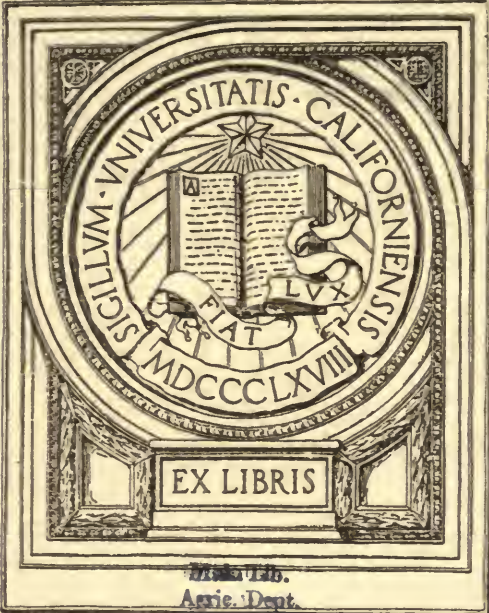


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United States Department of Agriculture,

BUREAU OF SOILS—CIRCULAR No. 11.

MILTON WHITNEY, *Chief of Bureau.*

RECLAMATION OF ALKALI LAND AT FRESNO, CALIFORNIA.

At the time of settlement of the country south of Fresno there was little indication of the presence of alkali in the soil and no one then suspected that serious damage would result from irrigation. When, after a few years, alkali commenced to show in the vineyards and orchards the attention of thoughtful men was directed toward remedying the evil, but up to the time of undertaking the experiment reported in this circular nothing effective had been accomplished.

In 1900 a party from the Bureau of Soils spent a season in studying the soil conditions around Fresno, and in a report, embodied in the report on field operations of the Division of Soils for 1900, recommended drainage, with frequent cultivation and copious irrigation during reclamation, as the solution of the alkali problem.

Notwithstanding the recommendations in this report and the repeated statements in subsequent reports on alkaline areas in different parts of the country that drainage is a practicable and the only safe and sure means of permanently reclaiming alkali lands, no steps had been taken by persons most deeply interested to check or remove the evil. The Bureau of Soils, after careful consideration, decided that the most convincing way of bringing the truth of its recommendations and the value of drainage in reclamation work before the people was to demonstrate it by the actual reclamation of some of the alkali land. For this purpose the Bureau selected a 20-acre tract of land belonging to S. M. Toft and N. H. Hansen, situated on Fig and Central avenues about $2\frac{1}{2}$ miles south of Fresno and entered into cooperation with these gentlemen to demonstrate to the people of the irrigated region that alkali lands can be easily and economically reclaimed.

The history of this land, as given by the owners, is as follows: The northern part of the tract was settled upon by Mr. Toft in 1876 and at that time showed no sign of alkali. In 1889 Mr. Toft bought an additional 20 acres at \$350 an acre, an average value for land in that vicinity at that time. The southern part of the tract was first settled upon in 1862 by Mr. Hansen and at that time was partially alkaline. It has never produced good crops. In 1890 alkali commenced to show on the northern part, and in 1898 and 1899 it was practically abandoned.

The tract lies in a level district where it was impossible to obtain a gravity outlet for the drainage water, except by digging a drain 2 miles long, so in order to raise the drainage water to the surface of the ground a chain pump operated by a water wheel was installed on Central Canal, where it crosses Fig avenue. A drainage system of this kind is admittedly not so desirable as one in which a gravity outlet can be maintained.

Three-inch, 4-inch, and 6-inch tile were laid over the tract at an average depth of a little over 3 feet and 150 feet apart. The original intention was to use nothing smaller than 4-inch tile, but the makers were unable to supply enough tile of this size, so the deficiency was made up by using 3-inch tile. It was found impossible to lay the tile during the summer season, owing to the nearness of the water table to the surface and the resulting condition of the subsoil, which was too soft to permit the digging of a deep ditch. The work of ditching was commenced in December, 1902, and was completed in February, 1903. The cost of ditching, tiling, and all incidentals except the cost of pump and water wheel amounted to \$16.50 per acre. The contract for the tile delivered in Fresno was for 3-inch tile, \$24 per thousand, for 4-inch tile, \$32 per thousand, and for 6-inch tile, \$72 per thousand.

