

DUPLICATE

R. G. BOWEN

FARM DRAINAGE NUMBER

VOLUME I

NUMBER 4

JUNE, 1914

**THE MINERAL RESOURCES
OF OREGON**

Published By

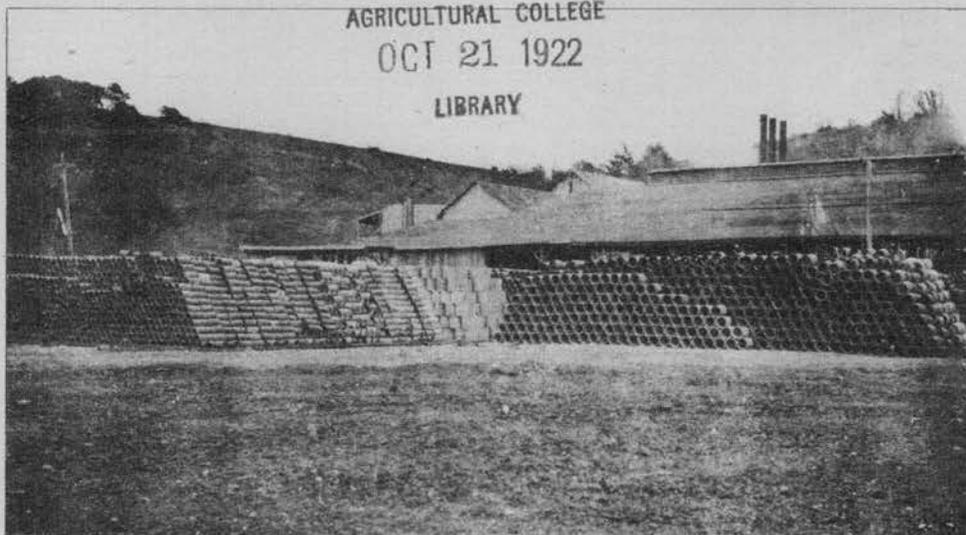
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81 Pages

46 Illustrations

Entered as second class matter at Corvallis, Ore. on Feb. 10, 1914, according to the Act of Aug. 24, 1912.

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JUNE, 1914

THE MINERAL RESOURCES OF OREGON

*A Periodical Devoted to the Development
of all her Minerals*

PUBLISHED MONTHLY AT CORVALLIS BY
THE OREGON BUREAU OF MINES AND GEOLOGY
H. M. PARKS, Director

THE DRAINAGE OF FARM LANDS IN THE WILLAMETTE AND TRIBUTARY VALLEYS OF OREGON

By Ira A. Williams.

The Willamette valley has long been noted for the fertility of its soils and the great productiveness of its farm lands. Much publicity has been given to the Willamette valley of Oregon as the "garden spot" of the Pacific coast country. As a place to live, and as a section of the state in which climate, soil and other natural conditions conspire to render habitancy pleasant and the securing of a livelihood on the farm easy, without the least doubt every word of highest praise that has been given to it is fully justified.

Such at any rate can with truth certainly be said of the valley as the early settlers found it 50 and 60 or more years ago. The uncropped virgin soils yielded bountifully with a minimum of labor expended in cultivation. Principally grains were raised and the most open "prairie" areas were first occupied because of the adaptability of their soils to wheat growing and, on account of the absence of the forest, the ease with which they could be subdued. Farmers made a living without effort, many became wealthy.

This has also been the case in other new regions, but the natural conditions were so much more favorable and so plentiful was the yield in Oregon that all farming operations were carried

on with little thought for the future. Doubtless few of the first farmers in the Willamette valley appreciated the possibility that so productive a soil could ever suffer depletion or approach exhaustion of its plant producing elements. Much less did they realize the value, nor did they possess a knowledge concerning the relation of proper cropping to the preservation of soil fertility and the maintenance of its primitive productiveness.

It followed, therefore, that farms were repeatedly cropped to the grains that could most profitably be grown, year after year, for ten, twenty, forty, fifty years or more. Intervening summer fallows served in a limited way to prolong the producing life of the soil, but, as has now come to pass, it was inevitable that yields should decrease until the same grains could no longer be grown at a profit.

