is generally very sparse, sometimes entirely absent over considerable tracts; locally there are areas in which certain plants are massed.

As to the thickness of these delta deposits, the only evidence as yet available is from a boring at Imperial made to determine the feasibility of obtaining artesian water in this region. This boring was carried to the depth of 685 (?) feet, without penetrating anything different from the various materials found at or near the surface, and without finding water. It is thus apparent that the Gulf was originally of very considerable depth. The level of the Salton salt deposit at the works is stated by Gannett to be 262 feet below sea level.

Successive Efforts at Investigation.—The attention of the Station Director was first called to the agricultural possibilities of this southern portion of the Colorado Desert in 1893, by a request on the part of several gentlemen who proposed to take out water from the Colorado River near Yuma, for the purpose of irrigating this region; and also proposed to fit out an expedition, properly equipped, in order that he might explore the country in question personally. Financial difficulties intervening prevented the carrying-out of the plan at that time; but a few samples of water from the lakes, and of soils superficially taken, proved that the latter were very similar to that of the immediate bottom of the Colorado River, which previous analyses had already shown to be of extraordinary intrinsic fertility.*

A similar effort was made in 1896–7 by other parties, who also supplied to the Station some soil and water samples for examination. These but corroborated the previous conclusions, with the added suggestion that a considerable proportion of alkali salts was present in soils as well as in waters; so that a thorough examination of the region in this respect was manifestly called for.

It was not until 1900, however, that the present organization, the "Imperial Land and Water Company," took active steps toward the construction of an irrigation canal, and renewed the proposition that the land should be explored under the supervision of this Station, in order to determine definitely its adaptation to general or special agriculture and horticulture. The first step was the taking of soil samples over a considerable portion of the district by an employé of the company, in substantial accordance with printed directions furnished. These samples, unfortunately, could not be very accurately located, in the absence of a regular land survey; but they furnished a fair general idea of the character of the lands, and further emphasized the necessity of a more definite and detailed examination, in order to determine what portions of the territory under the canal might or might not be considered suitable for general farming purposes.

To indicate the general idea obtained from the analysis of these twenty preliminary samples, the results have been calculated so as to show the soluble salts (alkali) to the depth of four feet, taking the average alkali content found in the soils to the depth to which each sample had been taken, and assuming that this represents approximately the saline condition for each foot.

---

* See report of California Experiment Station for 1882.

TABLE I. Preliminary Results of Alkali Leachings.

Locality.	Percentages.				Pounds Per Acre in 4 Feet.			
	Sulfates.	Carbonates.	Chlorids.	Total.	Sulfates.	Carbonates.	Chlorids.	Total.
1	.196	.013	.094	.303	31,360	2,080	15,040	48,480
2	.068	.010	.043	.121	10,880	1,600	6,880	19,360
3	.129	.012	.082	.223	20,640	1,920	13,120	35,680
4	.162	.007	.045	.214	25,920	1,120	7,200	34,240
5	.072	.010	.019	.101	11,520	1,600	3,040	16,160
6	.294	.008	.496	.798	47,040	1,280	79,360	127,680
7	.042	.009	.002	.053	6,720	1,440	160	8,280
8	.631	.013	.424	1.068	96,960	2,080	16,960	170,880
9	.179	.009	.162	.350	28,640	1,440	25,920	56,000
10	.207	.010	.027	.244	33,120	1,600	4,320	39,040
11	.173	.010	.056	.239	27,680	1,600	8,960	38,240
12	.172	.014	.044	.230	27,520	2,240	7,040	40,800
13	.141	.011	.164	.316	18,560	1,760	26,240	50,560
16	.142	.012	.137	.291	22,720	1,920	21,920	46,560
17	.080	.007	.035	.122	12,800	1,120	5,600	19,520
18	.056	.009	.001	.066	8,960	1,440	160	10,560
19	.129	.009	.005	.193	20,640	1,440	800	30,880
20	.152	.009	.154	.315	24,320	1,440	6,160	50,400
					575,320	29,120	248,880	853,320
Average in 4 feet					28,766	1,456	12,444	42,666
Minimum in 4 feet					6,720	1,120	160	8,280
Maximum in 4 feet					96,960	2,240	79,360	170,880

It will be observed that this preliminary examination indicates the average total alkali in the first four feet of soil to be about one per cent, or 40,000 pounds per acre; about two-sevenths of which is common salt and about two-thirds glauber salt. Further, the enormous variation from 8,280 to 170,880 pounds of soluble salts per acre—from a soil which will not injure citrus fruits to one that would be repugnant to all but the hardiest of alkali plants—shows that the land is quite "spotted," some localities being too highly charged with alkali to admit of any successful agricultural operations, while others do not exceed in amount the salts found in some of the better agricultural regions of the State. This condition suggested forcibly the need of a detailed local examination of the region.

Exploration by Mr. F. J. Snow.—The Director being unable to visit the region personally, Mr. F. J. Snow, at the time assistant in the laboratory of agricultural chemistry, was deputed to undertake the work of exploration, and the field work was carried out by him with the effective assistance and at the expense of the company, during the three weeks of Christmas vacation, 1900–1901. The examination of the numerous samples it was found necessary to collect occupied over four months of his time during 1901; and the resignation of Mr. Snow from the staff of the Station at the beginning of the session of 1901–2 unavoidably delayed the report of results until the vacancy thus created could be acceptably filled. Almost the entire laboratory work had

TABLE II. Physical Analyses of Salton Basin Soils.

Hydraulic Value (Velocity Per Second).	Diameter of Grains.	Character of Material.	Silt Soils.			Clay Soils.		Bottom Soil.
			†Special Typical Sample. No. 2325.	Locality No. 5. First Foot. T. 12 S., R. 13 E., Sec. 33. No. 2326	*Bottom Land, Gila River, near Yuma. No. 1197.	†Special Typical Sample. No. 2324.	Locality No. 15. First Foot. T. 15 S., R. 14 E., Sec. 16. No. 2327.	‡Colorado River, California. No. 506.
64 mm.	.50 to .30 mm.	Very coarse sand		.13	.28		.21	.13
64 to 32 mm.	.30 to .16 mm.	Coarse sand	.49	.27	2.79	.94	.34	.15
32 to 16 mm.	.16 to .12 mm.	Medium sand		1.63	22.00		1.48	.11
16 to 8 mm.	.12 to .072 mm.	Fine sand	5.19	13.64	33.97	.46	1.45	.75
8 to 4 mm.	.072 to .047 mm.	Very coarse silt	26.08	27.58	33.01	1.68	2.75	2.51
4 to 2 mm.	.047 to .036 mm.	Coarse silt	23.50	20.52	10.17	1.73	6.25	8.38
2 to 1 mm.	.036 to .025 mm.	Medium silt	13.32	9.61	3.21	1.31	8.81	12.64
1 to .5 mm.	.025 to .016 mm.	Medium silt	.61	2.42	2.04	.25	8.54	11.28
.5 to <.25 mm.	.016 ?	Fine silt	15.34	13.16	5.53	63.31	48.92	.79
<.25 to .0023 mm.		Colloidal clay	14.80	9.74	3.21	28.78	18.58	54.97
		Totals	99.63	98.70	94.22	96.46	97.32	91.71

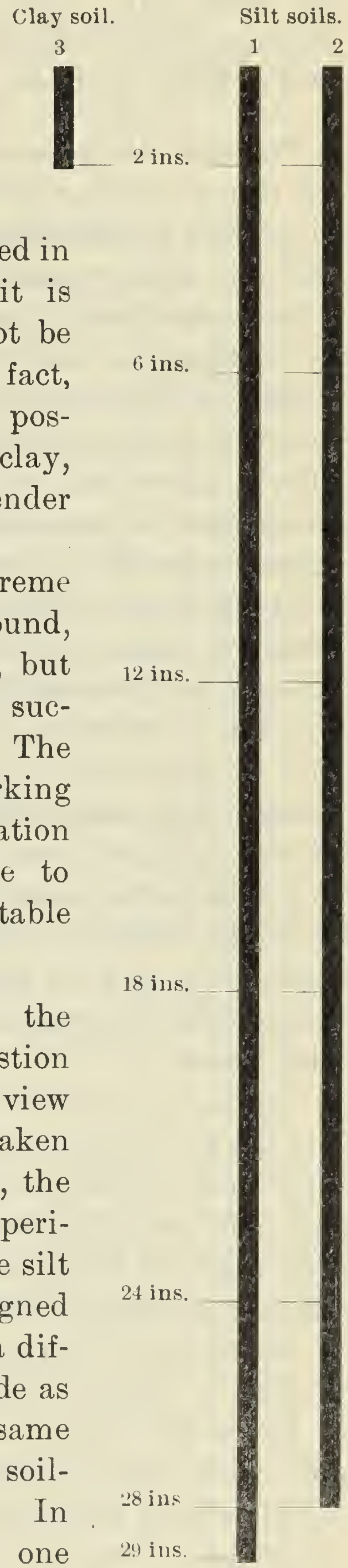
* Report of California Experiment Station, 1891-2, p. 45.

† NOTE.—These special samples were selected as being very typical of the class represented. Each consisted of about 50 pounds of soil taken to a depth of 4 feet, thoroughly mixed and reduced to convenient bulk by quartering. These samples were used by Mr. Snow for both the percolation, capillary, and other experiments, as well as for the complete chemical and mechanical analyses.

‡ Report of California Experiment Station, 1892-4, p. 70.

An examination of this table shows that the silt soil contains about 60 per cent of silt of medium to coarse grade, which imparts the distinctive character to the soil. It also carries from 10 to 15 per cent of very fine silt, which in some respects might act similarly to clay in respect to capillary power. The soil characterized as clay carries about 30 per cent of clay proper, and over 60 per cent of very fine silt; making over 90 per cent of extremely fine matter, which, when compacted (as much of it is), makes a material almost impervious to water. The truth of this latter statement is well illustrated by the results obtained in the percolation experiments (diagram I); and it is obvious that a material of this character can not be considered suitable for irrigation culture, or, in fact, for any of the usual crops under any practically possible treatment. It is too "fat" even for potter's clay, for which its high plasticity would otherwise render it suitable.

DIAGRAM I. Rate of percolation in 12 hours.



As is natural, intermixtures of these two extreme materials in various proportions are frequently found, often in shaly masses resembling the hard clay, but softening readily in water and quite capable of successful cultivation if freed from excess of alkali. The "hand test," by wetting with water and working between the palms of the hands, and the observation of their percolative power, will generally serve to distinguish these shaly clay-loams from the intractable hard clay of the New River banks.

Percolation of Water.—In irrigated regions the rapidity with which soils can be wetted is a question of prime importance to the farmer; and with a view of ascertaining the rate at which water will be taken by each of the two types of soils here discussed, the following experiments were undertaken. Experiments No. 1 and No. 2 were conducted with the silt soil, and No. 3 with the clay soil. No. 2 was designed as a check upon No. 1, and was conducted at a different time; but all essential conditions were made as similar as possible. In each experiment the same constant depth of water was maintained over the soil-column by means of a Marriotte apparatus. In experiment No. 1 the tube used was one and one half inches in diameter and thirty-eight inches in length, and contained 1,700 grams of soil. In experiment No. 2 the diameter of the tube was two inches, and the length thirty-two inches, the weight of the soil being 1,400 grams. In each case the soil was well settled in the tube. Experiment No. 1 was begun at 6:20 A. M., April 15th, and ended at 11:25 P. M. of the same day. Experiment No. 2 was begun at 5:20 A. M., May 2d, and ended at 9:14 P. M. of the same day. The rate of wetting is graphically presented in the accompanying exhibits (diagram I), in which the depth reached in twelve hours is shown.

Practical Deductions.—In soils as strong in alkali as these samples, the rate of wetting becomes even a more important factor for consideration than in non-alkali regions. Wherever the upper layers of the soil are highly charged with the salts, the first thing needful to be done—aside from thorough underdrainage—is that of heavy irrigation by flooding, in order to wash the excess of alkali from the upper layers to the lower, and thus reduce the amount in the upper four to six feet of soil below the limit of endurance for the various crops. (For a discussion of the "Tolerance of Alkali by Certain Cultures," the reader is referred to Bulletin No. 133 of this Station.) If an excessive amount of water has to be used in order to accomplish this washing-down, or if the water has to be kept upon the ground an undue length of time, there is the constant attendant danger of "swamping" the soil, and thus putting it out of good physical condition; and again, in a soil in which the lime carbonate runs as high as seems to be the case in these soils, there is the further danger of the development of black alkali, thus adding to the already serious condition of many of the sampled areas. If, however, the soil be of such a nature as to preclude the possibility of wetting it thoroughly to a depth of five or six feet within a reasonable length of time under irrigating conditions, then if it be placed under cultivation, there may be expected a considerable increase of alkali near the surface during the first three or four years.

Comparing these two soils it was found that under these experiments the silt soil became wet to the depth of three feet within 18 hours, while in the case of the clay soil it required 165 days for the water to reach the same depth; a rate entirely prohibitive of successfully handling this soil under its highly saline conditions. Further, the experiment indicates that this clay soil is so slow in taking moisture from above that in a period of ten days it would only become wet to a depth of seven inches, a rate too slow for agricultural operations.

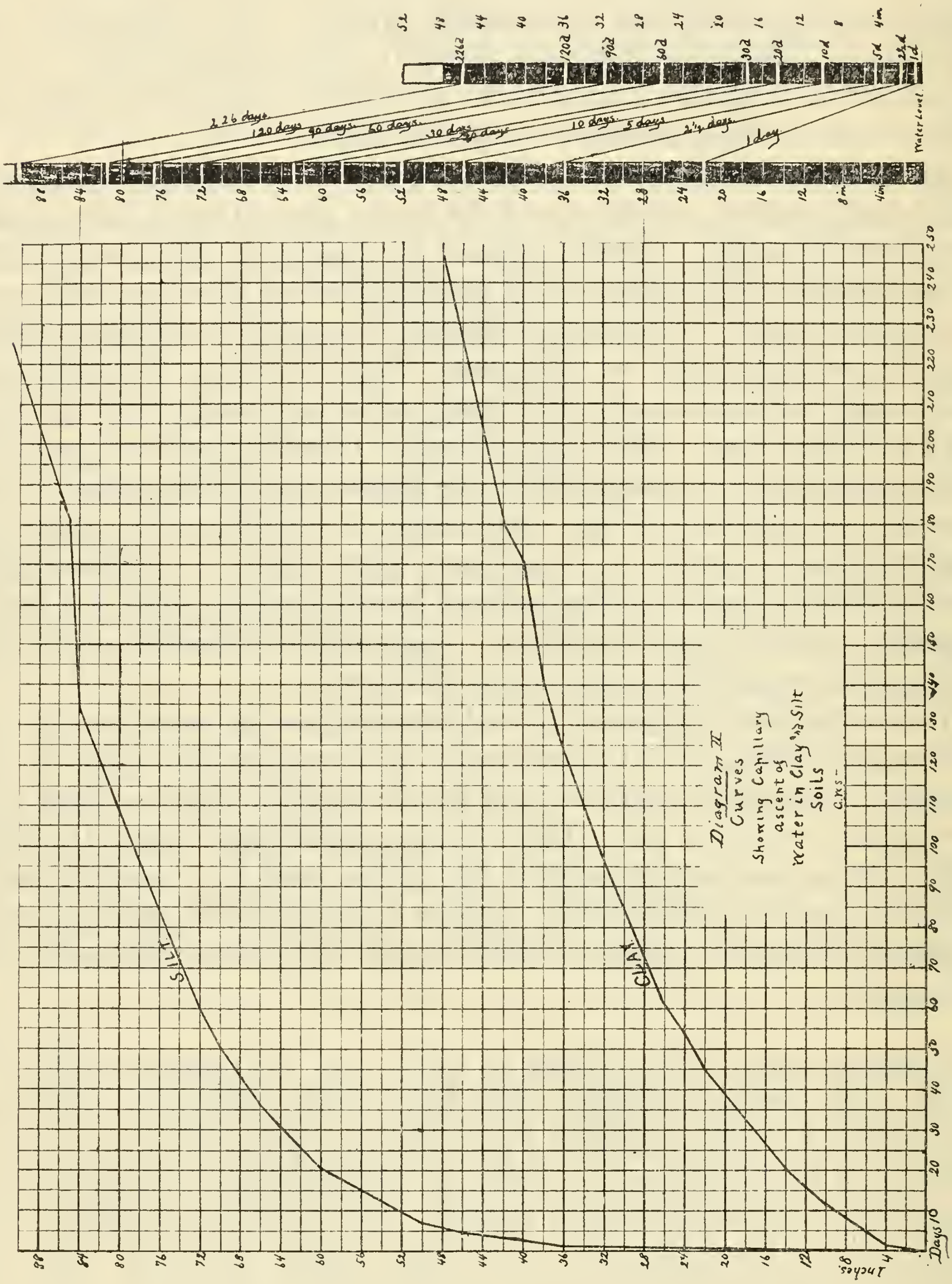
In the silt soil, the conditions for successful treatment under irrigation are much more favorable. Carrying, as it does, a heavy amount of alkali within the first three feet, the same method of heavy flooding and subsequent deep-furrow irrigation would have to be resorted to; and a study of the data shows that if the water will carry a considerable portion of the salts to a depth of four or five feet within a reasonable time, the conditions may be considered as favorable as in many other well-cultivated portions of the arid regions. The experiments show that this may be accomplished within a period of 18 to 36 hours, a time perfectly compatible with agricultural practice. The particular thing here shown should be distinctly borne in mind; namely, *that it is as important for intending settlers to be as careful to avoid the compact clay soils as those carrying excessive amounts of alkali.*