At the time of the installation of the drains 18 acres of the land contained too much alkali to produce a crop. Scattered over a part of the tract were small patches of alfalfa and an occasional fruit tree—remnants of former cultivation. About the 1st of March, 1903, irrigation was commenced. The land was divided into 30 checks, the size of each check depending upon the slope of the land. The largest checks, those on the level land, are about 2 acres in extent, while on the steeper slopes they are less than half an acre. The object was to divide the land in such a way that it could all be kept under water to a depth of 4 inches, and the reclamation was to be accomplished by maintaining the water at this depth until enough alkali had been washed out of the soil through the drains to enable a crop to be grown.

During the progress of flooding many difficulties were met, among them that of keeping the tiles from partially filling with sand and silt. Precaution was taken in laying the tile to put them in so the joints would be close, hay was thrown over the tile in the ditch before covering with earth, and a ridge of earth was thrown up to prevent the water from standing directly over the drains. In spite of these precautions the soil, which is very light, was so easily moved by water that it seemed to enter the joints almost as readily as did the water. This resulted in some of the drains becoming clogged, and it was necessary to relay a portion of the tile. After the land had been once thoroughly soaked and had settled, no difficulty was experienced from filling of the drains and it is hoped that there will be no further trouble from this source. Most of the trouble was with the 3-inch tile, which is admit-

tedly too small for use in soils of the light and silty character of the Toft-Hanson field. It is thought that there will be more or less silting up of the tiles whenever they are used in the sandy and white ash soils of the Fresno district, and it is recommended that every possible precaution be taken in putting them in. Much of the trouble may be obviated by using no tile smaller than 4 inches, or preferably 6 inches in diameter, and by giving the laterals such fall that the velocity of the water will be great enough to wash out the sand as rapidly as it enters the joints. The tile on the Toft-Hansen tract have a fall of 1 in 1,000 and the velocity of the water flowing through them is not sufficient to remove the sand. With a fall of 1 in 500 the velocity is great enough to remove practically all of the soil as fast as it enters.

To prevent entirely the clogging of the tile with sand, and to insure the removal of roots should any chance to enter, it is thought advisable to place in all tile a quarter inch galvanized strand-wire rope. Then two or three times a year, or oftener if necessary, a wire brush should be dragged through the tile in order to cut out all roots and stir up the sand and silt. Wire rope of this kind can be bought for about 1 cent a foot. Six-inch and 8-inch drains have been in operation for twelve years in the Sunnyside vineyard and have been kept in perfect order in this way. From the experience gained the Bureau can unhesitatingly recommend tile for drainage purposes, provided proper precautions are taken in its installation.

On July 15, 1903, after four and a half months of irrigation, an examination was made of the tract to determine what percentage of the land was sufficiently sweetened to grow a crop. This examination indicates that all of the land, with the exception of small spots amounting in the aggregate to less than 2 acres, is now ready for a crop. Most of it is sufficiently freed from alkali to warrant the sowing of alfalfa, but as midsummer is not the best time of year for seeding that crop, sorghum and Egyptian clover are being put in instead. These crops will mature by fall if the supply of irrigation water does not fail, and in the winter the land will be seeded to alfalfa. The small spots which are not yet ready for alfalfa are rapidly approaching that condition and will be ready for a crop during the coming winter. Thus it will be seen that practically all the land in this 20-acre tract has been returned to a state of profitable cultivation in a period of four and a half months after irrigation was commenced, and the statement seems justified that any alkali land in the Fresno district can be brought into profitable cultivation in less than one year's time, the two requisites for this being underdrainage and a copious supply of water for irrigation. While the Bureau considers the land of the Toft-Hansen field practically reclaimed at the present time, the demonstration will be continued until a satisfactory stand of alfalfa is secured.

GENERAL RECLAMATION IN THE FRESNO DISTRICT.

Having demonstrated that alkali land can in a remarkably short time be brought back into a state of fertility by underdrainage and flooding, it remains to indicate the most economical plan of extending the work to cover the larger districts affected by alkali or seepage water, or in danger of becoming thus affected.

That the rise of alkali is caused by a rise in the level of standing water in the soil is admitted by all, so that the solution of the alkali problem depends upon the solution of the drainage problem. It must not be supposed, however, that drainage alone will reclaim the alkali lands, for complete reclamation demands heavy irrigation or washing of the soil. In the case of the 20-acre tract now being reclaimed, it is seen that four and a half months' constant irrigation was necessary before a crop could be grown.