As settlement continued, more and more of the tillable lands of the valley have been brought under cultivation. As in the case of the oldest farms, many of those later taken up are likewise showing the effect of long continued use by a diminishing productiveness. Naturally the question arises, and it is coming home to an increasing number daily, what is the reason that our farm lands do not produce as they formerly did, and what means can be adopted to recover or rejuvenate their lost fertility?

It has already been suggested that an actual depletion of plant food elements, or a wearing out of the soil has been brought about by constant cereal cropping. Besides this loss, monotonous and unwise methods of tillage have resulted in a decrease of the organic matter or humus in the soil, or in its almost entire disappearance, as in some of the so-called "white lands" of the Willamette valley which have been and would otherwise be highly productive soils with proper handling.

Without doubt, however, by far the most important reason for the rapid wearing out of the soils in various sections of the valley is the presence of an excess of water in them throughout too long a portion of each year. Too much water in a soil limits its producing capacity in several ways. Only two of these will be mentioned at this point in order to emphasize the exceeding importance of this factor. When the pores of a soil layer are filled with water, and especially when the subsoil strata remain thoroughly saturated until late each spring, crops and plant growth

of any kind have no opportunity to extend their roots to the depth they naturally would, since roots cannot go beyond the limit to which atmospheric air is able to circulate among the soil particles. Root extension downward, therefore, is largely restricted or prevented during that period of a plant's growth when its natural tendency is to develop a ramifying root system rather than to grow above ground. Under these conditions rootlets can extend in and occupy only a comparatively shallow surface soil layer, to what they would were the excess of moisture not present at the beginning of the growing season. It is thus plain that since the plant must draw its sustenance largely from the layer in which its roots are developed, a more rapid depletion of the elements of plant food in the soil will take place than if the same crops were able to extend their roots to much greater depths, and consequently to draw upon the vastly greater source of food supply.

Again, this water, along with improper methods of cultivation, have so interfered with the normal processes of accumulation and decay of plant residues in the soil that the customary acids of decay have not been allowed to act freely upon its mineral constituents in order to unlock or render available for the use of plants even those food elements that they do contain. Excess moisture in soils is, therefore, seen to be a chief controlling agent in their value for agricultural purposes.

These few elementary observations have been made at the outset in order to call attention to the extreme importance, to present prosperity and to a perpetuated agriculture in any region where natural drainage is poor, or absent, of providing means for the prompt removal of all water in excess of what is required for the best growth of crops; in other words, artificial land drainage.

THE DRAINAGE PROBLEM

The traveler on the main railroad lines through this central valley of western Oregon will always be impressed with the successive broad areas of very level farming country across which he passes. Beautiful are they to look upon as their spring-time green or more somber summer hues blend to both the east and the west into the bordering ranges of forest-covered foothills. The signs of agricultural prosperity are there. Taken off his guard, the full meaning and the enormity of the problem presented

to the Oregon farmer by so much evenness of land surface, perhaps does not at once occur to even the experienced farmer from the middle states, as he rides comfortably through the valley or at his leisure stops to enjoy a few days' respite at interesting points, of which there are many.

The people of this great agricultural section of Oregon have long realized the handicap that poor drainage has put upon their farming operations, but it is only in very recent years that many of them have begun to recognize that farm drainage can profitably be done. To emphasize the importance of this feature in its influence upon the agricultural present and its future, let us bring our supposed visitor into the Willamette valley successively under three different sets of assumed conditions.