In connection with the silt soil, in view of its looseness of texture, its often highly saline condition, and the heavy percentage of lime carbonate which it carries, attention should be directed to the great liability to seepage from the higher ground, especially where near the main canal, to the lower lands. Instances of this are so common in irrigated regions that forewarned should be forearmed. Sooner or later there will arise the necessity of drainage canals to keep the seepage water from "swamping" the lower land. With this underflow of water there is a greater or less accumulation of alkali salts in the lower areas, which, taken in connection with the high natural lime content of the soils, is almost sure to result in the formation of considerable black alkali; a condition which may already be seen in a few isolated localties where there has been a periodic overflow from New River. One such is indicated on the map by the number 25, and covers about 200 acres.

In dealing with the grades of soil intermediate between the two extremes here tested, it will be advisable to determine *first of all* the rate at which water will penetrate them to the depth of not less than four, preferably five or six, feet. This will at once indicate whether the alkali salts can be successfully leached out of the land on a practical scale. The test can be made either by digging a pit, alongside of which water is put on the land; or else by following the water down by means of the soil auger.

Capillary Power.—The height to which, and the rapidity with which water will rise by capillary movement (wick action) in soils from underground or sub-irrigation water, and the ease of its general transmission in all directions, is a matter of vital importance in agricultural operations, particularly in arid regions. While both the height and the rapidity of transmission are to a large degree dependent upon the physical nature of the soils, yet it is reasonably certain that there are certain chemical factors involved as well. Inasmuch as this capillary power is dependent upon the size of the spaces between the particles constituting the soil, varying inversely as this space, capillary ascent is less in sandy than in clay soils. In the former the rise is more *rapid*, since there is less frictional resistance to the motion of the water; but there is, also, much less surface tension, and while the rise is rapid the water may not ascend more than a few inches.

As between silts and clays, such as we have to deal with in this discussion, the conditions are quite different and merit some attention,



particularly as these silt soils are so prevalent in the arid regions. The soils used in this experiment were from the same lot as those used in the percolation experiments and in the complete chemical and mechanical analyses described above. The soils were tapped into the tubes, which were then placed upon a perforated support in a water reservoir.

The results are shown graphically by means of both curves and vertical columns. In the case of the curves, the verticals represent equal heights in inches; the horizontals show the length of time in days. In the columns, to facilitate comparison, the points reached in each at the end of the several periods of time are connected by lines.

The particular point to attract attention in comparing these two soils is the great difference in the rapidity of the rise of water. In the case of the silt soil, in seven minutes it had ascended 2 inches, in eighteen minutes 4 inches, in one hour 7 inches, in one hour and forty-three minutes 10 inches; while it took the clay eleven hours and seventeen minutes to draw the water to a like height, or approximately ten times as long. This rate, however, diminishes somewhat more rapidly in the silt as the water column ascends, than it does in the clay. This rapid rise of water in soils of a somewhat similar character was noticed some years ago, and commented upon in the annual report of this Station for 1894. In the case of the alluvial soil from Gila River, near Yuma, the water rose 9½ inches in one hour; at the end of twelve hours it had reached a height of 24 inches, and at the end of the first day it had reached the height of 27½ inches; while the silt soil here under consideration reached the height of 30 inches in a like time. The clay soil of the region must be looked upon, then, as very slow in its capillary action when compared with the lighter alluvial silt, the ratio for the first few hours being about 1:10.

CHEMICAL COMPOSITION OF THE SOILS.

In a previous report* of this Station, analyses of three samples of soil from this region are given, and in the discussion of the results it was stated: "It will be noted, as a common factor of these three soils, that they are highly calcareous; they show the presence of the carbonate of lime by effervescence with acids. The Colorado River soil is very rich in potash; the Gila soil much less so, yet very adequately supplied; the amount of soda found does not indicate much alkali contamination. The Colorado soil has a good, but not high, supply of phosphoric acid; the Gila soils both show an unusually high percentage of that ingredient. The Colorado soil has a good supply of humus; the Gila soil is notably deficient therein for a bottom soil."

A complete chemical analysis of each of the types here under consideration was made by Mr. Snow, and the subjoined results obtained. The analysis of other soils from the same region, the discussion of which appears above, is included for the sake of comparison.

* Report of California Experiment Station, 1890, p. 50.

TABLE III. Analyses of Colorado Alluvial Soils.

	Clay Soil. No. 2324.	Silt Soil. No. 2325.	Colorado River, California, Bottom Soil. No. 506.	Gila River, Arizona, Bottom Soil. No. 1195.	Gila River, Arizona, Bottom Subsoil. No. 1197.
Coarse materials > 0.5^{mm}	----------	----------	----------	----------	----------
Fine earth	100.00	100.00	100.00	100.00	100.00
Analysis of Fine Earth.					
Insoluble matter	38.65	62.67	58.57	57.90	64.83
Soluble silica	15.79	10.93	5.33	13.49	11.85
Potash (K_2O)	.76	.74	1.18	.66	.67
Soda (Na_2O)	.34	.29	.16	.25	.39
Lime (CaO)	4.35	3.75	8.67	6.26	4.33
Magnesia (MgO)	1.24	1.68	2.97	.66	1.97
Br. ox. of manganese (Mn_3O_4)	.10	.01	.03	.08	.03
Peroxid of iron (Fe_2O_3)	6.15	3.71	4.14	5.57	6.27
Alumina (Al_2O_3)	10.52	4.26	8.38	7.48	4.27
Phosphoric acid (P_2O_5)	.23	.22	.13	.23	.17
Sulfuric acid (SO_3)	.49	.36	.15	.03	.05
Carbonic acid (CO_2)	5.30	2.32	7.82	2.63	3.56
Water and organic matter	15.84	8.93	3.34	4.98	1.14
Total	99.76	99.87	100.87	100.22	99.83
Humus	.38	.65	.75	.38	----------
" Ash	1.01	.69	1.15	.43	----------
" Nitrogen, per cent in humus	18.42	10.92	----------	----------	----------
" Nitrogen, per cent in soil	.07	.07	----------	----------	----------
Available phosphoric acid (citric acid method)	.012	.01	----------	----------	----------
Hygroscopic moisture (absorbed at 15° C.)	5.75	2.98	9.26	4.91	3.48
Water-holding power	74.39	46.26	48.40	----------	42.30

Intrinsic Fertility of these Soils.—In a general review of these soils, one is impressed at first by the general similarity in composition, bearing out the statements made several years ago and quoted above, viz: that the intrinsic fertility of the soils of this region is high. The lime content of all three is high; and the fact that this lime is present largely in the form of a carbonate, as indicated by the high per cent of carbonic dioxid, also indicates a high general availability of the other critical elements. In the case of the clay it will be noted that there is a much larger portion of soluble matter than in the silt, which is further shown by its higher alkali content, discussed later in this bulletin. In this latter respect both the silt and soil No. 506 have the advantage of the clay. This fact is also borne out by the higher per cent of both soda and sulfuric acid present in the clay when compared with the other soils. There is about two thirds as much soluble silica in the silt as in the clay. As to potash, all three soils are very rich, there being nearly four times as much as the average for soils of humid regions. In this respect the soils must be considered as permanently fertile. On the side of phosphoric acid there is little difference in the two types, both having an excellent supply, exceeding that of soil No. 506 quite materially; still, the latter could not be considered deficient. The humus content is good—better in the silt than in the clay—especially as the nitrogen content of the humus is high. The water-holding power is greater by 30 per cent in the case of the clay than in the silt, which might be expected on account of the difference in the nature of the two soils. All three of these soils must thus be ranked as exceptionally good in their supplies of plant food.

THE SOLUBLE SALTS IN THE SOIL.

Importance of the Alkali Factor in Arid Regions.—In the selection ot lands in arid regions it is highly essential that more than the physical nature and general fertility of the soils be considered. There are factors entering into the soil problems of such regions which are entirely foreign to those of humid climates, and which, in many cases, are far more complicated. A soil may possess all the elements, both physical and chemical, of intrinsic fertility, and still be entirely unsuited to agricultural operations under irrigated conditions; points which, in a humid region, might be considered very favorable to a soil may, under irrigation, if the alkali condition of the undersoil be not accurately known, cause the ruin of the land. Being unaware of these essential differences, settlers from the humid region are not infrequently led to select land which is, or may become, entirely unsuited to any kind of crop-growing. It is important, then, that the truth should be placed before them in these matters, not only that *they* may avoid financial loss, but also that the evil results sure to follow such unwise selections may not cast reflections upon the State. On the other hand, it is not at all uncommon for people temporarily residing in arid regions to make broad and sweeping condemnations of lands which experience and a thorough understanding of arid conditions will not bear out.

Alkali lands, when at all adapted to agriculture, are intrinsically of the very richest character; and may, as a rule, be considered as exceptionally fertile upon the mineral side when compared with the humid-region soils. In order to realize these advantages, however, care is needed in handling such lands, and ignorance of the true condition may cause very serious financial loss, both to the individual and to the State. A notable case is that of the Fresno plateau region—the divide between the San Joaquin and Kings rivers—where there were no signs of alkali when the region was settled and for some time thereafter. Gradually small spots of alkali appeared in the older settlements, enlarging from year to year as the point of tolerance was passed for the several crops, finally causing the death of vines and trees to such an extent as to attract serious attention. It has only required a thorough understanding of the conditions to point out an application of the rational treatment of drainage, combined with the use of gypsum, when needed, as a remedy for a trouble that threatened to overrun the country.

The alkali factor should always, therefore, receive careful attention as to both surface and undersoil conditions. Three points demand consideration in this connection, viz:

1. The soluble salt content of the soil itself;
2. The salt content of the available irrigation water;
3. The condition of the surface and sub-drainage in connection with the nature of the soil.

The Nature of Alkali.—The nature and kinds of alkali have been repeatedly treated of in the several publications of this Station, but it is deemed best to again state here that, "broadly speaking, it may be said that, the world over, alkali salts usually consist of three chief ingredients, namely, *common salt*, *glauber salt* (sulfate of soda), and *salsoda* or *carbonate of soda.* The latter causes what is popularly known as "black alkali," from the black spots or puddles seen on the surface of lands tainted with it, owing to the dissolution of the soil humus; while the other salts, often together with epsom salt, constitute "white alkali," which is known to be very much milder in its effect on plants than the black. In most cases all three are present, and all may be considered as practically valueless or noxious to plant growth. With them, however, there are almost always associated, in varying amounts, sulfate of potash, phosphate of soda, and nitrate of soda, representing the three elements—potassium, phosphorus, and nitrogen—upon the presence of which in the soil, in available form, the welfare of our crops so essentially depends, and which we aim to supply in fertilizers. The potash salt is usually present to the extent of from 5 to 20 per cent of the total salts; phosphate, from a fraction to as much as 4 per cent; the nitrate, from a fraction to as much as 20 per cent. In black alkali the nitrate is usually low, the phosphate high; in the white, the reverse is true."*

With regard to the relative injuriousness of the component salts it may be said that the glauber salt, *unless present in excessive amounts*, is comparatively innocuous and need not be considered a serious barrier to agricultural operations when conducted in a rational manner. The carbonate of soda, constituting the active ingredient in the so-called "black alkali," exerts a corrosive action on the root crown of the plant, and in many cases, especially in heavy soils, tends to destroy their tilth. But by the use of gypsum, it can readily be converted into the relatively innocuous sulfate. Experience on our substation tracts, as well as elsewhere, shows that any considerable amount of sodium chlorid (common salt) is fully as much to be feared as the more corrosive carbonate, since it can not be neutralized or changed within the soil, but must be bodily removed by drainage.

---

* Bulletin No. 128, California Experiment Station, p. 13.

ALKALI SALTS IN THE SALTON BASIN.

In considering only the *amounts* of alkali salts in the soils of this region, we find the outlook not altogether encouraging. While there is some land not too strongly impregnated to produce even now, without any special precautions, good crops of cereals, especially barley, also alfalfa, and some of the hardier orchard and small fruits, there is a very large proportion of the lands so strongly charged that, without due care, crops could be secured only for two or three years, and in some, none at all. As to *quality*, however, it is notable that there is in the great majority of cases a great predominance of the relatively innocuous sulfates—glauber salt, epsom salt, and throughout, a certain proportion of potash sulfate also, ranging in the determinations thus far made from two to over ten per cent of the total salts. Carbonate of soda is quite subordinate, because of the presence of gypsum throughout the materials. Common salt is rather abundant near the surface, but only in small supply below the first three feet, until a depth of twenty feet is reached, as is shown in the sections given below. Nitrates appear to be present throughout, to an extent varying from 1,000 to 1,800 pounds per acre (.025 to .044 per cent) in four feet depth; increasing from the surface downward, contrary to the usual rule. The alkali is, therefore, generally speaking, of the mildest "white" type, and it is not surprising that, as the crop reports given below show, seed germinates and a luxuriant growth of weeds is found even where the alkali salts are bodily blooming out along the ditches. It would thus seem that, on the whole, the hard clay is a more serious obstacle to the utilization of these extremely rich lands than are the alkali salts, so far at least as the lighter and more pervious soil qualities are concerned.

Sections of New River and Salton River Banks.—Below will be found tables and diagrams showing the results of analyses of samples taken in vertical sections from the banks of both the Salton and New rivers. These samples were taken, as indicated in the tables, to the depth of 22 feet 9 inches, and 22 feet respectively, the banks in each case having been dug away for 20 feet horizontally in order to get truly representative samples, avoiding the effects of concentration of salts by evaporation. These sections are of especial importance as indicating the general disposition of the soluble salts in the substrata of the valley; they consequently elucidate best the chances of getting rid of alkali by drainage, or by leaching downward on the land itself. The tables show the data obtained from the two stream banks, the nature of the materials being given alongside of the same.

