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A CHARACTERISTIC ALKALINE SPOT.

The RECLAMATION OF SEEPED AND ALKALI LANDS

By

C. F. BROWN and R. A. HART

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THE RECLAMATION OF SEEPEd AND ALKALI LANDS.


BY C. F. BROWN AND R. A. HART.

In the year 1905, Drainage Investigations were begun in the State of Utah by the Office of Experiment Stations of the United States Department of Agriculture, in co-operation with the Utah Experiment Station. Appropriations have been made by the Utah State Legislature for irrigation and drainage investigations on condition that the United States Department of Agriculture contribute an equal amount, and that the work be conducted jointly by the Federal department and the experiment station of the Agricultural College of Utah.

Under a mutual agreement between the experiment station and the Department of Agriculture, the drainage work was for a time carried on under the direction of drainage investigations of the Office of Experiment Stations. Under the co-operative agreement, experimental work and co-operative drainage with farmers has been carried on in various sections of the State and the results from time to time have been made public.

The object of this report is to give the results of drainage operations which have been carried on at Huntington, Emery County, Utah, from 1906 to 1910, and also at several points in western Colorado, where the soil and its peculiar structure and condition have made the reclamation of seeped lands extremely difficult. It is believed that a description of these difficulties and the results which have been obtained, together with recommendations deduced from experimental work in those sections, will be of use particularly to the Castle Valley
in Emery County, Utah, and to the entire Colorado Plateau, where similar soil conditions prevail.

These soils are principally alluvial deposits containing from 23 to 42 per cent of fine sand, and 28 to 55 per cent of silt, and are underlain by shale formations, the shale grading to a tough and tenacious clay at its upper layer and reducing to clay when exposed to the air. The shale is found in the foothills and extends out to the lower slopes in ridges and isolated knolls. There it lies in nearly horizontal strata, whatever dip there is being opposed to the surface slope. The strata increase in thickness and distance apart as the depth increases, some strata being 6 inches thick and 2 inches apart. The spaces between strata are filled with crystallized gypsum and alkaline salts. These spaces form natural water channels, and lead back to the foothills where they are cut by the supply canals. The pressure, due to the high head, causes the water to permeate every part of the formation, and where great enough, forces the water through the clay blanket and into the loose soil. A portion of the water finds its way to the surface and runs away, but by far the larger part seeps laterally into the soil, saturating it for great distances. Veritable bogs are thus formed, the surface of which is usually covered with deposits of alkali and is so soft that men and animals may not cross. The constant flow of the springs, forming these bogs, after drainage has been effected, indicates that the application of irrigation water is not responsible for them, but that the damaging water has its source in the supply canals.

As has been said, these conditions are not limited to Emery county, and have been especially noted in the Grand and Uncompahgre valleys of Colorado, where they have accompanied the irrigation of the same class of lands. To prevent loss of water from canals in the latter valley, they have been lined with cement in some instances, where they cut through the shale formations. In the Grand valley, temporary dams were thrown across the canals and the early flood water allowed to silt up the crevices, thereby preventing much of the loss.
That some loss still occurred is shown by the failure of the lands below. Lateral ditches cutting through shale formations are also a source of loss, but on account of the heavier slopes usually given the smaller canals it is almost impossible to silt them up.

Several years usually elapse between the turning of water into the canals and the appearance of seepage spots. This is due to the slow movement of ground water, the great distance often traversed, and the presence of soluble materials which absorb large quantities of water. This fact is often responsible for the sense of security which settlers on new lands generally have. Twenty-five years ago every foot of Emery county, then under cultivation, gave as much promise of continued fertility and freedom from seepage as any of the new projects in the county do now, and yet approximately 30 per cent of the former agricultural area is now worthless as far as production is concerned.

During 1904, studies of the drainage needs of this section were begun by the drainage investigations of the United States Department of Agriculture and the Utah Experiment Station. The several towns of the county were visited and the fluctuations of the ground water in the South Huntington field were observed for one year. Actual experimental work was undertaken at the end of that period, on the S. W. ¼ of the S. E. ¼ of Section 25, T. 19 S., R. 8 E. The owner, Mr. E. L. Geary, and the county co-operated with the Department and the State in the experiment. The work continued until 1909, when the demonstration was carried to a successful termination.