First, we will suppose that he is an early summer tourist who is viewing the country. He will be favorably impressed and to him this part of Oregon will remain a beautiful region of prosperous homes and apparently contented people. Again, he is a winter tourist viewing Oregon for the first time. He comes after the prolonged winter rains and the accumulated waters from surrounding slopes have soaked the ground to overflowing. He will then behold a valley on many of the farming portions of which every slight depression is filled with standing water. Every furrow stands full, many planted fields are partially or entirely inundated; all of the evidences of insufficient drainage are present. Perhaps the schedule of the train on which he rides is irregular because of uncontrolled high water, though the latter contingency is not necessary in order to leave with him a sufficiently bad impression. If he is not a person whose eyes are open to the true state of affairs, he will go back to his eastern home with an ineradicable picture of the Willamette valley in his mind as a country of extreme wetness. That his impression is really incorrect counts for nothing, for he knows only what he saw and he portrays to his neighbors a country of cold, wet farm lands and one unpleasant to live in.

If, on the other hand, he be one who has learned to appreciate the value of drainage, he will see here a country of untold possibilities. The sign of enterprise that will, though rarely, break the monotony of the watery outlook and especially delight our visitor, will be the occasional appearance of a drainage ditch and an area

of drained land contiguous to it. The free movement of water through this ditch tells him that the removal of water from other like areas is only a matter of providing an opportunity, an outlet, for the water to take care of itself. In this case his impression is very apt to be that the country through which he passes is one of backward and unprogressive people; in which his judgment again errs.

Now, to assume a third case, which besides being rather common, is one that more than any other has to do with determining the permanent increase of population in the Willamette valley. Our stranger visitor comes for an inspection of the valley with a view to finding a home for himself and family. He likely represents a community "back home," the decisions of individuals of which to come to Oregon will rest upon the favorableness of the report of their representative. His brief visit to us is made in winter. It is brief because what he sees in many sections through which he passes does not appear to him as indicative of a good farming country. Why? Because of the standing water, and water-logged condition of the soils, many of them in crops. His report to his friends is rendered accordingly and neither he nor his neighbors come to Oregon.

Possibly and as frequently his trip is made in summer. If he comes before the wet areas of winter have become parched, forbidding and brown under the summer sun, his idea of the country is apt to be highly satisfying. A location is selected for himself and friends and several families are thus added to the population of the state. Winter rains come on and if, either by lack of information or through the ill-advised assistance of over-zealous real estate dealers, a poorly drained locality has been chosen, that particular community has in its midst what is worse than vacant lands—dissatisfied people.

The especially painful feature of such a situation is that, after all, there are no real grounds for misapprehension as to the agricultural possibilities of the Willamette valley and its desirability as a place to live. True, there are undrained sections and large portions of it now under cultivation which, because of poor drainage, are not yielding a tithe of what they are capable of producing. It is to be appreciated, however, that most of these areas can be relieved of their water by the application of proper drainage

methods; and that, under intelligent management, they and other similarly environed portions of our state can be developed to an unrivaled producing capacity. That this is possible in a high degree is amply demonstrated by the results obtained in every locality, and there are a few in this valley, where up-to-date methods of draining and of farming have been practiced. **Thorough drainage is, therefore, the next essential step in the development of this magnificent agricultural country.** Upon drainage depends its future and the fostering of the varied other industries that always follow closely in the wake of substantial agricultural activity.

This section of Oregon has, therefore, reached a stage in its growth where, for the present, attention should be focused upon its own upbuilding rather than upon outside advertising and an attempt to secure increased population. The importance of this cannot be too strongly emphasized. Internal growth and development, the bringing of our present farming sections up to their maximum capabilities will, under present conditions, be a far more important accomplishment in its effect upon the prosperity of the state as a whole, than any influx of new settlers that might be induced.

The results of over-zealous representations to prospective newcomers on the part of commercial clubs, real estate and other promotion organizations, at the expense of the promotion of home growth, is certain to be disastrous ultimately. Substantial settlement of all sections should be encouraged, but it should be brought about and will come by development within the valley itself, so that the signs of progress and enduring prosperity are evident on every hand to the new arrival, the visitor, and to even the railroad and automobile traveler. This condition can be most largely contributed to, by the provision of drainage for the at present large areas of wet farm lands. Moreover, the installation of artificial drainage systems can not only be accomplished at a justifiable cost, but in many sections of this valley it is rapidly becoming apparent that drainage is an indispensable essential to continued use of the soil in whatsoever class of agricultural pursuit.