TABLE IV. Section from New River Bank: 22 Feet, Locality No. 33.

Percentages.				Physical Characteristics of Each Thickness.	Pounds per Acre.			
Sulfates	Carbonates	Chlorids	Total		Sulfates	Carbonates	Chlorids	Total
.916	.008	.092	1.016	8 in. Surface compacted clay; crumbles easily.	24,427	213	2,653	27,293
1.321	.010	.265	1.596	12 in. Compacted clay; crumbles easily.	52,840	400	10,600	63,840
1.164	.008	.096	1.268	12 in. Very tough clay; will not break nor crumble.	46,560	320	3,840	50,720
.736	.016	.060	.812	4 in. Very hard; breaks in cakes	9,813	214	800	10,827
.556	.016	.037	.609	12 in. Compacted, but not as hard	22,240	640	1,480	24,360
.572	.012	.032	.616	12 in. Very hard; breaks in cakes	22,880	480	1,280	24,640
.593	.007	.036	.636	12 in. Very hard; breaks in cakes	23,720	280	1,440	25,440
.286	.007	.249	.542	12 in. In large chunks; very hard	11,440	280	9,960	21,680
.371	.013	.018	.402	12 in. Not as hard; more silt; mixed	14,840	520	720	16,000
.376	.010	.014	.400	6 in. Not as hard; more silt; mixed	7,520	200	280	8,000
.631	.012	.076	.719	12 in. Hard compact clay; caked in chunks.	25,240	480	3,040	28,760
.661	.013	.016	.690	12 in. Hard compact clay; caked in chunks.	26,440	520	640	27,600
.522	.013	.029	.564	12 in. Compact; some silt	20,880	520	1,160	22,560
.584	.009	.011	.604	12 in. Compact; more silt	23,360	360	440	24,160
.572	.014	.078	.604	6 in. Compact; more silt	10,240	280	1,560	12,080
.258	.007	.015	.280	12 in. Loose silt and sand	10,320	280	600	11,200
.232	.008	.025	.265	12 in. Loose silt and sand	9,280	320	1,000	10,600
.195	.008	.021	.224	12 in. Loose silt and sand	7,800	320	840	8,960
.257	.007	.003	.267	12 in. Loose silt and sand	10,280	280	120	10,680
1.188	.010	.006	1.204	12 in. Very compact	47,520	400	240	48,160
1.130	.008	.068	1.206	12 in. Very compact	45,200	320	2,720	48,240
1.244	.012	.026	1.282	12 in. Very compact	49,760	480	1,040	51,280
1.143	.005	.036	1.184	12 in. Very compact	45,720	200	1,440	47,360
1.162	.007	.063	1.232	12 in. Very compact	46,480	280	2,540	49,280

Sand and water at 22 feet.

TABLE V. Section from Salton River Bank: 22 Feet 9 Inches, Locality No. 34.

.195	.007	.080	.282	12 in. Silty; some clay somewhat compacted.	7,800	280	3,200	11,280
.603	.012	.329	.944	12 in. Similar to above, but more compact.	24,120	480	13,160	37,760
.356	.008	.038	.402	6 in. Like first foot	7,120	160	760	8,040
.233	.008	.025	.266	12 in. Like first foot	9,320	320	1,000	10,640
.095	.007	.006	.107	12 in. Like first foot	3,800	270	240	4,280
.181	.008	.013	.202	12 in. Very loose, silty soil; a little sand.	7,240	320	520	8,080
.129	.011	.003	.143	12 in. Very loose, silty soil; a little sand.	5,160	440	120	5,720
.121	.009	.009	.143	6 in. Silt; some clay; slightly compact.	2,420	180	180	2,860
.164	.010	.012	.186	12 in. Silt; compact breaks to silt soil.	6,560	400	480	7,440
.225	.008	.003	.236	12 in. Silt; some clay	9,000	320	120	9,440
.260	.005	.007	.272	12 in. Silt; some clay somewhat compacted.	10,400	200	280	10,880
.467	.007	.009	.483	3 in. Silt; some clay somewhat compacted.	4,670	70	90	4,830
.331	.009	.028	.368	12 in. Silt; some clay somewhat compacted.	13,240	360	1,120	14,720
.417	.009	.026	.452	12 in. Silt; very loose	16,680	360	1,040	18,080
.207	.008	.011	.226	12 in. Silt; very loose	8,280	320	440	9,040
.315	.012	.015	.342	12 in. Silt; very loose	12,600	480	600	13,680
.998	.008	.012	1.018	6 in. Clay; compact	19,960	160	240	20,360
.372	.008	.006	.386	12 in. Silt; some clay	14,880	320	240	15,440
.193	.014	.074	.281	12 in. Silt; some clay	7,720	560	2,960	11,240
.292	.020	.044	.356	12 in. Silt; lumps crumble easily	11,680	800	1,760	14,240
.132	.008	.008	.148	12 in. Silt; very fine	5,380	320	320	5,290
.092	.010	.089	.191	12 in. Silt; very fine	3,680	400	3,560	7,640
.416	.008	.168	.592	12 in. Clay; compact	16,640	320	6,720	23,680
.686	.009	.285	.980	12 in. Clay; compact	27,440	360	11,400	39,200
.771	.010	.739	1.520	12 in. Clay; compact	30,840	400	29,560	60,800

TABLE VI. Showing Summary of Soluble Salts in the River Sections.
(Pounds per acre.)

	Salton River Silt.				New River Clay.			
	Sulfates.	Carbonates.	Chlorids.	Total.	Sulfates.	Carbonates.	Chlorids.	Total.
	For Total Depth: 22 ft. 9 in.				For Total Depth: 22 ft.			
Total	281,864	7,348	73,590	362,802	663,806	8,580	52,402	722,788
Average per foot	12,812	334	3,345	16,491	30,173	390	2,291	32,854
Min. in any foot	3,680	200	120	4,280	7,800	200	120	8,960
Max. in any foot	30,840	800	29,560	60,800	50,780	640	10,600	63,840
	For First 4 Feet.				For First 4 Feet.			
Total	50,044	1,376	18,240	69,660	155,888	1,788	13,372	177,040
Average per foot	12,511	344	4,560	17,415	38,972	447	5,343	44,260
Min. in any foot	6,560	295	620	7,460	22,240	346	1,480	24,360
Max. in any foot	24,120	480	13,160	37,160	50,780	640	8,347	59,133
	For the Next 6 Feet.				For the Next 4 Feet.			
Total	42,678	1,992	1,818	46,560	109,320	2,340	20,070	131,760
Average per foot	7,113	332	303	7,760	18,225	390	3,345	21,960
Min. in any foot	5,000	295	120	5,720	11,440	280	720	16,000
Max. in any foot	10,400	400	480	10,880	23,720	520	9,960	25,440

In comparing the column of total salts, it is at once apparent that the New River materials are much more heavily charged with salts than are those on Salton River. Looking closer at the nature of these materials, we find, moreover, that while the Salton profile shows mostly silts and sands, which make an easily worked loam soil, the material of the New River bank is prevalently a very close-grained, fine clay, which is practically impervious to water, as shown in the percolation experiment previously recorded. (See p. 11.) In the Salton profile we also find occasional layers of this clay; and inspection shows that in nearly all cases *this clay is more heavily charged with salts than is the silt* and sand. Thus this clay, which wets with great difficulty and when wet becomes extremely tough and plastic, is a very unwelcome soil ingredient, as it is incapable of tillage and will be penetrated only by such hardy roots as those of the mesquit and greasewood, and possibly by those of the saltbushes. It is quite unlikely that other useful trees will be able to force their roots through this uncanny material, and settlers will quite early find from experience what is quite evident from these experiments: that these clay lands are ill adapted to agricultural operations, even where a few feet of silt forms the surface.

There are, as stated, many grades of transition between this pure, tough clay and the silt, which is eminently suitable as a soil material, and when mixed with a moderate amount of the clay forms excellent

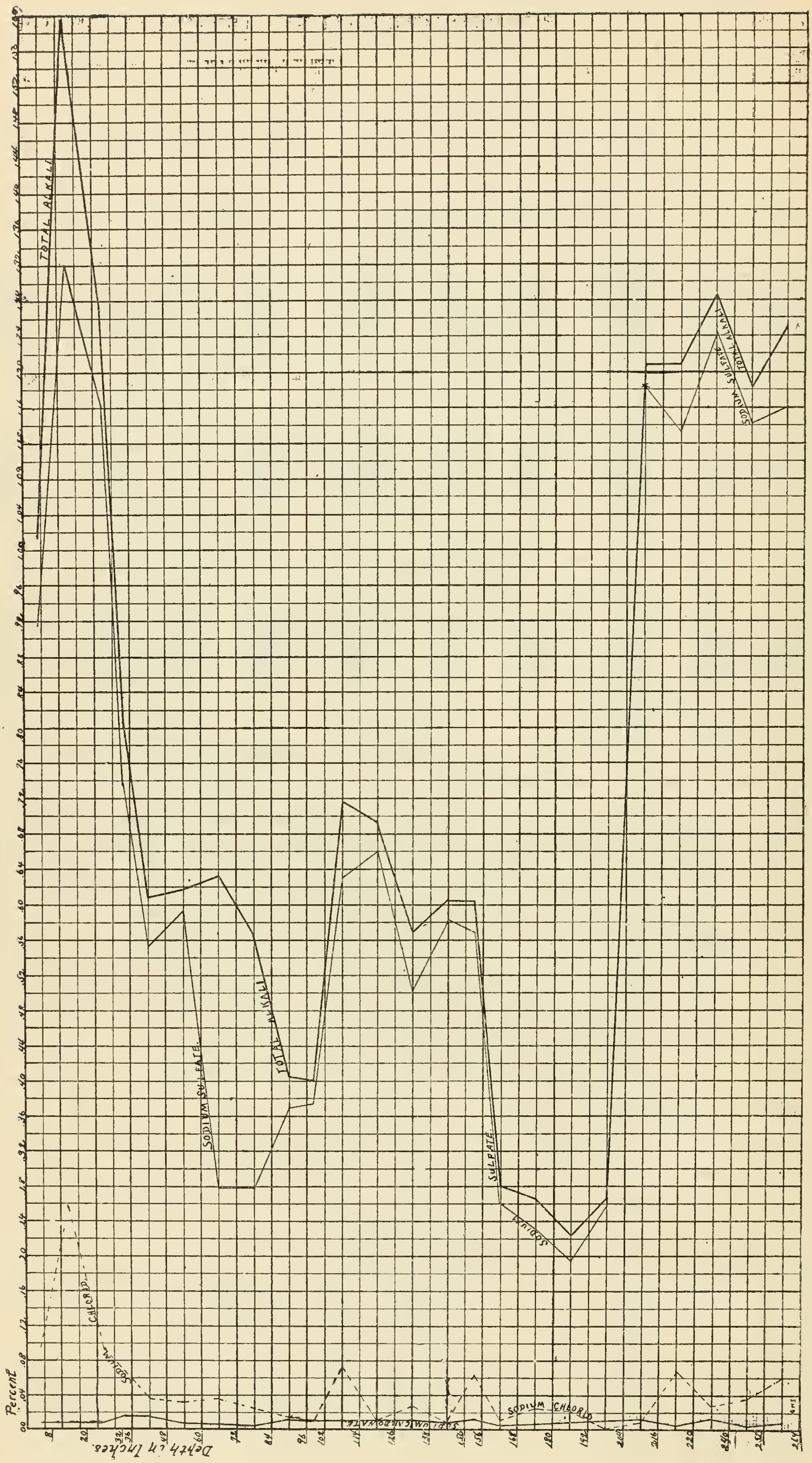


DIAGRAM III. Graphic illustration of distribution of alkali salts in New River section. See Table IV.

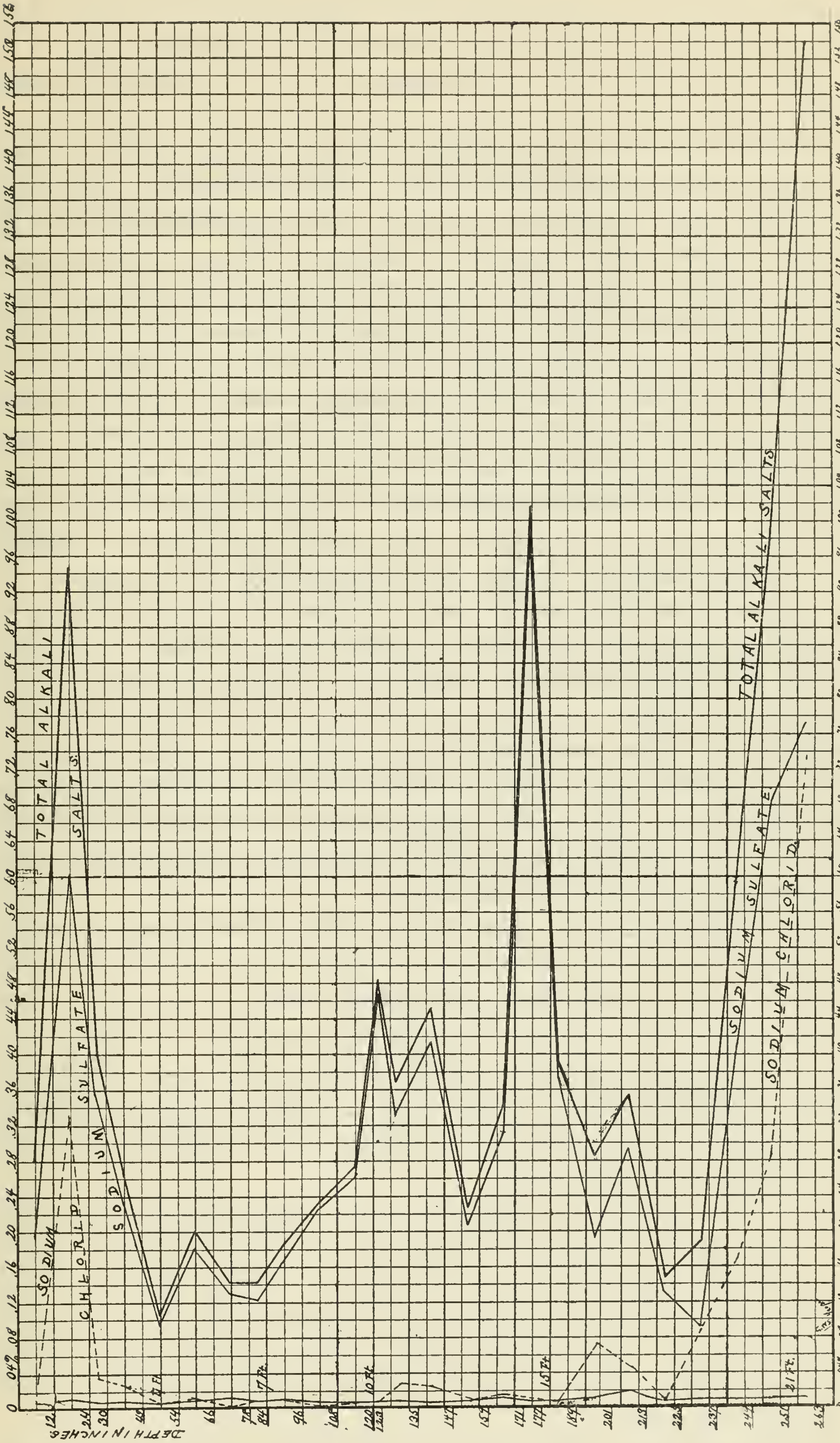


Diagram IV. Graphic illustration of distribution of salts in Salton River section. See Table V.

loams or clayey soils. Such soils sometimes constitute the surface soil itself, more frequently form layers of the substrata within reach of the roots of culture plants, and of course should be well distinguished from the practically impenetrable clay described above, as well as from the loose silts proper.