This particular tract was selected because it was typical of the worst land in the country, and thought by the people generally to be irreclaimable. It lay within one-half mile of an arroyo 20 feet deep, within a few feet of the banks of which the water rose to the surface. This condition was cited as proof that such lands could not be drained. The present condition of the Geary farm, however, discloses the fallacy of this popular opinion. Farm operations may now be carried on anywhere on the tract and heavily loaded wagons drawn safely
across spots that formerly would not support the weight of a man.

While the first experimental work, under the given conditions, was done on the Geary tract, a greater amount of work has been done on the western slope of Colorado, and the sup-

![Map of Huntington Field showing location of Experimental Tract.](image)

Fig. 1. Map of Huntington Field showing location of Experimental Tract.

plementary results give foundation for the recommendations offered in this paper. These recommendations are intended especially for the farmers of these parts, to aid them in their efforts to reclaim their injured lands, and to caution those
bringing new lands under cultivation to profit by the experience of those who have gone before.

**Geary Farm Experiment.**

This tract, as shown on the accompanying field and farm maps, contains 40 acres, and slopes almost uniformly from N. E. to S. W., the fall across the tract in this direction being over 30 feet. The soils are the typical fine sandy and silt deposits with clay patches in the vicinity of the two shale

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Fig. 2. Plan of draining Geary Farm, Huntington, Utah. Heavy lines show the effective system as it now stands. The bogs have completely dried up.
knolls, which rise nearly to the surface, at the points indicated by the location of the swamps on the maps. The sand and silt deposit varies in depth from 3 or 4 feet near these knolls to over 15 feet at points a few hundred feet away. In the region of these swampy spots the soil was so soft that a 2-inch augur could be readily pushed into the ground a distance of 15 feet and an augur hole would not stand open more than a foot or two below the surface of the ground. Wherever this subsurface condition obtained the surface was barren of useful vegetation and generally covered with thick incrustations of alkali. In the immediate vicinity of the springs, within the zone of running water, the surface was sodded slightly and some grass grew. Here the clay blanket over the shale was found at a depth of only 18 inches, the surface being so soft that the sod would not support the weight of a man. Borings into the shale disclosed the fact that the water was under pressure and was being forced through the clay blanket. Some water rose to the surface and ran away in a little gully. During the nights and in cool weather the water ran entirely across the tract, but in dry, hot weather it sunk into the ground after several hundred feet. The frontispiece shows the surface conditions of one of these spots as it appeared in 1905.*

The survey from which the field and farm maps were drawn was made at this time and the Bureau of Soils made a soil survey to determine the nature and amount of the alkaline salts present. The results of the soil survey show that the surface foot carried from 1 to 3 per cent of alkali, over a large portion of the farm, and that this average was maintained throughout the first 6 feet. An analysis of the white crust showed that magnesium sulphate (Epsom’s Salts) and sodium sulphate (white alkali) made up 90 per cent of the whole. The limit of tolerance of these alkalies for cultivated plants, such as the cereals and old alfalfa, is below 1 per cent of the surface soil, hence the crop failures.

*Notice the efflorescence which sometimes covers the ground to a depth of several inches.
When first brought under cultivation this farm was very productive. As late as 1890 it continued to yield from 4 to 5 tons of alfalfa, 40 bushels of wheat and 50 bushels of oats per acre. Water began to rise from the knolls on this tract and from similar ones on the Johnson farm, to the south, in 1903, and complete failure of crops soon followed, so that by 1905 nothing remained but two small patches of white sweet clover.

The first step in designing a drainage system to relieve these conditions was to make careful surface and subsurface surveys, the latter to ascertain the physical construction of the soil, the location of the water table throughout the tract and the actual source of seepage water. The examinations disclosed the fact that there were two sources: lateral seepage from adjacent farms, that were being heavily irrigated, and the more disastrous pressure seepage from the shale knolls.

A system was designed to intercept the flow from both sources. The tract was to be protected from lateral seepage by means of two lines of covered drains paralleling the two higher sides of the tract. The water collected by these lines was to be carried to a common outlet in the lowest corner of the tract, by means of drain lines paralleling its two lower sides. These lines would also accomplish some drainage and provide an outlet for leaching the alkaline salts out of the soil. The protection against pressure seepage was to consist of a line of covered drain, leading from the same outlet, through the center of the field and tapping the fountain head in both shale knolls. The location of the proposed drain lines is shown on the farm map.