LANDS IN NEED OF DRAINAGE

Within the watershed of the Willamette river system are embraced in round numbers 8,000,000 acres of land. Of this acreage approximately 3,000,000 can be classed as agricultural land including foothill and valley regions. Of this last number over one-half is valley, or, as they were originally called, "prairie" lands and creek and river bottom lands. Dr. James Withycombe is authority for the statement that there are 4,000,000 acres of farm land in western Oregon whose production could be doubled by tile drainage, at a cost that could be met by increased crops in four or five years. Fully one-half of this vast area lies within the limits of the Willamette watershed.

A general inspection of the Willamette valley will show that it is a broad depression in between the Coast and Cascade ranges of mountains extending from Portland on the north where it opens out into the Columbia basin, to somewhat beyond Eugene in Lane county on the south. It has a length of over 125 miles. In places the agricultural portions of the valley attain a width between foothills of more than 20 miles. Some idea of the vastness of the area, a good portion of which is comparatively flat valley floor, may be gained from these figures.

In the northern part of this area the floor of the valley is somewhat broken by low ranges of hills, and as we progress southward, its boundaries widen at intervals where it is joined by the valleys of the main tributaries of the Willamette river. In the case of most of the tributary streams the flat lands of their valleys are co-extensive with the main valley floor and in them are to be found many areas in which drainage is either very poor or quite lacking. The principal rivers entering from the Cascades side of the main valley are, the Clackamas, the Molalla, Butte creek and Pudding river, the Santiam, the Callapooia and the Mackenzie rivers. From the west come the Tualatin, Yamhill, Luckamute, Marys and Long Tom rivers. Most of these flow through valleys of greater or less agricultural importance and each presents its own individual drainage problems.

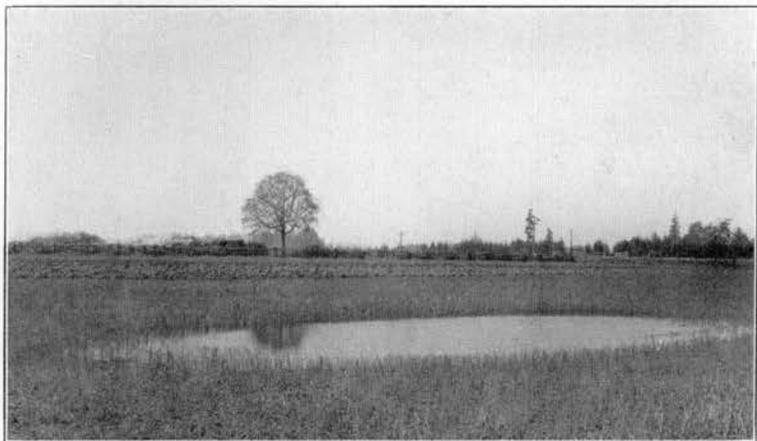
In the Willamette valley proper the principal areas badly in need of drainage are found from Oregon City southward, notably centered about Salem and Albany. Indeed, with the exception of occasional stretches of rolling country, flatness is a conspicuous

feature from above Woodburn in Marion county almost to Eugene in Lane county. West of Woodburn, south and especially east of Albany, are expanses of monotonously flat lands on which, at nearly any time of the year, the crops and the natural features of the country itself amply attest the need of drainage. The Albany area stretches eastward to Lebanon on the Santiam and to Brownsville on the Callapooia; and southward to Harrisburg and beyond.