The distribution of the salts is better shown to the eye in the graphic form, as given on diagrams III and IV. Here we see at a glance that there are two high maxima of total salts, viz: near the top and at the base of the profile, with a minor one midway between in the case of New River; while in that of the Salton River there is at 15 feet as heavy a maximum as near the surface, with minor increases above and below. Another and very important point of difference is that while on New River there is no notable increase of the common salt near the base of the profile, on the Salton the sodium chlorid seems to increase very materially, almost equaling the sulfate, which elsewhere is throughout the sections in considerable excess. The sulfate (glauber salt) being the least noxious by far of the three salts usually contained in "alkali," this is a strong redeeming feature of the conditions in the region. It must be noted, however, that in both profiles the common salt is in quite heavy supply *near the surface*, constituting one fourth of one per cent of the soil in the New River banks, and one third of one per cent in that of Salton River.

Comparing the total content of salts in the two profiles, we see at once that it is by far the heavier in the New River profile, where the average content per acre of the entire section, as shown in the table on pages 20–21, is 32,854 pounds; while the same on Salton River is only 16,491 pounds, or just one half as much.

The New River section is mainly clay; that on the Salton is mainly silt and sand, but with an occasional sheet of clay. It will be noted that wherever such a sheet occurs, the alkali content is heavier; in full agreement with the same fact at the New River section. *The clay, then, must be regarded not only as an obstacle to tillage and root penetration, but also as a prolific source of alkali salts. Wherever it is at, or within less than three feet of the surface*, the land should be considered as unsuitable for cultivation at this time.

The conclusion as to alkali content is again corroborated by the shallower sections from which soil samples were collected by Mr. Snow; thus, in localities Nos. 3, 6, 14, 15, 16, 17 (see tables below). There is also a decided increase wherever the silt is compacted by the presence of considerable clay. In a few cases only, mostly near the surface, where one would naturally expect an accumulation, is the loose silt strongly impregnated with salts.

Again, in comparing these two river-bank sections in respect to the upper four feet of soil, it is found that the same fact, *i. e.* that the clay is the stronger in alkali, still holds good, for the average is about two and a half times higher in the case of the New River clay than in the Salton silt, and the minimum in the latter is 4,280, against twice as much in the former. What is true of the åverage of the total salts is also true of the average of each ingredient; and it is still further interesting to note that in general *the same fact holds for the next four feet*, which includes a depth as great as need be considered in any agricultural practice.

Disregarding the hard clay as being unsuitable for agricultural operations, and looking more closely at the silt, it will be seen that in the six feet underlying the upper four the average of the total salts is less than one half as high as in the latter; thus indicating that the proper treatment of these lands will be that of heavy flooding for reducing the amount of salts in the upper layers of the soil, followed by deep-furrow irrigation until leaching by underdrainage shall become practically feasible.

SOILS OF THE GENERAL SURFACE OF THE BASIN.

Besides the profiles on the banks of the two rivers, soil samples were taken in the open country, with a view to making them representative of the various districts, so far as time permitted. In so doing, the several layers of materials encountered in boring were taken separately, generally to the depth of six feet when conditions permitted; and a specimen of each layer was preserved for analysis. The general aspect and "lay" of the land were recorded, and the vegetation, if any, noted and specimens thereof preserved for subsequent identification, as possible indicators of the strength and character of the alkali salts.

PHYSIOGRAPHIC FEATURES.

(BY MR. SNOW.)

"Localities Nos. 1, 5, 6, 7, 17, 18, 19, and 23 represent that portion of the region lying west of New River; Nos. 1, 5, 6, and 23 representing that portion north of the proposed townsite. This latter area is a level country many miles in extent. The soil is generally a hard, compact clay, and in spots bears a heavy growth of greasewood; in the immediate locality of No. 23 there is a rank growth of pig-weed. Three miles from this point a 27-foot well has been dug, in which the clay extends to a depth of 12 feet, the remainder of the depth being sand. Localities Nos. 17, 18, and 19 were south of the proposed townsite, near the Mexican border, and represent an area of very level country extending parallel to New River far across the line into Mexico. The soil of this area, also, is a heavy, compact clay. The vegetation along the river and around the lakes is very rank and abundant, but on the agricultural land represented by these samples it is scarce and scattered. Over more or less of this area there are numerous hummocks, on which are found *dead* mesquit and greasewood bushes.

"Localities Nos. 3, 4, 8, 12, 13, 14, 15, 16, 26, and 27 were between the two rivers. Localities Nos. 3, 4, and 8 represent land lying north of the proposed townsite, over which a hard, compact clay soil predominates, and all of which is without vegetation. Near the point where sample 8 was obtained was a water-hole containing very saline water. A dense growth of trees, particularly willows and poplars, occurs in the river-bed at this point. Samples 14, 15, 16, and 26 were taken around the proposed townsite, and represent a large body of level land lying near the center of the agricultural district. The land has but little vegetation and is composed of hard, compact, impervious clay soil. Sample 27 represents a large area of so-called 'blown-out' land lying near Blue Lake, and a larger area of similar land lying on the west bank of the Salton River and joining the Mexican line on the south. Near sample 27 is a small body of black-alkali land.

"The locality represented by 9, 11, and 20 is that known as the 'East Side Tract,' a large area of land extending from the east bank of the Salton River to the sand hills on the east, and including all the irrigable lands to the Mexican line. These lands for some distance back from the river are much broken by large arroyos which lead into the Salton River. The soil is generally of a silty character, more or less mixed with clay in the northern part, and becoming more silty and sandy as the Mexican line is approached. Over this area the vegetation is scarce in the northern part, but near the Mexican line there is a rank growth of pig-weed, saltbush, greasewood, arrow-wood,* and sand verbena (*Abronia*). All the plants are to be found in this part of the country in abundance, and reach an enormous size.

"The country represented by localities Nos. 21 and 22 lies in Mexico, and consists of a loose, pervious, silty soil, which is overflowed annually by the waters of the Colorado River. The vegetation in these localities is very rank and abundant."

* By this name are indicated two different plants; see list, p. 42.

TABLE VII. Alkali Salts in Soils Contiguous to New River, San Diego County.

Locality No. 1—T. 14 S., R. 14 E., Sec. 6.

Depth (inches)	Thickness (inches)	Percentages.				Physical Characteristics.	Pounds per Acre.			
		Sulfates	Carbonates	Chlorids	Total		Sulfates	Carbonates	Chlorids	Total
12	12	.218	.005	.001	.224	Silt; loose	8,720	200	40	8,960
24	12	.090	.013	.004	.107	Silt; very fine	3,600	520	160	4,280
36	12	.026	.019	.001	.046	ditto	1,040	760	40	1,840
48	12	.092	.014	------	.106	ditto	3,680	560	------	4,240
60	12	.136	.007	.001	.144	Silt; some sand	5,440	280	40	5,760
72	12	.155	.015	.004	.174	ditto	6,200	600	160	6,960
Total for vertical section							28,680	2,920	440	32,040

Locality No. 3—T. 12 S., R. 13 E., Sec. 36.

Depth (inches)	Thickness (inches)	Sulfates	Carbonates	Chlorids	Total	Physical Characteristics	Sulfates	Carbonates	Chlorids	Total
10	10	.767	.010	.157	.934	Clay; slightly compact	25,567	333	5,233	31,133
22	12	.995	.009	.392	1.396	ditto	39,800	360	15,680	55,840
36	14	.172	.012	.010	.194	ditto	8,026	560	467	9,053
Total for vertical section							73,393	1,253	21,380	96,026

Locality No. 4—T. 13 S., R. 14 E., Sec. 5.

Depth (inches)	Thickness (inches)	Sulfates	Carbonates	Chlorids	Total	Physical Characteristics	Sulfates	Carbonates	Chlorids	Total
12	12	.755	.013	.318	1.086	Silt; very fine	30,200	520	12,720	43,440
24	12	.179	.012	.019	.210	ditto	7,160	480	760	8,400
36	12	.081	.012	.005	.098	ditto	3,240	480	200	3,920
48	12	.057	.012	.009	.078	ditto	2,280	480	360	3,120
60	12	.063	.016	.009	.088	ditto	2,520	640	360	3,520
Total for vertical section							45,400	2,600	14,400	62,400

Locality No. 5—T. 12 S., R. 13 E., Sec. 33.

Depth (inches)	Thickness (inches)	Sulfates	Carbonates	Chlorids	Total	Physical Characteristics	Sulfates	Carbonates	Chlorids	Total
12	12	.254	.020	.014	.288	Silt; very loose	10,160	800	560	11,520
16	4	.079	.010	.033	.122	ditto	1,053	133	440	1,626
30	14	.105	.007	.014	.126	ditto	4,900	327	653	5,880
42	12	.081	.012	.014	.107	ditto	3,240	480	560	4,280
54	12	.095	.014	.009	.118	ditto	3,800	560	360	4,720
72	18	.120	.006	.014	.140	Clay; compact	7,200	360	840	8,400
Total for vertical section							30,353	2,660	3,413	36,426

Locality No. 6—T. 13 S., R. 14 E., Sec. 18.

Depth (inches)	Thickness (inches)	Sulfates	Carbonates	Chlorids	Total	Physical Characteristics	Sulfates	Carbonates	Chlorids	Total
12	12	.070	.046	trace	.116	Silty clay; compact	2,800	1,840	trace	4,640
18	6	.244	.008	trace	.253	Silty clay; loose	4,880	160	trace	5,040
32	14	.140	.008	.140	.288	Clay; very compact	6,534	373	6,533	13,440
44	12	.063	.009	.002	.074	Silt; very loose	2,520	360	80	2,960
60	16	.058	.019	.002	.079	ditto	3,100	993	107	4,200
72	12	.062	.010	trace	.072	ditto	2,840	40	trace	2,880
Total for vertical section							22,674	3,766	6,720	33,160

TABLE VII—Continued.

Locality No. 7—T. 13 S., R. 13 E., Sec. 11.

Depth (inches)	Thickness (inches)	Percentages. Sulfates	Percentages. Carbonates	Percentages. Chlorids	Percentages. Total	Physical Characteristics.	Pounds per Acre. Sulfates	Pounds per Acre. Carbonates	Pounds per Acre. Chlorids	Pounds per Acre. Total
6	6	.862	.019	.276	1.157	Silty clay; loose	17,240	380	5,520	23,140
12	6	.317	.008	.239	.564	Clay; compact	6,340	160	4,780	11,280
16	4	.335	.010	.009	.354	Silt; loose	4,466	134	120	4,720
18	2	.427	.009	.117	.553	ditto	2,846	60	780	3,686
30	12	.151	.001	.047	.205	ditto	6,040	280	1,880	8,200
42	12	.165	.011	.014	.190	ditto	6,600	440	560	7,600
48	6	.111	.012	.023	.146	ditto	2,220	240	460	2,920
51	3	.185	.009	.028	.222	Silty clay; compact	1,850	90	280	2,220
53	2	.121	.010	.019	.150	Silty clay; loose	807	67	126	1,000
56	3	.279	.014	.033	.326	Clay; compact	2,790	140	330	3,260
72	16	.061	.013	.014	.088	Silty clay; loose	3,253	693	747	4,693
Total for vertical section							54,452	2,684	15,583	72,719

Locality No. 8—T. 13 S., R. 14 E., Sec. 6.

12	12	.097	.014	.017	.128	Silt	3,880	560	680	5,120
24	12	.903	.002	.173	1.078	Silt	36,120	80	6,920	43,120
Total for vertical section							40,000	640	7,600	48,240

Locality No. 14—T. 15 S., R. 13 E., Sec. 13.

4	4	.731	.007	.075	.813	Clay; somewhat compact.	9,747	93	1,000	10,840
16	12	.642	.012	.211	.865	ditto	25,680	480	8,440	34,600
30	12	.423	.013	.154	.590	ditto	16,920	520	6,160	23,600
40	10	.301	.013	.150	.464	Clay; compact	10,033	433	5,000	15,466
56	16	.335	.012	.323	.670	Clay; somewhat compact.	17,867	640	17,226	35,733
68	12	.388	.009	.103	.500	ditto	15,520	360	4,120	20,000
72	6	.592	.009	.080	.681	ditto	11,840	180	1,600	13,620
Total for vertical section							107,607	2,706	43,546	153,859

Locality No. 15—T. 15 S., R. 14 E., Sec. 16.

12	12	.249	.005	1.928	2.182	Clay; lumpy	9,960	200	77,120	87,280
24	12	.621	.003	1.076	1.700	ditto	24,840	120	43,040	68,000
36	12	.476	.025	.497	.998	ditto	19,040	1,000	19,880	39,920
48	12	.396	.021	.181	.598	ditto	15,840	840	7,240	23,920
60	12	.399	.019	.170	.588	Clay; compact	15,960	760	6,800	23,520
72	12	.245	.015	.070	.330	ditto	9,800	600	2,800	13,200
Total for vertical section							93,440	3,520	156,880	255,840

Locality No. 16—T. 15 S., R. 14 E., Sec. 18. (Imperial.)

12	12	.478	.007	.013	.498	Clay; lumpy	19,120	280	19,920	39,420
72	12	.243	.019	.006	.268	Clay; compact	9,720	760	240	10,720
72	72	.562	.012	.018	.592		134,880	2,880	4,320	142,080
Total for vertical section							134,880	2,880	4,320	142,080

TABLE VII—Continued.

Locality No. 17—T. 16 S., R. 13 E., Sec. 33.

Depth (inches)	Thickness (inches)	Percentages. Sulfates	Carbonates	Chlorids	Total	Physical Characteristics.	Pounds per Acre. Sulfates	Carbonates	Chlorids	Total
9	9	.241	.009	.014	.264	Clay; lumpy	7,230	270	420	7,920
24	15	.572	.009	.051	.632	Clay; compact	28,600	450	2,550	31,600
Total for vertical section							35,830	720	2,970	39,520

Locality No. 18—T. 17 S., R. 13 E., Sec. 20.

Depth (inches)	Thickness (inches)	Percentages. Sulfates	Carbonates	Chlorids	Total	Physical Characteristics.	Pounds per Acre. Sulfates	Carbonates	Chlorids	Total
12	12	.302	.013	.014	.329	Clay; lumpy	12,080	520	560	13,160
18	6	.575	.015	.426	1.016	Clay; very compact	11,500	300	8,520	20,320
30	12	.400	.020	.136	.556	Clay; lumpy	16,000	800	5,440	22,240
34	4	.188	.017	.033	.238	Silt; very loose	2,507	240	1,320	3,167
46	12	.180	.021	.014	.215	ditto	7,200	840	560	8,600
58	12	.158	.012	.019	.189	ditto	6,320	480	760	7,570
72	14	.078	.027	.009	.114	ditto	3,640	1,260	420	5,320
Total for vertical section							59,147	4,440	17,580	80,377

Locality No. 19—T. 17 S., R. 14 E., Sec. 21.

Depth (inches)	Thickness (inches)	Percentages. Sulfates	Carbonates	Chlorids	Total	Physical Characteristics.	Pounds per Acre. Sulfates	Carbonates	Chlorids	Total
12	12	.480	.008	trace	.488	Silty clay; lumpy	19,200	320	trace	19,520
24	12	.333	.008	.094	.435	Clay; lumpy	13,320	320	3,760	17,400
36	12	.065	.020	.005	.090	ditto	2,600	800	200	3,600
42	6	.117	.013	trace	.130	Silty clay; compact	2,340	260	trace	2,600
54	12	.013	.025	trace	.038	Sandy; loose	520	1,000	trace	1,520
66	12	.065	.009	trace	.074	ditto	2,600	360	trace	2,960
72	6	.051	.009	trace	.060	ditto	1,020	180	trace	1,200
Total for vertical section							41,600	3,240	3,960	48,800

Locality No. 21—Mexico.