Anything, however, which lowers the water table will assist in the reclamation of the alkali lands and will allow of heavier flooding to effect this reclamation. Thus it is evident that if the bottoms of all irrigating canals were cemented and the loss of water by seepage prevented there would be a prompt falling in the level of standing water and heavier irrigation would be possible, thus enabling large areas of alkali land to be reclaimed by washing the alkali into the subsoil. This alone, without drainage, would not be a permanent removal of the alkali, for if the water table should by any means be raised again the alkali would promptly reappear at the surface. It is likely that the water table would be raised eventually, for upon the cementing of the canals and the consequent drop in the water level vines, trees, and plants with their root systems adjusted to the present water level would suffer and irrigation would be necessary in fields that now are never watered from the surface. It is also likely that all the water saved from seepage through the canal bottoms would eventually be applied to the land from the surface. Probably a larger proportion of this water would be lost by evaporation than now, but it is extremely doubtful if the conditions would be bettered. Again, if the farmers understood the proper amount of water to use and used only that amount, keeping the soil in the most perfect condition as regards moisture, much water might be saved and the water table lowered to such an extent that drainage would be unnecessary and satisfactory crops could be produced. But it is difficult to get the farmers to use just the right amount of water in practice, as they have a tendency always to apply it in excess. To drain the excess away before damage to the land results is the problem before the people.

Another scheme for reclamation is presented by Mr. J. B. Lippincott in his report, issued by the U. S. Geological Survey, on "Water Storage in Kings River." Mr. Lippincott proposes to establish electric power

plants in the mountain canyons of Kings River, to transmit this power to the plains and to distribute it to the farmer for use in running pumping plants. With cheap power of this kind pumping plants could be used on the Fresno plains at points not reached by canals, or, even during a season of short supply, on lands under existing canals. Pumping would tend to lower the water table, and as probably 50 per cent of the water applied to the land would be lost by evaporation and transpiration by vegetation, there would result a permanent lowering of the level of underground water. For the lowering to amount to much rather extensive pumping would be necessary, and to accomplish this a cheap power must be had. This lowering of the water table would have the same effect as drainage and would permit the reclamation of alkali land.

During the winter months the level of standing water falls, the average depth being from 6 to 10 feet and in some places even more. This level is manifestly lower than could be obtained by any drainage scheme and if maintained would obviate the necessity for artificial drainage. A great deal could be done towards alkali land reclamation in the winter months by pumping from wells and keeping the land flooded. In this way the alkali which is at the surface would be washed into and distributed through the subsoil. This process, of course, would not get rid of the alkali, for it still remains in the subsoil and heavy flooding every few years would be necessary to keep it down.

These are some of the practical suggestions offered for the reclamation of alkali land, but none of them is as feasible and as economical as the method proposed and demonstrated by the Bureau of Soils, and none of them guarantees a permanent reclamation. The only way to permanently rid the Fresno district of alkali and seepage water is by underdrainage.

It was necessary in the reclamation of the Toft-Hansen tract to effect drainage by pumping, but fortunately in the area at large there is no necessity for pumping, since, with the exception of very small areas, all land tributary to the district under consideration can be drained by gravity. While the cost of pumping water has been very much reduced in recent years and pumping plants are being used in irrigation and drainage, the experience gained by the Bureau's field parties and the facts brought out by a study of pumping plants for drainage at home and abroad are strongly opposed to the use of such plants when it is possible, without too great outlay, to carry off the water by gravity. The conditions around Fresno are exceptionally favorable for a gravity system.

Having determined that a gravity system is feasible, the next step is to find out how such a system can best be operated, whether through the use of open or closed drains. Open drains of the proper depth for

main, primary, and secondary drains in the Fresno district would have to be dug largely below the level of standing water in what is frequently a quicksand. Such drains, if they are to stand, would have to be boxed in at the bottom and sides and made very wide at the top. The plan has been proposed of placing these drains along the county roads running east and west. There is not always room in these roads to permit a 20-foot ditch being dug without encroaching on private property; hence over more than half the distance a right of way would have to be purchased. The building of bridges and the necessity for annual cleaning are items of expense to be included in the cost of open drains. A comparison of the original cost of open and of tile drains is given below.

The estimates of open drains are based upon prices of similar work in other parts of the country and are, if anything, rather low. The cost of tile draining should vary little from the estimate given.

Cost of open drains per mile.