The cost of hauling clay tile so far from a railroad was prohibitive, and the use of cement was, at that time, questionable, so it was decided to employ lumber boxes. The type ordinarily used consists of an inverted rectangular trough, braced by means of cleats, as shown in the accompanying sketch. This open bottomed box drain, as it is called, had given satisfactory results elsewhere, and it was believed that it would be serviceable here.
Ordinary methods of construction were employed and were, for the most part, efficient and practicable. Upon nearing the bogs, however, it was found that special methods were necessary as the earth was so wet and soft that a trench would not stand open for any length of time, the banks sloughing off in great masses and forming a mire hole in the trench. The cost of cleaning out one of these cave-ins was several times as much as that of digging the original trench. It was found that the ground would stand up long enough to lay a section of box and blind it. A considerable length of bank caved in, due to a sudden storm, and was an important factor in the final high cost of the experiment. This could have been avoided if the box had been laid right up to the end of the trench as the digging proceeded. To accomplish this, teams of four men should be employed, three digging trench and the fourth laying the boxes and doing odd jobs, so that the diggers need

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Fig. 3. Types of lumber box drains. (a) Open bottom form first used. (b) Box provided with bottom and spaces for entrance of water.
not be continually getting in and out of the trench. The diggers should keep close together, each taking out a spading and completing the trench down full depth as rapidly as possible after the crust is broken. Some of the ground, however, was a veritable slush and it was found impossible to dig a trench in it, as the material ran in as rapidly as it could be shoveled out. Several expedients were resorted to, but the greatest success was obtained by sluicing out a trench with irrigation water. Only a shallow depth was secured by this operation, but the drying influence of the drain permitted a trench of full depth to be dug without difficulty later.

When the system was finally completed a number of observation wells were installed, the purpose of which was to study the effect of the drains on the water table. Weekly readings were taken of the distance from the ground surface to the ground water level and a record kept of the discharge of the system as well. The discharge data indicate that the flow is constant except after heavy storms or heavy applications of irrigation water. Chemical analyses of the drain water show that large quantities of alkaline salts were constantly being removed, and calculations based on the average discharge of water and an analysis made as late as 1910 show that not less than 3,000 tons of harmful salts have been removed.

By 1906 the worst spots had dried out sufficiently to permit of the construction of drains to a depth of 5 feet, and the center line has been reconstructed. It was found necessary to give the drains a depth of 5 feet on account of the capillary action of the soil, which lifted the alkaline salt solutions to the ground surface, where the depth was less.

A great deal of trouble had been experienced from the saturated soil entering the drains from beneath. Irrigation water applied over or near the drains always resulted in this sort of difficulty, followed sometimes by a complete choking up of the conduit. If the obstructions were flushed out by means of water the soil would continue to flow into the drain for several days after the flushing, with the result that large
holes appeared here and there along the length of the drains. Eventually some of the lines were permanently obstructed and the pent up water was forced to the surface, forming new bogs and alkaline barrens. By 1906 it was seen that the open bottomed box was a failure, and the work of providing the boxes with bottoms was begun. By 1910 all operative portions of the system were thus provided. The construction of this type is shown on the accompanying sketch. The bottom is held away from the sides by means of short pieces of lath tacked at intervals of 3 or 4 feet to the lower edge of each side. The slit thus left forms the inlet for the water, and around it is packed fine gravel, which acts as a filter to keep out silt and quicksand. Wherever the closed box, provided with a gravel filter, has been used no trouble has been experienced, but it is not deemed wise to irrigate immediately over a drain line.

By 1910 the general conditions were so good that it was decided to put the entire system into perfect working order. Accordingly 750 feet of the center line and 750 feet of the east line were provided with bottoms and graveled; the north 375 feet of the center line, which had never been operative, was cleaned out; 100 feet of the branch into the upper bog was deepened until the last trace of the seepage was removed, and 500 feet of new line constructed up the gully, down which the seepage from the upper bog was wont to flow away.