Depth (inches)	Thickness (inches)	Percentages. Sulfates	Carbonates	Chlorids	Total	Physical Characteristics.	Pounds per Acre. Sulfates	Carbonates	Chlorids	Total
8	8	.231	.011	trace	.242	Clay	6,159	294	trace	6,453
14	6	.736	.019	.037	.792	Clay	14,720	380	740	15,840
26	12	.316	.014	.004	.334	Clay; compact	12,640	560	160	13,360
38	12	.118	.011	.002	.131	ditto	4,720	440	80	5,240
46	8	.076	.019	.001	.096	ditto	2,280	253	27	2,560
55	9	.159	.013	trace	.172	Silty clay; lumpy	4,770	390	trace	5,160
60	5	.143	.025	.061	.229	ditto	2,393	417	1,016	3,816
72	12	.151	.020	.004	.175	ditto	6,240	80	160	7,000
Total for vertical section							54,432	2,814	2,183	59,429

Locality No. 23—T. 13 S., R. 14 E., Sec. 15.

Depth (inches)	Thickness (inches)	Percentages. Sulfates	Carbonates	Chlorids	Total	Physical Characteristics.	Pounds per Acre. Sulfates	Carbonates	Chlorids	Total
12	12	.508	.003	.445	.956	Silty clay; lumpy	20,320	120	17,800	38,240
24	12	.652	.003	.215	.870	Clay; compact	26,080	120	8,600	34,800
36	12	.580	.010	.080	.670	ditto	23,200	400	3,200	26,800
48	12	.424	.005	.066	.495	ditto	16,960	200	2,640	19,800
60	12	.333	.012	.183	.528	ditto	13,320	480	7,320	21,120
72	12	.617	.009	.131	.757	ditto	24,680	360	5,240	30,280
Total for vertical section							124,560	1,680	44,800	171,040

TABLE VII—Continued.

Locality No. 26—T. 15 S., R. 13 E., Sec. 25.

Depth (inches)	Thickness (inches)	Percentages. Sulfates	Carbonates	Chlorids	Total	Physical Characteristics.	Pounds per Acre. Sulfates	Carbonates	Chlorids	Total
4	4	.138	.007	.009	.154	Clay; compact	1,840	93	120	2,053
16	12	.362	.004	.098	.464	ditto	14,480	160	3,920	18,560
28	12	.200	.001	.065	.266	ditto	8,000	40	2,600	10,640
40	12	.163	.016	.033	.212	ditto	6,520	640	1,320	8,480
52	12	.165	.004	.023	.192	ditto	6,600	160	920	7,680
64	12	.129	.006	.019	.154	ditto	5,160	240	760	6,160
Total for vertical section							42,600	1,333	9,640	53,573

Locality No. 27—T. 15 S., R. 13 E., Sec. 34.

12	12	.044	.012	trace	.056	Silt; loose	1,760	480	trace	2,240
30	18	.032	.020	trace	.052	ditto	1,920	1,200	trace	3,120
36	6	.001	.024	trace	.025	Clay; lumpy	20	480	trace	500
42	6	.032	.017	.005	.054	Silt; loose	640	340	100	1,080
54	12	.027	.011	trace	.038	ditto	1,080	440	trace	1,520
66	12	.092	.012	.014	.118	ditto	3,680	480	560	4,720
72	6	.195	.016	.037	.248	ditto	3,900	320	740	4,960
Total for vertical section							13,000	3,740	1,400	18,140

TABLE VIII. Summary Table, showing Soluble Salts to Depth of 4 Feet. New River Region.

Locality.	Pounds per Acre. Sulfates.	Carbonates.	Chlorids.	Total.
1	17,040	2,040	240	19,320
4	42,880	1,960	14,040	58,880
5	21,253	3,020	2,393	25,666
6	17,509	2,977	6,640	27,026
7	45,752	1,694	14,100	61,546
14	71,313	2,036	29,213	102,372
15	69,680	2,160	148,280	219,120
16	89,920	1,920	2,847	94,787
18	30,340	2,780	16,527	49,627
19	37,720	1,200	3,960	42,880
21	43,579	2,024	1,007	46,610
23	96,560	840	32,240	119,640
26	35,240	1,039	8,573	44.852
27	4,880	2,720	100	7,700
Average	44,547	2,028	20,011	66,586
Minimum	4,880	840	100	7,700
Maximum	96,560	3,020	148,280	219,120

TABLE IX. Alkali Salts in Soils Contiguous to Salton River.

Locality No. 2—T. 13 S., R. 14 E., Sec. 4.

Depth (inches)	Thickness (inches)	Percentages. Sulfates	Percentages. Carbonates	Percentages. Chlorids	Percentages. Total	Physical Characteristics.	Pounds per Acre. Sulfates	Pounds per Acre. Carbonates	Pounds per Acre. Chlorids	Pounds per Acre. Total
48	48	.072	.008	.014	.094	Clay; compact	11,520	1,280	2,240	15,040

Locality No. 9—T. 13 S., R. 15 E., Sec. 2.

6	6	.343	.014	.075	.432	Clay; lumpy	6,860	280	1,500	8,640
18	12	.623	.016	.117	.756	Clay; very compact	24,920	640	4,680	30,240
30	12	.444	.017	.145	.606	ditto	17,760	680	5,800	24,040
36	6	.333	.013	.098	.444	ditto	6,660	260	1,960	8,880
48	12	.120	.013	.047	.180	Silt; some sand	4,800	520	1,880	7,200
60	12	.258	.014	.220	.492	Clay; very compact	10,320	580	8,800	19,680
72	12	.115	.013	.103	.231	ditto	4,600	520	4,120	9,240
Total for vertical section							75,920	3,480	28,740	108,120

Locality No. 10—T. 13 S., R. 16 E., Sec. 6.

11	11	.118	.006	.008	.132	Sand; fine, very loose	4,327	220	293	4,840
16	5	.101	.008	.002	.111	Sand and gravel	1,683	134	33	1,850
30	14	.106	.008	.004	.118	Coarse sand	4,046	373	187	5,506
36	6	.486	.008	.026	.520		9,720	160	520	10,400
Total for vertical section							20,676	887	1,033	22,596

Locality No. 11—T. 13 S., R. 15 E., Sec. 36.

14	14	.527	.017	.150	.694	Clay; shaly	24,593	793	7,000	32,386
23	9	.282	.012	.028	.322	Silt; very loose	8,460	360	840	9,660
35	12	.189	.014	.079	.282	ditto	7,560	560	3,160	11,280
41	6	.238	.011	.009	.258	Clay; compact	4,760	220	180	5,160
53	12	.192	.011	.009	.212	ditto	4,680	440	360	8,480
57	4	.087	.014	.009	.110	Silt; loose	1,160	186	120	1,466
Total for vertical section							54,213	2,559	11,660	58,432

Locality No. 20—T. 16 S., R. 16 E., Sec. 22.

12	12	.161	.010	.033	.204	Clay; shaly	6,440	400	1,320	8,160
30	18	.151	.012	.005	.168	ditto	9,060	720	300	10,080
42	12	*	-----	-----	-----		-----	-----	-----	-----
54	12	.022	.010	trace	.032	Sandy	880	400	trace	1,280
72	18	.017	.008	.005	.030	ditto	1,020	480	300	1,800

*Sample spoiled by becoming wet.

Locality No. 22—8 miles south from Sec. 8, R. 17 E., Mexican line.

12	12	.224	.012	.001	.237	Silt; very fine	8,960	480	40	9,480
24	12	.341	.012	.033	.386	ditto	13,640	480	1,320	15,440
36	12	.376	.012	.014	.302	ditto	15,040	480	560	12,080
48	12	.275	.014	.047	.336	ditto	11,000	560	1,880	13,440
Total for vertical section							48,640	1,900	3,800	50,440

TABLE X. Summary Table, showing Soluble Salts to the Depth of 4 feet in localities near Salton River.

Locality.	Pounds per Acre.			
	Sulfates.	Carbonates.	Chlorids.	Total.
2	11,520	1,280	2,240	15,040
9	61,000	2,380	15,820	79,200
11	48,103	2,190	11,390	61,596
22	48,640	1,900	3,800	50,440
Average	42,314	1,938	8,312	52,564
Minimum	11,520	1,280	2,240	15,040
Maximum	61,000	2,380	15,820	79,200

Even a cursory glance at the preceding tables shows that the distribution of the silty and clay lands is very much "spotted"; for while there is a general predominance of clay on the west, contiguous to New River, especially in the westward bend of that channel, in range 13, there are also two silt localities (Nos. 5 and 7) in the same range, together with localities 1, 4, 6, 8, and 19 in range 14. Elsewhere we find in ranges 14 and 15, localities 2 and 9 with compact clay soils, although generally silts are predominant on the Salton. Only detailed mapping can therefore segregate the several areas; but each one can test the soil character easily by boring or digging, or preferably by the irrigation test, *i. e.*, noting how rapidly the water will penetrate to the depth of from three to six feet, according to the crops it is intended to plant. In the absence of ditches, water sufficient for the purpose can be hauled to the spot.

That the two deep vertical sections do not represent the worst of the land is shown in the more shallow sections from near New River, where eight out of fourteen of the more shallow sections exceed the deep section from New River bank in the total alkali present. In the case of the shallow sections from near Salton River, however, the condition does not appear to be as bad, for but one out of four exceeds the river-bank section in the total alkali present in the first four feet.

In looking closely at the lesser sections, as well as at those taken from the river banks, there will be seen a general tendency for a break to occur in the total alkali content after the second foot, which generally seems to carry a larger amount of salts than the top foot. This break will serve largely as a saving clause for the lands, in many cases rendering it possible to reduce the alkali in the upper layers of the soil below the maximum of tolerance for crops. Particularly will this be true in growing alfalfa, which has been found to resist a surprising amount of alkali *when it is once well rooted*. In this same region excellent fields have been grown where the soil carried as high as 110,000 pounds of alkali to the depth of six feet, and 79,760 pounds to the depth of four feet. The figures showing the alkali content of two of the alfalfa fields near Yuma are herewith presented.

Sample 28 was taken two miles south of Yuma in Mr. C. C. Dyer's alfalfa field.

Sample 31 was taken from the alfalfa field adjoining Mr. Smith's dairy, one and one half miles south of Yuma. The soil was moist to a depth of 5 feet.

TABLE XI. Showing Soluble Salts in Yuma Alfalfa Lands.

	Physical Characteristics.	Depth (inches)	Thickness (ins.)	Percentages. Sulfates	Percentages. Carbonates	Percentages. Chlorids	Percentages. Total Salts	Pounds per Acre. Sulfates	Pounds per Acre. Carbonates	Pounds per Acre. Chlorids	Pounds per Acre. Total Salts
Sample 28.	Silt; very loose	12	12	.402	.010	.012	.424	16,080	400	480	16,960
	ditto	24	12	.683	.013	.038	.734	27,320	520	1,520	29,360
	ditto	36	12	.456	.008	.016	.480	18,240	320	640	19,200
	ditto	48	12	.328	.008	.014	.350	13,120	320	560	14,000
				.467	.009	.020	.499	74,760	1,560	3,200	79,520
Sample 31.	Silt; loose	12	12	.356	.008	.018	.382	14,240	320	720	15,280
	ditto	24	12	.829	.010	.031	.870	33,160	400	1,240	34,800
	ditto	36	12	.416	.008	.044	.468	16,640	320	1,760	18,720
	ditto	48	12	.248	.009	.017	.274	9,920	360	680	10,960
	Clay; lumpy	60	12	.342	.009	.027	.378	13,680	360	1,080	15,120
	Silty clay; lumpy	72	12	.371	.008	.007	.386	14,840	320	280	15,440
				.427	.009	.024	.459	102,480	2,080	5,760	110,320

It is safe to say that much of the land near Salton River will produce excellent crops of this forage plant if it can once be started. The young plants of this crop are quite sensitive to alkali, and in most instances it would be necessary to reduce the salts in the upper layer of the soil by heavy and deep irrigation in order to secure a stand. It took four years to secure good stands in the above fields.

That it is possible to do this in most cases on the Salton River silts can be seen by referring not only to the sections from the river bank, but also to the lesser sections. In a previous publication from this Station (Bulletin No. 133), Dr. Loughridge has shown that when young this plant will stand in the neighborhood of 12,000 pounds of salts. When the distribution of the alkali in the silt soil is considered in connection with the rapidity of percolation, as shown by the experiments previously discussed, the condition for crop-growing on these soils seems quite favorable. There is, however, a distinct disadvantage in the case of the silt soil for crops which require open culture, namely the high capillary power; which will tend to bring up the alkali rapidly when exposed to surface evaporation after irrigation. To successfully cultivate these lands and not experience a very serious "rise of alkali," it is very imperative that they be at all times kept in good tilth by frequent and deep cultivation. *If this be not done there is almost sure to follow a very serious alkali condition in the upper layers of the soil.*

Looking again at the tables and profiles, we find throughout that the carbonates are insignificant, and, except so far as there is a likelihood that under heavy irrigation they may be formed in the future, can be left out of consideration at present. As to the chlorids, the land near New River seems to carry the larger amount; which might be expected from what has been said heretofore. It shows the enormous range of 100 to 148,280 pounds per acre to a depth of four feet; and when the generally high chlorid content of these clays is considered, together with their other unfavorable properties, it is apparent what a hopeless task it will be to attempt to handle them successfully. The people who have been unfortunate enough to settle upon these dense, hard clay soils should change to some more auspicious location, the sooner the better.

THE IRRIGATION WATER.

A consideration of the soluble salt content of the available irrigation water is of nearly as great importance as a like consideration of the soils themselves; for when water highly impregnated with alkali is used for irrigation purposes, all the alkali in that portion of the water which evaporates from the surface will be left in the land, and if the water be very bad the land may soon become so highly charged with alkali from this cause alone that it will not grow profitable crops. This fact is the more important in case the lands to be irrigated are themselves as heavily loaded with alkali as those under consideration; for the salts left after the evaporation of the water become an added evil with which to contend, and may prove "the straw that breaks the camel's back."

It is not easy to state absolute figures as to what constitutes an excess of salts in water to be used for irrigation purposes, for not only must the nature of the saline content of the water be considered, but also that of the land to be irrigated. The far more variable factor, the quantity and frequency of irrigation required, also demands attention.

Speaking along this line in a previous publication, the Director of the Station has said: "Broadly speaking, the extreme limit of mineral content usually assigned for potable waters, viz: 40 grains per gallon, also applies to irrigation waters. Yet it sometimes happens that all or most of the solid content is gypsum and epsom salt; when only a large excess of the latter would constitute a bar to irrigation use. When, on the contrary, a large portion of the solids consists of carbonate of soda, or common salt, even a smaller proportion of salts than 40 grains might preclude its regular use, depending upon the nature of the soil to be irrigated. For in a clay loam, or heavy adobe, not only do the salts accumulate nearer the surface, but the sub-drainage being slow and imperfect (unless the land is underdrained), it becomes difficult, or impossible, to wash out the saline accumulations from time to time, as is readily feasible in sandy soils."

Subjoined is a table showing analyses of the water of the Colorado River which is used for irrigation purposes in the region. In the same table are shown analyses of water from two of the lakes, and of a well in the region, all the analyses having been made by Mr. Snow.

TABLE XII. Water Analyses.