Ditch 4 feet wide on bottom, average depth 7 feet, slope 1 to 1 -----	\$2,257.00
Two road bridges at \$75 each -----	150.00
Four farm bridges at \$50 each -----	200.00
Right of way, 1½ acres at \$150 per acre (half the area occupied by ditch) -	187.50
Total cost per mile -----	2,794.50

The cost of the tile drain per mile will vary from \$1,000 for 6-inch, to \$4,000 for 24-inch tile. The average cost per mile will be about \$2,440, a figure below the estimated cost of open ditches. When it is seen that no estimate can be made for boxing the open ditches and when the greater convenience of the tile is considered, it is obvious that the tile are far cheaper and far more desirable.

A detailed study of the conditions existing in the district south of Fresno at present most urgently in need of drainage has developed the following plan, as the one most economical and practical: Parallel lines of tile should be run through the district, following the maximum slope of the ground in a general east and west direction, and at an average distance of one-half mile apart. These lines begin with 6-inch tile, and in the longest lines end with 24-inch tile, all laid at an average depth of 7 feet. The exact location of the lines, whether along the roads or in the fields, will depend largely upon the surface conditions of the soil. No attempt should be made to lay down perfectly straight lines, for slight deviations from an east to west direction will frequently be of great advantage. The tile are laid on a board bed to prevent sinking in the soft subsoil, and at intervals of 500 feet redwood silt boxes are placed with the bottom 1½ feet below the bottom of the tile for the collection of sediment and debris. Each line of tile is supplied with a one-quarter inch galvanized strand-wire rope so that a cleaning brush can be drawn through two or three times a year to remove roots and stir up sediment.

The water from these parallel drains will be collected in an open ditch running in a southwesterly direction just west of West Park. This drainage ditch will have a fall of $1\frac{1}{2}$ to 3 feet per mile throughout its course, dropping where necessary to keep the bottom below the opening of the tile, and will deliver water at the surface of the ground for irrigation south of the Southern Pacific Railroad, between Ormus Station and McMullin.

Such a system could be built for a total cost not to exceed \$10 an acre, based upon a district 25,000 acres in extent.

A system of this sort will lower the water table to 5 feet and will not allow it to rise above this level for more than a few days at any one time. With water at 5 feet below the surface the spread of alkali will cease and those lands only slightly damaged will be at once easily reclaimed. Those tracts where alkali is now greatly accumulated it is deemed best to drain with additional lateral tile laid at from 4 to $4\frac{1}{2}$ feet below the surface and 150 feet to 300 feet apart. Laid at a depth of 4 feet and 200 feet apart, such drainage will cost about \$16 per acre.

Land so tiled, even if badly alkaline, can be returned to profitable cultivation in six months if heavily irrigated, and within one year can be used for the production of any crop suited to the climate.

As bearing on the cost of tile drainage it may be mentioned that through the efforts of the Bureau of Soils several deposits of good clay have been located within convenient distances of Fresno and that tile-making tests have been carried out. Excellent tile have been made from these clays, and it is hoped that when their manufacture has further developed prices much more in keeping with the cost of production can be obtained on tile, especially when ordered in large quantities. Fuel is cheaper than in the tile-making districts of the east, and the cost of labor is about the same, so there is no reason why tile should not be manufactured and sold at Fresno at very little if any advance, for instance, over the prices asked in Illinois. The foregoing estimates are, however, based upon prices 15 per cent above Illinois prices. We have received assurances from responsible clay workers that if the prices quoted by local firms are not consistent with the value of the article, a tile factory will be built and tile sold at a fair profit.

The drainage system outlined above can reasonably be expected to flow 30 cubic feet of water per second throughout the irrigating season, which, at the present value of water around Fresno, would be worth \$15,000. This water will be brought to the surface of the ground in a district southwest of Fresno which only needs water to render it fertile. There is a great deal of alkali land which could be reclaimed with this water and made to produce valuable crops. The drainage water from the Toft-Hansen tract has been repeatedly analyzed to determine its

value for irrigation purposes. The following analyses show the composition of the water during three weeks when it was most concentrated:

Chemical analyses of drainage water from the Toft-Hansen reclamation tract.