**Results.**

In addition to the construction, careful observations of the progress of the drainage have been carried on, so that it is with a deep sense of assurance that the following results are stated.

First and most important of all the results has been a permanent lowering of the ground water level, so that the growing depth of soil is perfectly drained, allowing farm operations to be carried on, not only in all parts of the tract but on the farms to the south and east. The lowering of the ground water level has permitted the leaching out of the harm-
Plate I. TRANSFORMATION OF THE GEARY TRACT.

Upper figure shows characteristic vegetation of seeped areas, with alkali bog in background. Lower figure shows stand of stubble from which a good crop of grain was harvested. The bog has disappeared.
ful alkaline salts by means of rain and snow as well as by means of irrigation water, and although little attention has been paid to the latter, nearly the entire tract is now free from an excess of these salts, so that useful vegetation may grow. Had proper subsequent treatment in the way of cropping and irrigation been given, the entire tract would now be producing good crop. As it is, approximately three-fourths of the tract is productive and a considerable area of land farther down the slope is also giving returns. The accompanying photographs show the present state of affairs on portions of the field that were for a long time barren and covered with a deposit of alkaline salts. Another important result is that, due to the well drained condition of the soil, planting can be done earlier in the spring than on undrained farms and a longer season thus provided. The physical structure of the very soil itself has also been bettered. Finally, drainage has accomplished a result that is too little understood by farmers generally, and one that might have been overlooked very easily. This is the soil, being properly drained, now preserves the proper balance between moisture, air and heat. The latter two are of as much importance as the former, and can not be had in a saturated soil.

As far as drainage itself goes, the experiment has been successfully concluded, and complete restoration to the former productive state is dependent only on proper subsequent treatment. Care and attention are all that is now wanted to make this one-time eyesore as good as it was at its best. It must be borne in mind that the work on the Geary farm was an experiment, pure and simple, and that while the methods determined to be most efficient here are applicable elsewhere under like conditions, and that the same results may be expected, that there can be no comparison of costs, as much of the money spent here was for demonstration purposes. The methods devised here are applicable not only in Castle valley and Emery county but throughout the Colorado plateau, and if these recommendations be carefully followed there is no question but that success will follow the effort.
Recommendations.

Following is a condensed set of recommendations intended to cover general conditions as found throughout the plateau.

Prospect the field which it is intended to drain, and neighboring fields, carefully, by means of auger borings and test pits, to determine the exact source of water supply. If the source is in underground shale knolls, drains should be laid at a depth of not less than 5 feet from some suitable outlet through the natural course of the seepage and directly into the shale knolls, tapping the very fountain head of the damaging water. The deeper the drain cuts into the shale, the more widespread the results will be, but this depth should never be less than 6 feet. As the work of construction in the shale progresses, the proposed line may be run into dry ground. Should this occur it is advisable to change the direction of the

Plate II. View of the reclaimed area crop harvested in 1908.
drain in order to keep in water, and it may prove desirable to run a branch or two in different directions. If the source of water is at the foot of a shale ridge which rises above the surrounding ground and the water flows in a sheet down the slope, the drain should be constructed from a suitable outlet and at a depth of not less than 5 feet up through the wettest portion of the field to the foot of the ridge, from which point two branches should be constructed, on in either direction, along the foot of the ridge, and so planned that they will have sufficient fall toward the main drain and cut into the shale formation at least 2 feet, and more if it is found that water is flowing between deeper strata. The depth of these branches should not be less than 6 feet.

To avoid expensive construction, drainage should be done as soon as seepage makes its appearance. This does not mean that localities that have already been seeped for a long time should be abandoned, but it is a gentle warning against pro-
crastination. Almost any tract in Emery county is well worth reclaiming, and if care is used it can be done economically. In cases where saturation is complete and of long standing, shallow trenches should be scooped out with water and closed boxes laid and protected by means of gravel. The trench should also be partly refilled to prevent displacement of the boxes. This will allow the soil to dry out so serviceable drains may be installed later. The final drain should be placed at a little distance from the temporary line. By all means an ordinary open ditch should not be employed as it cannot be relied upon, and even should it maintain itself it would not be nearly as efficient.