	Colorado River "near Head Gates."				Blue Lake.		Well at Cameron Lake.		Cameron Lake.	
	Turbid.		Clear.							
	Grains per Gallon....	Parts in 10,000....	Grains per Gallon...	Parts in 10,000....	Grains per Gallon.	Parts in 10,000.....	Grains per Gallon.	Parts in 10,000.....	Grains per Gallon.	Parts in 10,000.....
Total residue by evaporation	79.73	13.65	51.11	8.75	26.57	4.55	43.69	7.38	104.96	17.97
Soluble in water after evaporation	33.57	5.75	33.59	5.75	16.94	2.90	23.95	4.10	78.56	13.45
Insoluble in water after evaporation	38.55	6.60	9.93	1.70	6.42	1.10	15.07	2.58	16.65	2.85
Organic matter and chemically combined water	7.59	1.30	7.59	1.30	3.21	.55	4.67	.80	9.75	1.67
The soluble part consists of—										
Sodium and Potassium sulfates (glauber salt, etc.)	19.35	3.32	21.20	3.64	2.33	.40	21.22	3.64	40.45	6.93
Sodium chlorid (common salt)	6.75	1.16	6.82	1.16	4.09	.70	2.73	.46	23.87	4.08
Sodium carbonate (sal soda)	7.42	1.27	5.57	.95	------	------	trace	trace	14.24	2.44
The insoluble part consists of—										
Calcium and magnesium carbonates	21.32	3.65	9.35	1.60	5.55	.95	13.73	2.35	sm.	
Calcium sulfate (gypsum)					trace	----	sm.	-----	16.36	2.80
Silica	17.23	2.95	.58	.10	.87	.15	1.34	.23	.29	.05
Residue upon slight ignition	Browns.		Does not blacken.		Blackens.		Browns.		Blackens.	

In connection with the above table we give two analyses of the Colorado River water from the Eleventh Annual Report of the Arizona Experiment Station. Each analysis represents water from samples taken over periods of a week:

	Grains per U. S. Gallon.	
	Jan. 22–28. Low water.	Apr. 25–May 1. Medium flow.
Silt by volume	.17%	.392%
Silt by weight	.058%	.115%
Total soluble solids	58.41	33.24
Sodium chlorid	21.07	10.26
Permanent hardness; stated as calcium sulfate	9.67	8.24

These analyses show the composition of the water to be quite variable at different periods of the same season and in different seasons. It will be noted that the maximum concentration shown is over 58 grains of soluble salts per gallon when the water is at a low stage, and that these fall to about 30 grains per gallon during the period of medium flow. In the Arizona report previously referred to it is further stated that "the total soluble solids were observed to average as low as 25 parts per 100,000 (14.5 grains per gallon) for months at a time." It is during this time, so far as possible, that the water would be mainly used for irrigation purposes, thus indicating the water to be of fair quality for use upon the silt soils. The quantity of soluble salts is influenced by the stage of the water and by the seepage from irrigation districts; the latter materially influences the character of the salts present. That this is so may be seen by comparing the proportion of sodium chlorid present at the several times, for at one period (in 1900) this ingredient reaches a maximum of one third of the total soluble salts, and in another constitutes only about one fifth. The carbonates appear to form about one sixth of the total. While this water could be used with impunity upon the silts, it would but increase the extremely undesirable saline conditions of the clay soils of the region.

Manner of Irrigating Alkali Lands.—The manner of using water upon these lands, in order that the salts may not be brought to the surface and thus increase the saline condition, especially of the upper foot, is of great importance in handling these strongly saline lands. The general principle has been indicated at several points in this publication, viz: that of leaching down the salts in the soil itself, thus reducing the amount of alkali in the upper foot, and taking it out of reach of the tender rootlets of the young plants especially. The water under these conditions should not be kept on the tract for a less period than twenty-four hours, and for a thorough leaching-down a considerably longer time should be given. The behavior of the soil when irrigated should be the first thing tried in order to test the possibilities of successful cultivation; taking into consideration the known fact that the rapidity of absorption ("taking water") gradually increases under cultural conditions, largely because of the loosening of the soil by the crop roots, as well as by tillage.

"It is not practicable, as many suppose, to wash the salts off the surface by a rush of water, even when visibly accumulated there, as they instantly soak into the ground at the first touch. Nor is there any sensible relief from allowing the water to stand on the land and then drawing it off; in this case also the salts soak down ahead of the water, and the water standing on the surface remains almost unchanged. In very pervious soils, and in the case of white alkali, the washing-out can often be accomplished without special provision for underdrainage, by leaving the water on the land sufficiently long. But the laying of regular underdrains greatly accelerates the work, and renders success certain."*

After the salts have been washed down so as to relieve the surface soil of any excess injurious to the germination of seeds or the life of young seedlings, irrigation by flooding must, except in the case of crops that fully shade the ground, be practiced only at long intervals, if at all. To prevent the "rise of the alkali" that is sure to follow continued surface flooding, the water should thereafter be applied in deep furrows, from which the water will chiefly soak downward and sideways only, and preferably not rise to the surface at all. *Evaporation from the soil surface is the cause of the accumulation of the salts at and near that surface;* to prevent it it is necessary to avoid wetting the latter, and this is best brought about by deep-furrow irrigation, which, at the same time, allows of a considerable saving of water, while tending to deepen the root-system and so to bring it out of reach of the destructive heat and drought of summer.

Diagram V illustrates the manner in which irrigation water can be used so as to prevent its reaching the surface to any such extent as to cause a serious amount of evaporation. The solid lines represent the manner of penetration of water from furrows 8 inches deep, as actually observed at the Southern California substation near Pomona (see Bulletin No. 138, page 38) in two different soils, of which the heavier (to the left) resembles most nearly in texture the silt and loam soils of the Salton Basin. The dotted lines show the effects that would have been produced had the furrow been made deeper to the extent of 7 inches; in which case the water would have reached the surface only at the edges of the furrows, so that when these are subsequently closed by plowing there would be practically no surface evaporation, and no after-cultivation would be required to prevent crusting-over.

* Bulletin No. 128, California Experiment Station.

It is evident that with the proper implements for the purpose, such deep-furrow irrigation, to prevent the re-ascent of alkali near the surface, could be made a ready means of utilizing a large proportion of the alkali lands here in question without any difficulty, and with a

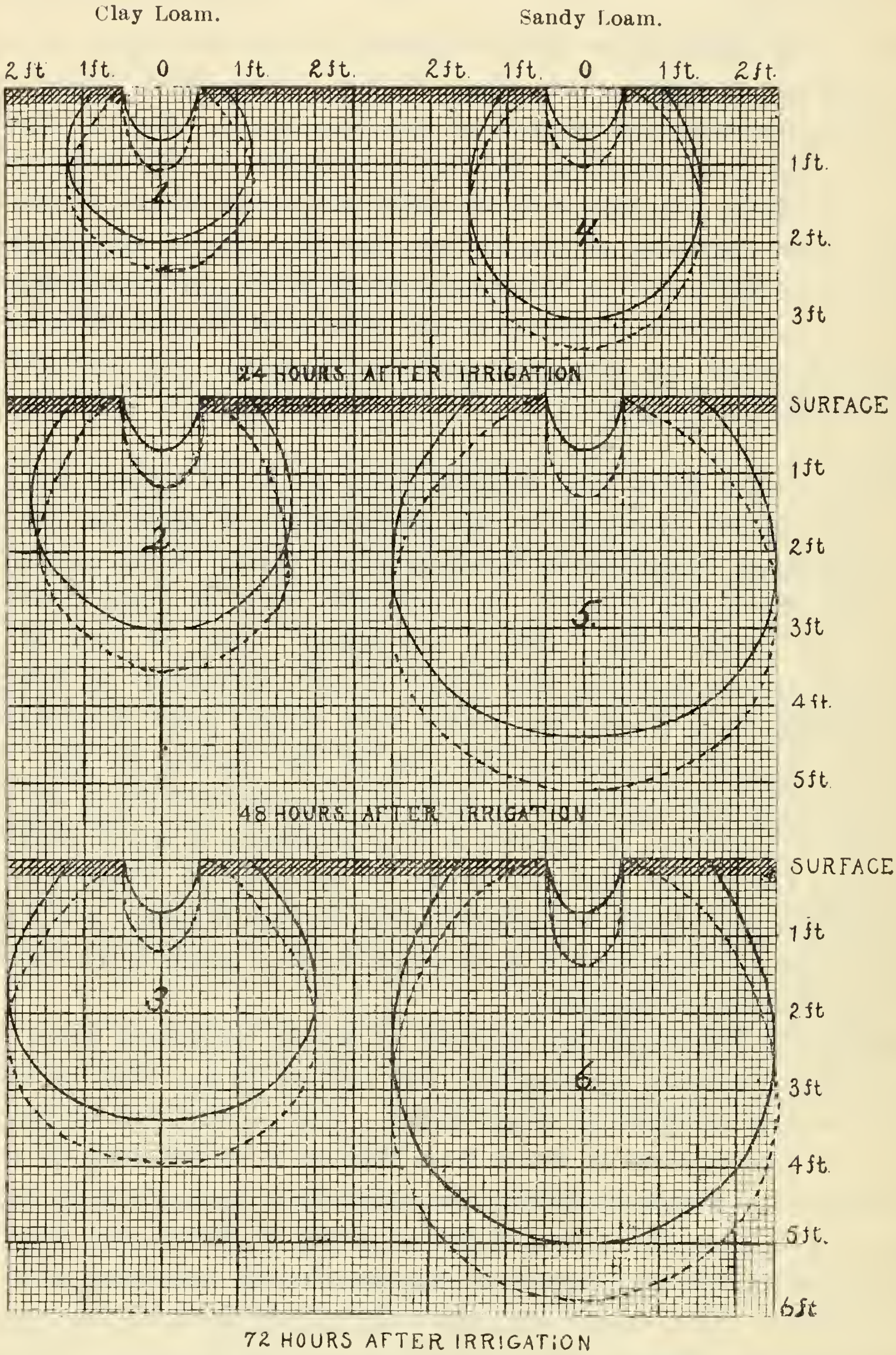


Diagram V. Percolation experiments. Spread of water from deep furrows in heavy and light soils.

material saving of water and cost of surface cultivation, in addition to the advantages secured in the deeper penetration of the roots into materials which, as the sections of the river banks show, are but very slightly tainted with alkali salts.

Of course, this method is best applicable to crops grown in rows, as orchards and vineyards, sorghum, corn, etc. For broadcast crops it can only be used in rather pervious soils, which can be irrigated by lateral seepage when laid off in "lands" of a width proportionate to the rapidity of water-penetration. In the Mussel Slough district such lands are made about 50 feet wide; but as the soils here in question are not nearly as open, they would have to be made narrower. By following this method carefully and intelligently, most of the lands of the silty character can probably be successfully cultivated to crops not too sensitive to alkali, provided they are not underlaid at too shallow a depth by the impervious clay; as is frequently the case between the two rivers. The clay will of course arrest the alkali-laden irrigation water in its downward course, and thus from a depth of a few feet it will be constantly reascending toward the surface. Such land will be hard to cultivate successfully without actual underdrainage, except to the hardiest crops, such as sorghum, barley, and shallow-rooted plants generally. Alfalfa can hardly be a success on land having the clay within less than five feet; for fifteen or twenty feet are ordinary depths of penetration for its roots. When the clay layer is not of great thickness and is underlaid by silty materials, success in tree-planting may be attained by blasting with giant powder; as is commonly done with hardpan of other kinds, when a good soil material is known to lie beneath. *In the case of alfalfa, modiola, and other plants which eventually cover and shade the ground very fully, the evaporation through the roots and leaves will largely prevent the rise of the alkali, even when flooding is practiced.*

It is clear that, in this region at least, no farmer can afford to be ignorant of the undersoil conditions upon his land; and if heavy irrigation is practiced, he should make absolutely sure by personal observation that the soil is actually being wetted to the depth of five or six feet, and note how long it takes to bring about this wetting. Such examination can be made either by means of a long-shafted posthole auger or two-inch carpenter's auger; or more quickly, after some practice has been acquired, by the use of a pointed prod made of quarter-inch square steel, with a loop for a cross-handle, which can be pushed down by twisting it slightly alternately in opposite directions. This rod also serves admirably for preliminary tests of the subsoil in the examination of lands.

Drainage.—The natural slope of these lands toward Mesquit Lake, as shown by the contour lines of the map, together with the good percolative power of the lighter silty and sandy lands, renders the leaching of their salts into drainage ditches running toward the lake perfectly feasible, and simplifies the problem of ultimate successful cultivation.*

* In studying the contour lines on the map it should be noted that the small figures appearing on these lines do not indicate directly the elevation above the sea, but only the relative altitude of the several points. The point of reference used is 1,000 feet above sea level, and the true altitude (or rather depression) can be found by deducting 1,000 from these figures.

For the permanent betterment of the lands, those interested should, by community action, devise a thorough system of drainage. Such a system might at the beginning be a number of deep ditches, into which the alkali-charged seepage-water could enter from flooded areas, until the far preferable plan of tiling could be profitably introduced.

An illustration in point obtains in the case of the Patterson ranch, at Oxnard, a portion of which became much "salt-stricken," but where, after the construction of a deep drainage canal into which were led laterals, there was, and is, a constant removal of the accumulated salts at a surprisingly rapid rate.

VEGETATIVE CHARACTERISTICS OF THE SALTON BASIN.

That the vegetation of any region supplies important information concerning its agricultural adaptations is so well known in practice as not to require discussion. It is especially instructive in its application to alkali lands; and Mr. Snow was therefore instructed to observe and collect for determination specimens of all the plants to be found on the territory explored by him.

"While the adaptation or non-adaptation of particular alkali lands to certain cultures may be determined by sampling the soil and subjecting the leachings to chemical analysis, it is obviously desirable that some other means, if possible available to the farmer himself, should be found to determine the reclaimability and adaptation of such lands for general or special cultures. The natural plant growth seems to afford such means, both as regards the quality and quantity of the saline ingredients. The most superficial observation shows that certain plants indicate extremely strong alkali lands where they occupy the ground alone; others indicate preëminently the presence of common salt; the presence or absence of still others forms definite or probable indications of reclaimability or non-reclaimability. Many such characteristic plants are well known to and readily recognized by the farmers of the alkali districts. 'Alkali weeds' are commonly talked about almost everywhere; but the meaning of this term—*i. e.*, the kind of plant designated thereby—varies materially from place to place, according to climate as well as to the quality of the soil. Yet if these characteristic plants could be definitely observed, described, and named, while also ascertaining the amount and kind of alkali they indicate as existing in the land, lists could be formed for the several districts, which would indicate, in a manner intelligible to the farmer himself, the kind and degree of impregnation with which he would have to deal in the reclamation work, thus enabling him to go to work on the basis of his own judgment, without previous reference to this Station." *

The season at which the exploration took place (Christmas vacation)

* Bulletin No. 128, California Experiment Station, p. 35.

was of course unfavorable to the finding of all the kinds of plants that might occur somewhat later. Only twenty-two species in all were collected, and these were submitted for determination to Mr. Joseph Burtt Davy, Assistant Botanist to the Station. Mr. Davy's results and comments are given herewith, together with the annotations of Mr. Snow, placed in brackets.

ANNOTATED LIST OF PLANTS FROM THE SALTON BASIN.

(Collected by F. J. Snow.)

By Jos. Burtt Davy, Assistant Botanist.

CRUCIFERÆ.

1. *Lepidium lasiocarpum*, Nutt. *Pepper-cress.*

Five miles south of proposed townsite. [Very abundant near Mexican line.]

Salton River, near Patton's camp. [Abundant in scattering places.]

T. 13, R. 15. [Scarce, except in small patches.]

Mexico: 15 miles from line. [Scarce.]

A common desert annual, probably tolerant of some alkali, as are many other species of the genus, but not necessarily indicative. It is sometimes found also in moist alluvial soils, and ranges from Santa Barbara through the Mojave plateau region and, east of the Sierra, northward to Keeler.