Constituent.	May 9, Sample No. 9.	May 16, Sample No. 10.	May 23, Sample No. 11.
Ions:	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
Calcium (Ca)	3.57	3.58	5.36
Magnesium (Mg)	3.64	3.76	4.28
Sodium (Na)	20.49	19.72	15.47
Potassium (K)	1.58	1.44	1.76
Sulphuric acid (SO ₄)	2.06	1.88	3.06
Chlorine (Cl)	9.62	9.69	10.73
Bicarbonic acid (HCO ₃)	51.82	54.79	59.34
Carbonic acid (CO ₃)	7.22	5.14	-----
Conventional combinations:			
Calcium sulphate (CaSO ₄)	2.88	2.63	4.36
Calcium chloride (CaCl ₂)	7.56	2.63	11.17
Magnesium bicarbonate Mg (HCO ₃) ₂	21.94	22.68	25.89
Potassium chloride (KCl)	3.03	2.76	3.37
Sodium bicarbonate (NaHCO ₃)	46.17	49.49	52.00
Sodium chloride (NaCl)	5.57	5.59	3.21
Sodium carbonate (Na ₂ CO ₃)	12.86	9.09	-----
Total solids in 100,000 parts water	145.4	159.2	130.6

Of the salts shown to be in the drainage water about three-fourths may be regarded as harmful. The remaining 25 per cent are principally salts of lime and magnesium, which would precipitate out by evaporation as the water concentrates upon a field. Sodium carbonate or black alkali, although the predominating salt found in the surface of the soil, is not present in any quantity in the drainage water. Sodium carbonate has never been found in the drainage water as it comes from the tile, but after the water stands and aerates this salt forms by the decomposition of the sodium bicarbonate, so that though we have removed large quantities of black alkali from the soil it has never appeared as such in the drainage water. The explanation of this is that the sodium carbonate or black alkali seldom exists as such except in the first few inches of surface soil, and as soon as it is washed into the soil it absorbs carbonic acid gas, with which the soil air is always more strongly charged than is the atmospheric air, and forms the much less harmful sodium bicarbonate.

Numerous examples can be given where waters of greater concentration than this drainage water are successfully used for irrigation, both in the United States and in other countries, and it can be definitely stated that water of this character can be used for irrigation upon any soil where adequate underdrainage is maintained. If such water were used upon poorly drained soil the inevitable result would be an accumulation of alkali at the surface. The drainage water from the entire

alkaline area will not be as concentrated, as that shown in the table above; on the contrary it will be much better for irrigation purposes. These analyses are typical of what might be, the maximum quantity of harmful salts, and moreover represent a condition which can exist but a few months at the most, when the drains are first installed.

The reclamation work on the Toft-Hansen tract has progressed so far that the most skeptical must be convinced that drainage and irrigation will reclaim alkali lands. A district of nearly 26,000 acres is now suffering more or less from alkali and seepage water, and it rests with the owners of this land to form a drainage district under the act passed by the last legislature of California, approved March 20, 1903. The formation of this district will allow the construction of a drainage system which will result in the reclamation of all lands now alkaline and the prevention of further damage from this source.

The system recommended, after over three years' study of the conditions, consists of tile drains varying in size from 4 inches to 24 inches. The main drain will be an open ditch collecting the water from the parallel tile drains one-half mile apart. This main will deliver the water at the surface of the ground in the district west of Fresno where it can be used for irrigation. The main tile will be laid in approximately straight lines, increasing in size up to 24 inches in diameter. On the fields badly charged by alkali further drainage by 4-inch, 5-inch, and 6-inch tile laterals may be necessary, but such fields are comparatively few. The cost of this system, calculated on a basis of 20,000 to 26,000 acres, should not exceed \$10 per acre. The work of the Bureau of Soils legitimately ends with the demonstration now being completed on the Toft-Hansen tract. The formation of the district and the building of drains and the reclamation of land will rest entirely with the voters and the owners of the land.

THOMAS H. MEANS,
W. H. HEILEMAN.

Approved:

JAMES WILSON,
Secretary of Agriculture.

WASHINGTON, D. C., *September 1, 1903.*

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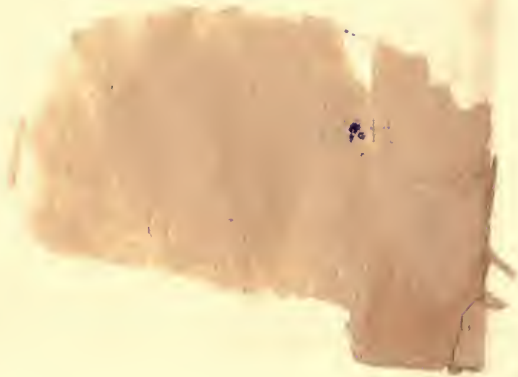
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