If several tracts in the same neighborhood show the evil effects of seepage, an attempt should be made to secure cooperation among the various owners, as a more efficient and cheaper system can be designed. It is always advisable to have the lines carefully laid out and grade stakes set. The accompanying sketch shows the best method of setting grade stakes for inexperienced trenchers. In this method (see sketch) the grade stakes are set an equal distance above grade at every point. Grades should be as uniform as possible, and if it becomes necessary to change to a lighter grade toward the outlet, a sand trap should be placed at the junction to serve as a settling basin. A suitable design for a sand trap is shown in the accompanying sketch. It should be provided with a bottom and a top that may be locked down.

As has been said, the diggers should keep close together and dig the trench in short sections, laying, gravelling and blinding a box as soon as a sufficient length of trench is dug. In blinding the box, the surface edge of the trench should be caved off. Care should be taken that men or animals do not stand near the edge of the trench until the box has been blinded.

After the drainage system has been completed, it is advisable to turn irrigation water in at the head so that any silt or mud that may have accidentally entered the conduit may be flushed out. Indeed, it is well to arrange a permanent flushing
box at the upper end of all drains for this purpose. To prevent the entrance of mud into the conduit during construction, a gate for the upper end of the box should always be used. The lower end of all drainage systems should be provided with gratings to prevent the entrance of small animals. Subsequent treatment will be necessary in most parts of Emery county.

Vigorous cultivation in the fall, to give the rains and snows an opportunity to leach out the alkaline salts deposited on the surface is one of the first steps. More cultivation in the spring, followed by a liberal application of irrigation water, is another
important factor in the reclamation. The alkaline resistant crops should be planted. If conditions are very bad, it is advisable to plant even sweet clover at first, for although this is not a particularly valuable crop in itself, it shades the ground and prevents excessive evaporation from the surface. It is also a great nitrogen gatherer, and when plowed under enriches the soil and makes up for any nitrogenous foods that may have been leached out along with the alkaline salts. If oats are planted, the ground should be cultivated and irrigated all that the crops will stand. Also, if grains are planted, the planting should be done in the fall, so the stems may attain a sturdy growth before the burning effect of the alkali sets in.

Care should be taken not to irrigate directly over the drain lines, and wherever an irrigation ditch crosses a drain the water should be conducted through a flume.

The cost of drainage of lands in Emery county will in general be a little higher than elsewhere, on account of the construction through the bogs and in the shale, but on the other hand, a drain has a more far-reaching effect than in most localities. The cost of draining small tracts will probably average $18.00 per acre in the lands that have been long seeped. This cost is based on the use of lumber box drains. It would be out of the question to employ clay tile in this locality, and there is some risk attached to the use of cement tile when made by inexperienced persons. Taken altogether, lumber is very satisfactory, as the alkali impregnated water seems to have a preserving effect and the drains have a permanence unsuspected by many.

The results obtained on the Geary tract and in western Colorado, and the recommendations above made, are applicable to the older settlements of Castle Dale, Orangeville, Ferron and Emery, as they have the same general soil characteristics and topography, and to the new lands between Huntington and Price, where the identity of subsurface conditions is unsuspected by people in general. The methods outlined are applicable in general throughout the whole plateau, including
similar lands at Green River, Utah, and Grand Junction, Fruita, Delta and Montrose, Colorado.

Conclusions.

The soils of this section are rich and the climate favorable for general farming and horticulture, so every attempt should be made to reclaim lands now unproductive from seepage and alkali, and to protect new lands from such deterioration.

The costs of such reclamation and protection are within the limits of profitable expenditure, if the suggestions herein offered are followed by intelligent effort.

The cost of protecting new lands is small when compared with the cost of reclamation of the same lands when in the advanced stages of deterioration. The protective work should be done when the ground water level reaches a dangerous proximity to the surface, and not after water-logging actually commences. Special methods of construction and design must be devised and employed to meet peculiar soil and water source conditions.

In addition to the successful results obtained on the Geary tract detailed herein, similar lands in the Grand valley and other parts of Colorado have been drained successfully and reclaimed.

The seepage is in general due to losses from the canals, and could be prevented by lining or silting them where they cut through shale formations.

Drainage must be followed by subsequent treatment, vigorous cultivation and generous application of irrigation water, but irrigation must not take place directly over the drains, at least for a year or two, until the ground in the trench has packed.