ZYGOPHYLLACEÆ.

2. *Larrea tridentata* (DC.) Coville. *Creosote-bush.*

Along Salton River. [Abundant in places along the river. Very abundant toward Mexican line.]

Locality 9, T. 13, R. 15. [A few scattering live bushes.]

Mexico: 15 miles from line. [A few bushes. Becomes very abundant near Mexican line along Salton River.]

One of the most characteristic desert plants, occurring almost throughout the Lower Sonoran zone from the bottom of Death Valley about 300 feet below sea level to an altitude of 5,500 feet in the Panamint Mountains. It is not an alkali plant, and usually grows on well-drained soils well above the alkali line; but at its lower limit a few scattered specimens are often found in the *Atriplex polycarpa* belt, in a mixture of gravel and clay with some visible trace of alkali.

LEGUMINOSÆ.

3. *Astragalus mortoni*, Nutt. *Morton's loco-weed; "Loco-weed"; "Wild pea."*

Salton River bed; "if cattle eat, will go crazy." [Scattering plants along the river-bed.]

New River bed. [A number of plants near north end of river-bed.]

Moist grounds along the eastern base of the Sierra Nevada, in the vicinity of Mono Lake, and northward to the interior of Oregon and Utah. Well known as "a deadly sheep poison." We have no information as to its tolerance of alkali, but other species of the genus are characteristic alkali plants.

4. *Prosopis juliflora* (Swartz) DC. *Mesquit-tree; Algaroba; Honey mesquit.*

Near Mexican line—a few miles from Blue Lakes. [Abundant.]

Characteristic of desert areas with moist subsoil. It sometimes occurs on the edge of alkali marshes in company with *Atriplex canescens* and *Suæda suffrutescens*, where a slight alkali efflorescence or thin crust occurs, but above the heavily alkaline soils, though below the *Atriplex polycarpa* belt. I have found it in somewhat alkaline soils near Bakersfield. Though tolerant of some alkali, it is not an alkali indicator. Its altitudinal range varies from 328 feet below sea level, to 5,650 feet above.

FICOIDEÆ.

5. *Sesuvium portulacastrum*, L. *Lowland purslane.*

New River channel. [Found at the north end of New River channel; but few plants to be seen elsewhere.]

A very characteristic plant of moist alkali and saltmarsh soils both in the interior and along the seacoast. It is found in alkali marshes in the Mojave Desert and the Tulare Valley, and in the Great Basin region from northern Nevada to Colorado and New Mexico. It is said that in the interior it often occurs with much broader leaves than is usual when growing along the seashore. We have no analysis showing the tolerance of alkali by this plant, but it has been found growing in soils so heavily impregnated with salts that scarcely any other plants grew there.

COMPOSITÆ.

6. *Bigelovia veneta* (H. B. K.) Gray. *Bigelovia.*

Ten miles south of Blue Lakes. [Abundant.]

Alkali meadow at monument east of Salton River. [Abundant.]

A plant of the Lower Sonoran zone, common in moist alkali soils, but apparently not tolerant of a very large percentage. In the Bakersfield region the salt tolerance of this plant was found to vary from 1,800 pounds of salts per acre to 24,320 pounds. It was not found in soils heavily charged with alkali.

7. *Baccharis* sp. (imperfect material). *Sausal; Baccharis;* (also *Arrow-wood*, in part).

Salton River bed. [Found only in river-bed in numerous places.]

Our species of *Baccharis* are swamp plants, usually growing on the borders of rivers and streams or in "washes." As a rule they are found in fresh water, but at least one species (not this one) sometimes occurs in slightly alkaline water. Two other species, *B. emoryi*, Gray, and *B. sergiloides*, Gray (to neither of which does the specimen appear to belong), occur in the Colorado Desert region.

8. *Pluchea sericea* (Nutt.) Coville. *Cachimilla; Arrow-wood.*

Salton River bed.
New River.
New River channel.
} [Abundant along portions of the river channels and banks.]

T. 13, R. 15. [Scarce.]

Reported as occurring along sandy borders of streams from Ventura County eastward to Utah and south through Arizona to New Mexico. Both of our species of *Pluchea* frequent moist alkali swamps, and one of them occurs both in the interior in the Suisun marshes and in the saltmarshes of San Francisco Bay. The amount of alkali tolerated is evidently considerable, as *P. sericea* occurs in association with Alkali tussock-grass (*Sporobolus airoides* (Torr.) Thurb.) and Salt-grass (*Distichlis spicata* (L.) Greene) in the Mojave Desert plateau region.

HYDROPHYLLACEÆ.

9. *Nama hispidum*, Benth.

Salton River bed. [Scarce, except in certain portions of the river-bed.]

A desert annual, apparently restricted to the Colorado Desert, and probably not indicative of alkali.

BORAGINACEÆ.

10. *Coldenia palmeri*, Gray.

Sample 10, T. 13, R. 16. [On sandy, high lands. Not very abundant.]

A dwarf, desert perennial occurring on sand-hills along the Colorado and lower part of the Mojave and adjacent Arizona. (*Bot. Calif.*)

11. *Heliotropium curassavicum*, L. *Wild heliotrope.*

Along Salton.
New River.
New River channel.
} [Abundant along the river-bed.]

Alkali meadow at monument east of Salton River. [Abundant.]

A nearly cosmopolitan weed, common in sands of the seashore, and in moist alkaline soils of the interior. It generally indicates the presence of alkali and moisture, but is sometimes found in soils apparently free from alkali.

AMARANTACEÆ.

12. *Amarantus chlorostachys*, Willd. *Pigweed.*

Salton River near Patton's camp. [Scattering dead plants, with here and there live plants of rank growth. To the west, about 2 miles, they thrive and attain a very rank growth. It is also found east of Salton River near the Mexican line.]

A semi-tropical weed, probably naturalized.

13. *Amarantus palmeri*, Wats. (?)

Sample 11, T. 13, R. 15. [Scattering plants; abundant toward the Mexican line.]

A desert species, apparently indigenous to the Colorado Desert and Rio Grande regions. The Amaranths are such omnivorous, weedy plants that they can not be relied upon as alkali indicators.

CHENOPODIACEÆ.

14. *Atriplex lentiformis* (Torr.) Wats. *Lens-fruited saltbush.*

New River. [Found scattered in New River country; abundant in places and in river-bed.]

Mexico: 15 miles from line. [Scarce in this locality; but abundant near Mexican line.]

Alkali meadow at monument east of Salton River. [Abundant.]

A desert species, ranging from the Tulare Valley to the Colorado Desert and eastward through Arizona. We have no record as to its tolerance of alkali, but the list of localities in which it has been found and the plants with which it is associated, indicate that it is an alkali plant.

15. *Atriplex polycarpa* (Torr.) Wats. *Scrub saltbush;* called "*Greasewood*" in the Mojave Desert, but not the "*Greasewood*" of the Great Basin region.

Mexico: 15 miles from line. [Abundant in certain localities near Mexican line.]

A characteristic desert species, ranging through the Lower Sonoran zone from the Tulare Valley through the Mojave and Colorado deserts to the Williams River in Arizona. Common in clayey valley bottoms, usually in dry soils. Analyses of scrub saltbush soils near Bakersfield show that its tolerance of salts ranges from 840 pounds to 78,000 pounds per acre.

16. *Atriplex canescens* (Pursh) James. *Shad scale;* sometimes called "*greasewood.*"

Sample 9, T. 13, R. 15. [Many dead bushes on small hummocks. A few live bushes, which are very large, are found scattered near.]

Sample 11, T. 13, R. 15. [Many dead bushes are found in this vicinity.]

T. 13, R. 15. [Many dead bushes on small hummocks; also scattering live bushes.]

Near Mexican line, a few miles from Blue Lakes. [Abundant near the lake.]

Mexico: 15 miles from line. [Scarce; but very abundant near the line on Salton River.]

A common and characteristic species, occurring in dry soils both in the Upper and Lower Sonoran zones in the Mojave and Colorado deserts, and in the Great Basin region from northern Nevada and Colorado to New Mexico. It does not appear to reach the Tulare Valley. It occurs in dry soils, on mountain slopes at altitudes ranging between 2,300 and 4,700 feet, and does not seem to be indicative of the presence of alkali. Like the Mesquit and Creosote-bush, it is sometimes found sparingly in slightly alkaline soils at its lower limit.

17. *Atriplex* sp. (immature).

Sample 8, T. 11, R. 14. [A few scattering dead bushes.]

Sample 9, T. 13, R. 15. [Dead bushes are found on small hummocks.]

18. *Suæda* sp. (immature). *Saltwort; Glasswort.*

Salton River bed. [Abundant along the river-bed.]

New River. [Abundant along the river-bed.]

The saltworts are characteristic alkali indicators, and are not known to occur elsewhere than in moist alkali soils. The total amount of salts tolerated has a wide range of variation, running from 3,700 pounds to 153,000 pounds per acre; but saltwort has been found in greatest luxuriance where the total amount of salts was 130,000 pounds per acre. The saltworts appreciate more common salt (sodium chlorid) than many other characteristic alkali plants, but appear to be somewhat easily affected by salsoda (sodium carbonate).

POLYGONACEÆ.

19. *Rumex* sp. (immature). *Dock.*
Along Salton. [Abundant in places along the river bank.]
Salton River bed. [Abundant in places along the river-bed.]
At monument east of Salton River. [Abundant.]

Two or three species are found in moist places in the Mojave and Colorado deserts.

GRAMINEÆ (TRUE GRASSES).

20. *Leptochloa imbricata*, Thurb. *Alkali slender-grass.*
Near Salton River bed, 15 miles from line. [Not abundant.]

Common in moist places and alkali plains from the Tulare Valley through the Colorado Desert to Lower California, and eastward into Mexico and Texas. A somewhat stout perennial, 1 to 3 feet high, "abundant in fields and gardens, thrifty on alkali plains and near soft [salt?] water; abundant in August and September, when alfalfa is dried up; a good forage plant, cut and fed to animals." (*Dr. Ed. Palmer.*)

GNETACEÆ.

21. *Ephedra* sp. (immature).
Ten miles from Blue Lakes. [Abundant near the lake and along New River near the Mexican line.]
Characteristic desert shrubs, said to be sometimes found in alkali soils.

UNCLASSIFIED.

22. Dwarf annual (immature and not recognized).
Sample 8, T. 11, R. 14. [Only a few plants to be found.]
Sample 9, T. 13, R. 15. [Only a few plants to be found.]

The list of plants here given is notable for the absence of most of the species considered elsewhere as prominent alkali indicators. We miss at once the salt- or alkali-grass (*Distichlis*), the "greasewood" of Nevada (*Sarcobatus*) and that of the San Joaquin Valley (*Allenrolfea*), the samphire (*Salicornia*), and the tussock-grass (*Sporobolus airoides*). Of the saltbushes proper (*Atriplex*), two (*A. polycarpa* and *lentiformis*) appear elsewhere as species indicating the probable presence of considerable alkali, while the other two species observed are not known as alkali plants. The two plants that may be considered as indicators of strong alkali, especially of common salt, are the saltwort (*Suæda*) and the lowland purslane (*Sesuvium*); their indication is strengthened by their occurence in the river channels, at whose level the profiles (pp. 20 and 21) show an abundance of salt. But as a whole, the collection made does not speak of "irreclaimable" alkali land, so far as we know their habits. The heliotrope will grow luxuriantly in non-saline lands, but also where common salt can be seen by the seaside. The creosote bush (*Larrea*), the pepper-cress (*Lepidium*), the pigweeds (*Amarantus*), the Bigelovia (yellow-flowered, sometimes called green sage) are not plants addicted to alkali lands. Taken as a whole, the native vegetation does not altogether confirm the unfavorable impression derived from the leaching of the soil samples. It is hoped that a more detailed examination of the flora at a more favorable season, soon to be undertaken, will throw more light on these questions.

CLIMATE OF THE SALTON BASIN.

The high summer temperature and dryness of the air in the Salton region are well known, being in this respect similar to the rest of the Colorado Desert. While the thermometer during summer usually rises to and above 100° Fahr. (124° having been recorded twice at Salton during 1901), the heat is not oppressive, on account of the dryness of the air, which evaporates the perspiration as soon as formed. The nights are usually decidedly cool to the sensation. The winter temperatures are in strong contrast to the summer heat, as will be seen from the small table, given below, of observations made by Mr. Snow during December, 1900, and January, 1901. It will be noted that a minimum temperature of 13° occurred on January 2d, so that ice two inches thick formed near camp. Such a temperature would at once prohibit the culture of citrus fruits, but may occur only locally, on low ground. Still, the run of December temperatures, from observations all over the region, indicates clearly that "semi-tropic" growths will incur considerable risks, unless protected in winter.

Morning Temperatures Observed in Salton Basin at 8 o'clock.

1900.		1900.		1901.	
Dec. 22	23°	Dec. 27	21°	Jan. 1	38°
23	*21	28	25	2	13
23	†70	28	††73	3 §	23
24	‡24	29	28	4	30
25	23	30	26	5	40
26	20	31	24	6	30

* Dec. 23. Ice in washpan and on pond two inches thick.
† Dec. 23. For the day.
‡ Dec. 24, 25, 26, and 27. Ice in ponds.
†† Dec. 28. For the day.
§ Jan. 3. Surveyors' Camp 17.

CROPS FOR THE SALTON BASIN.

As to crops for the silt soils of this region, it must be said that the showing here made is not at all encouraging for extensive fruit-growing at the present time. While there may be localities in the region which could grow the fruits more tolerant of alkali and dry heat, yet we deem it unwise at present to encourage the planting of fruit, except the date-palm, to any considerable extent. The date-palm would doubtless be one of the fruits which could be most successfully grown, taking into consideration both the climate and the alkali soils. To this might be added olives, figs, table, sherry, and port grapes; and on the sandier lands, almonds, peaches, and some of the Japanese plums (all on Myrobalan stock) might be grown. Of ordinary crops, alfalfa, barley, sorghum, and beets for stock food, together with the saltbushes, are those that will be most likely to succeed before drainage to carry off the alkali salts has been made effective. Among the vegetables, the egg-plant, melons, cucumber, carrot, celery, asparagus, onion, sea-kale, and New Zealand spinach are those most likely to succeed.

It must not be forgotten that high summer temperature will militate materially against the production of the ordinary deciduous fruits, even after the lands have been successfully leached of their alkali to the extent necessary to permit the growth of such trees. The effects of hot northers upon these trees in other parts of the State indicate plainly what is likely to be the effect of the normal atmospheric conditions of the Colorado Desert upon them. The cultural experience had at Indio will be valuable in determining the reasonable prospects for successful culture of several crops, always keeping in mind that the light sandy soils of that portion of the region, containing but little alkali and easily leached of what there is by flooding, are more easily handled than those of the alluvial area here in question.

The following list of possible crops for alkali soils has been compiled by Mr. Joseph Burtt Davy, Assistant Botanist of the Station. It should be understood that while the plants mentioned in this list are all more or less alkali-resistant, yet the extreme climatic conditions existing in the Salton Basin render the actual success of many very questionable, although worthy of trial. The "toleration" list will aid in making selections for experiment.

POSSIBLE CROPS FOR ALKALI SOILS.

EDIBLE FRUITS.

Strawberry tomato (*Physalis pubescens*, L.).

Cape gooseberry (*Physalis peruviana*, L.).

Date-palm (*Phœnix dactylifera*, L.). In Arabia it is said to grow in soil "strongly impregnated with salt," and that "the water for irrigation may be slightly brackish."

Oleaster (*Elæagnus augustifolia orientalis*, Schlecht). Produces the fruit known as "Trebizonde dates."

Olive (*Olea europæa*, L.). The Mission variety should be first tried.

Black mulberry (*Morus nigra*, L.). The Black Persian is probably derived from this species. It is likely that other species, also, would tolerate alkali.

Grape (*Vitis vinifera*, L.), especially the southern (sherry and port) varieties.

Golden currant (*Ribes aureum*, Pursh.) is said to tolerate an alkaline soil. It is also known as the Missouri, Utah, Utah hybrid, and Buffalo currant. The best cultivated varieties are said to be the "Crandall," "Deseret," and "Jelly." It is doubtful if it will resist the dry heat of the Salton Basin.

Alkali currant (*Ribes aureum tenuiflorum* (Lindl.) Torr.). Grows in strongly saline soil in Washington, Oregon, northern California, and Nevada.

Fig (*Ficus carica*, L.).

VEGETABLES.

Jerusalem artichoke (*Helianthus tuberosus*, L.). The white variety is said to be the best for alkali soils.

Beet-root (*Beta vulgaris hortensis*).

Carrot (*Daucus carota*, L.).

Spinach (*Spinacia oleracea*, L.). (Medium alkali.)

Radish (*Raphanus sativus*, L.).

Celery (*Apium graveolens*, L.).

Celeriac (*Apium graveolens rapaceum*, DC.).

Asparagus (*Asparagus officinalis*, L.).

Onion (*Allium cepa*, L.).

Swiss chard (*Beta vulgaris cicla*).

Globe artichoke (*Cynara scolymus*, L.).

Cardoon (*Cynara cardunculus*, L.).

Tomato (*Lycopersicum esculentum*, Mill.); worth trial.

Egg-plant (*Solanum melongena*, L.). Very hardy against dry heat.

Sea-kale (*Crambe maritima*, L.).

Garden cress (*Lepidium sativum*, L.).

Roselle (*Hibiscus sabdariffa*, L.).

New Zealand spinach (*Tetragonia expansa*, Murr.).

Quinoa (*Chenopodium quinoa*, Willd.). The foliage makes a savory and wholesome greens.

STARCH FOODS.

Quinoa (*Chenopodium quinoa*, Willd.). The seeds form one of the most important foodstuffs of the inhabitants of Peru and Chile, who make a nutritious porridge of it.

SUGAR CROPS.

Sugar-beet (*Beta vulgaris altissima*).

Sugar sorghum (*Andropogon sorghum saccharatus* (L.) Kœrn).

OIL PLANTS.

Russian sunflower (*Helianthus annuus*, L.).

Niger seed (*Guizotia abyssinica*, Cass.). This plant is worth a trial on alkali soils.

FORAGE PLANTS.

Root crops:

Jerusalem artichoke (*Helianthus tuberosus*, L.). Valuable tuber for hogs. The white variety seems to be better adapted for alkali soils than the red.

Mangold-wurzel (*Beta vulgaris rapa*).

Seed crops:

Russian sunflower (*Helianthus annuus*, L.). The seeds furnish a valuable poultry food. The sunflower is reported to endure the excessive summer heat of central Australia better than any other cultivated herb tried there. The wild form of this plant (indigenous to California) has been found to tolerate easily 12,500 pounds of salts in an acre-foot at Chino.

Barley (*Hordeum vulgare*, L.).

Japanese barnyard millet (*Panicum crusgalli maximum*, Hort.).

Pasture, soiling, and hay plants:

Alfalfa (*Medicago sativa*, L.).

Saltbushes (*Atriplex semibaccata*, R.Br.; *A. leptocarpa*, F.v.M.; *A. vesicaria*, Howard; *A. kochiana*, Maiden; *A. spongiosa*, F.v.M.; *A. halimoides*, Lindl.; *A. holocarpa*, F.v.M., and *A. campanulata*, Benth.; *Kochia aphylla*, R.Br., and *K. pyramidata*, Benth.; *Rhagodia billardieri*, R.Br.; *R. parabolica*, R.Br.; *R. hastata*, R.Br., and *R. linifolia*, R.Br.; *Sclerolæna bicornis*, Lindl.).

Modiola (*Modiola decumbens*, G. Don).

New Zealand spinach (*Tetragonia expansa*, Murray).

Slough-grass (*Beckmannia erucæformis*, Host.).

Alkali tussock-grass (*Sporobolus airoides* (Torr.) Thurb.)

Alkali slender-grass (*Leptochloa imbricata*, Thurb.).

Saccaton (*Sporobolus wrightii*, Munro).

Alkali saccaton (*Panicum bulbosum*, H. B. K.).

Salt-grass (*Distichlis spicata* (L.) Greene).

Alkali lyme-grass (*Elymus salinus*, Jones).

Barnyard-grass (*Panicum crusgalli*, L.).

Japanese barnyard millet (*Panicum crusgalli maximum*, Hort.).

Switch-grass (*Panicum virgatum*, L.).

Nevada blue-grass (*Poa nevadensis*, Vasey).

Mexican salt-grass (*Eragrostis obtusiflora*, Scribn.).

Wild rye (*Elymus condensatus*, Presl.).

Meadow barley-grass (*Hordeum nodosum*, L.).

Little barley-grass (*Hordeum pusillum*, Nutt.).

Creeping bent-grass (*Agrostis alba stolonifera*).

Kaffir corn, Jerusalem corn, Durra, and Milo maize (*Andropogon sorghum sativus*, Hack.).

Egyptian corn (*Andropogon sorghum cernuus*, Kœrn).

Teosinte (*Euchlæna luxurians* (Durieu) Aschers).

Usar-grass (*Sporobolus orientalis*, Kth.).

Purslane (*Portulaca oleracea*, L.).

Bulbous-rooted foxtail (*Alopecurus bulbosus*, Huds.).

Korean lawn-grass (*Zoysia pungens*, Willd.).

Barley (*Hordeum vulgare*, L.).

Bermuda-grass (*Cynodon dactylon* (L.) Pers.).

Quitch-grass (*Agropyron repens*, Beauv.).

Johnson-grass (*Andropogon halepensis* (L.) Brot.).

The three last-named grasses (Bermuda-grass, Quitch-grass, and Johnson-grass) are liable to become terrible weeds in cultivated ground, and should not be planted where there is any danger of their spreading among orchards or cultivated crops, nor, in fact, in any place which is not to be given up *entirely and permanently* to pasture.

Browsing shrubs:

Tea-tree (*Leptospermum lanigerum*, Smith).

Myalls (*Acacia homalophylla*, Cunn., and *A. pendula*, Cunn.).

Shrubby saltbushes (*Atriplex nummularia*, Lindl.; *A. pamparum*, Griseb.; *Rhagodia spinescens inermis*).

PAPER-MAKING MATERIALS.

Esparto-grass (*Stipa tenacissima*, L.).

Albardin (*Lygeum spartum*, L.).

SHADE AND ORNAMENTAL TREES AND SHRUBS.

Kœlreuteria paniculata, Laxm.

Acacia pendula, Cunn.

Acacia homalophylla, Cunn.

Albizzia lophantha, Benth.

Albizzia lebbek, Benth.

Canary date-palm (*Phœnix canariensis*, Hort.).

Washington palm (*Washingtonia filifera*, Wendl.).

Oriental sycamore (*Platanus orientalis*, L.).

Manna gum (*Eucalyptus viminalis*, Labill.).

Peppermint gum (*Eucalyptus amygdalina*, Labill.).

Red gum (*Eucalyptus rostrata*, Schlecht.).

Yate tree (*Eucalyptus cornuta*, Labill.).

It should be borne in mind that these several plants are not equally tolerant of alkali, and that local experimentation is necessary in order to determine the adaptation of each one to local conditions.

TOLERANCE OF VARIOUS CROPS FOR ALKALI SALTS.

The subjoined table, originally published in Bulletin No. 133 of this Station, is of interest in connection with the discussion of the availability of the Salton Basin lands for cultural purposes. For comparison with other publications it should be remembered that the calculation of the "pounds per acre," most readily understood by farmers, is based on the estimated weight of an acre-foot of soil at four millions of pounds. Hence, one per cent is equal to 40,000 pounds; one-tenth of one per cent, 4,000 pounds. It will be noted that the *total of salts* alone is but a very rough criterion of the possibilities of culture, on account of the very different effects of the several compounds on plants. The sulfates (of potash, soda, and magnesia) are the least injurious, and happily predominate widely in the Salton Basin. Carbonate of soda, though very injurious as such, is easily transformed into the bland sulfate by dressings of gypsum. Common salt is really the worst ingredient.

Highest Amount of Alkali in Which Fruit Trees Were Found Unaffected.

Arranged from highest to lowest. Pounds per acre in four feet depth.

Sulfates (Glauber Salt).		Carbonate (Salsoda).		Chlorid (Common Salt).		Total Alkali.	
Grapes	40,800	Grapes	7,550	Grapes	9,640	Grapes	45,760
Olives	30,640	Oranges	3,840	Olives	6,640	Olives	40,160
Figs	24,480	Olives	2,880	Oranges	3,360	Almonds	26,560
Almonds	22,720	Pears	1,760	Almonds	2,400	Figs	26,400
Oranges	18,600	Almonds	1,440	Mulberry	2,240	Oranges	21,840
Pears	17,800	Prunes	1,360	Pears	1,360	Pears	20,920
Apples	14,240	Figs	1,120	Apples	1,240	Apples	16,120
Peaches	9,600	Peaches	680	Prunes	1,200	Prunes	11,800
Prunes	9,240	Apples	640	Peaches	1,000	Peaches	11,280
Apricots	8,640	Apricots	480	Apricots	960	Apricots	10,080
Lemons	4,480	Lemons	480	Lemons	800	Lemons	5,760
Mulberry	3,360	Mulberry	160	Figs	800	Mulberry	5,760

Other Trees.

Kölreuteria	51,040	Kölreuteria	9,920	Or. Sycamore	20,320	Kölreuteria	73,600
Eucal. am.	34,720	Or. Sycamore	3,200	Kölreuteria	12,640	Or. Sycamore	42,760
Or. Sycamore	19,240	Date Palms	2,800	Eucal. am.	2,960	Eucal. am.	40,400
Wash. Palms	13,040	Eucal. am.	2,720	Camph. Tree	1,420	Wash. Palms	15,280
Date Palms	5,500	Wash. Palms	1,200	Wash. Palms	1,040	Date Palms	8,320
Camph. Tree	5,280	Camph. Tree	320			Camph. Tree	7,020

Small Cultures.

Saltbush	125,640	Saltbush	18,560	Modiola	40,860	Saltbush	156,720
Alfalfa, old	102,480	Barley	12,170	Saltbush	12,520	Alfalfa, old	110,320
Alfalfa, young	11,120	Bur Clover	11,300	Sorghum	9,680	Alfalfa, young	13,120
Hairy Vetch	63,720	Sorghum	9,840	Celery	9,600	Sorghum	81,360
Sorghum	61,840	Radish	8,720	Alfalfa, old	5,760	Hairy Vetch	69,360
Sugar Beet	52,640	Modiola	4,760	Alfalfa, yo'ng	760	Radish	62,840
Sunflower	52,640	Sugar Beet	4,000	Sunflower	5,440	Sunflower	59,840
Radish	51,880	Gluten Wheat	3,000	Sugar Beet	5,440	Sugar Beet	59,840
Artichoke	38,720	Artichoke	2,760	Barley	5,100	Modiola	52,420
Carrot	24,880	Lupin	2,720	Hairy Vetch	3,160	Artichoke	42,960
Gluten Wheat	20,960	Hairy Vetch	2,480	Lupin	3,040	Carrot	28,480
Wheat	15,120	Alfalfa	2,360	Carrot	2,360	Barley	25,520
Barley	12,020	Grasses	2,300	Radish	2,240	Gluten Wheat	24,320
Goat's Rue	10,880	Kaffir Corn	1,800	Rye	1,720	Wheat	17,280
Rye	9,800	Sweet Corn	1,800	Artichoke	1,480	Bur Clover	17,000
Cañaigre	9,160	Sunflower	1,760	Gluten Wheat	1,480	Celery	13,680
Ray Grass	6,920	Wheat	1,480	Wheat	1,160	Rye	12,480
Modiola	6,800	Carrot	1,240	Grasses	1,000	Goat's Rue	11,800
Bur Clover	5,700	Rye	960	White Melilot	440	Lupin	11,200
Lupin	5,440	Goat's Rue	760	Goat's Rue	160	Cañaigre	9,360
White Melilot	4,920	White Melilot	480	Cañaigre	80	Ray Grass	6,920
Celery	4,080	Cañaigre	120			White Melilot	5,840

JANUARY CROP REPORTS FROM ACTUAL SETTLERS.

Reports have been received from sections 19 and 20, in township 14 south, range 15 east, sections 29, 32, and 33, in township 16 south, range 14 east, and on land adjoining the town of Imperial on the south. They show apparent success, during the past season, in growing alfalfa, sorghum, barley, millet, Kaffir corn, and watermelons, with a few lesser tracts of garden vegetables. As an illustration of the tone of these reports, we present the following extract from a letter received from Thomas Beach, Calexico; a region which, however, is outside of the worst clay and alkali belts:

"Between the last of June and middle of August of last year I put in about 325 acres of sorghum, 30 of millet, 20 of field corn, 25 of Kaffir corn, 2 of melons, 1 of cotton, and 1 acre of pumpkins. The sorghum was watered six times and the others about four. The former gave about 5 tons per acre, and the millet yielded 2 tons; the corn did not do as well. I raised some Rocky Ford melons from seed ripened the same year at Indio, and can say that I never tasted better; the same is true of watermelons and pumpkins. The ground took water well, and during the summer months I was able to disc it three days after flooding. I now (January 28th) have barley 2 feet high that has been watered but twice; some alfalfa I sowed on the 20th of September is up 6 or 8 inches in height, with roots a foot long and has had but two irrigations."

These reports do not in any sense contradict the facts stated in the earlier pages of this report; for it will be noted in the first place that these are, in nearly every case, *alkali-resistant crops.*

Upon inspection of the maps and tables it will be further seen that, in general, the first foot of soil does not carry the heavy percentage of alkali which exists at a depth of two to three feet. An irrigation, either just preceding or just following seeding, would tend to temporarily reduce the alkali in this upper foot even below the amount shown in the tables, and below the maximum tolerance of the essentially alkali-resistant plants named above; and probably also below that for many of much less resistant kinds. There is little doubt that, *at the outset*, most plants climatically adapted could be started with more or less success under the common methods of irrigation. These early results can only be taken as indicating that the alkali in the top foot *at this time and in those localities* was not sufficiently strong to interfere seriously with the germination of seed—retardation possibly excepted.

The reports can not, however, be taken as indicative of what may be expected after surface irrigation has been practiced for a few years; for such treatment is sure to result in the rise of alkali to such an extent as to cause serious injury to the crop and consequent financial loss to the grower.

Mention has already been made of the alkali-resistant nature of these crops, except millet and watermelons. In the case of the former, which is closely related to sorghum, it may be expected to be quite resistant, although no figures are at hand touching upon the matter; the watermelon is essentially a desert plant, related plants being indigenous to the African deserts. The growth of these crops in these localities simply adds weight to the evidence that these plants are quite tolerant of alkali.

People should not be deceived by a rank growth of plants in arid regions, unless the characteristics of such plants be definitely known; for the very fact of the existence of alkali is evidence of intrinsic fertility of the soils, and crops are well known to have a luxuriant growth on such lands, provided only that the saline matter is not present to such an extent as to approach the limit of tolerance of the crops grown.

Notwithstanding the present success with the alkali-resistant crops named, residents are urged to adopt the methods laid down in this publication as those which alone may reasonably be expected to give immunity from alkali damage for any considerable length of time.

o