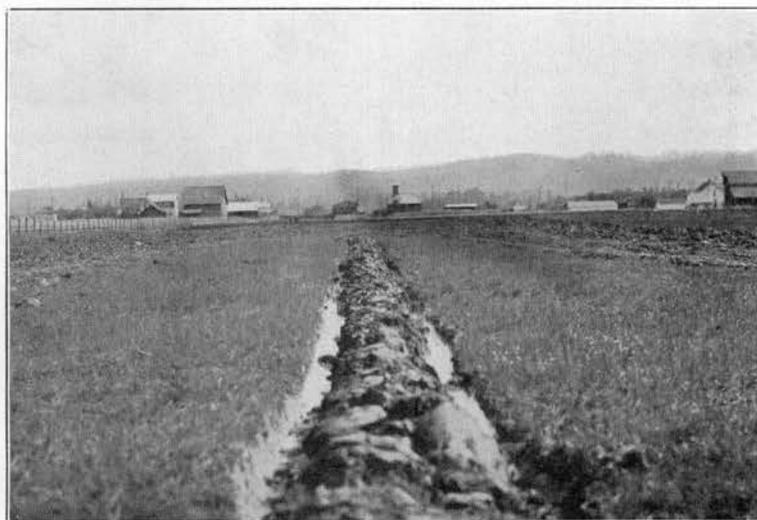
West of the river there are thousands of acres from Eugene northward in the Long Tom section and in the Little Muddy and Marys watersheds south of Corvallis, the successful farming of which awaits the installation of drainage systems. Many other specific portions of the valley might be cited for which drainage must be provided. The Tualatin river in Washington county flows through one of the most fertile and productive valleys in the state. Although the need and value of drainage and of the application of careful methods of farming were realized here by a few people many years ago, only a comparatively small amount of careful drainage has actually been done. It is, nevertheless, unquestionably due to the small beginning that some of the most progressive and wealthy farmers in Oregon are to be found in this valley. At present a large project is underway by which lake Wapato, near Gaston, will be drained by diking and a pumping plant. The latter, it is proposed, is to serve also for lifting water from the river for irrigation in the dry season. A drainage district is organized to drain lake Louisignout, a tract covering about 1,100 acres of rich farm land beginning three and one-half miles northwest of Forest Grove. These projects, and a few others, are evidence of an awakening appreciation of the value of drainage, and it is confidently predicted that they will prove to be the "entering wedge" to the broad field of drainage work and enthusiasm that is sure to open up in the coming few years.

To an equal extent do parts of the Columbia river basin require drainage. This is particularly true of that portion through which the Willamette passes and from the confluence of the two rivers westward to the mouth of the Columbia. Large areas here are overflow and tide lands the drainage of which will require dikes and sluices or pumping plants.

Without question a large proportion of the rolling as well as flat prairie lands, and much of the river bottom land within these



**Fig. 1. Pond in Cultivated Field, Middle of May, 1914, Near Salem, Ore.
Poor Drainage Conditions.**



**Fig. 2. Soil Filled with Water Preventing Cultivation. Late in May,
1914, Near Forest Grove, Ore.**



Fig. 3. The Wooden Box Drain. An Antiquated Type. Now Little Used Because of Its Short Life.



Fig. 4. Buckeye Traction Ditcher Co. Ditching Machine at Work.

limits, would be greatly benefited by drainage. In the case of many areas drainage is essential to their agricultural use in any capacity whatever. Besides lands already under cultivation there are also large tracts in different parts of the valley that are covered with water so large a proportion of each year that they are either absolutely worthless to the owner or are used only for pasture during a brief period in the summer. In nearly every instance these lands, too, are susceptible of drainage and when relieved of the water possess the most productive of soils. Such are some of the so-called "beaver dam" and "lake bed" lands. Comprehensive drainage will, therefore, both relieve over-wet farm lands as well as actually reclaim many thousands of acres from the swamp condition.

THE EVIDENCES OF POOR DRAINAGE

It will be asked, what are the evidences in a region of the lack of drainage, or of such poor drainage that the farming and highest productivity of the lands are interfered with? As a rule, the presence of standing water, in natural depressions, in furrows and along roadsides, or for longer than a day or so at a time anywhere on farm lands, is an indication of imperfect drainage. The appearance of water on the surface during the rainy season means that the water level has risen from below to that position; in other words, that the ground is completely filled or saturated with water. Overflow from natural waterways, even during periods of high water, is a condition which is likewise an evidence of impeded drainage. On cultivated fields the sickly or dwarfed appearance of the winter crops and their slowness in starting after the winter rains are over, are usually signs of too much water, whether or not moisture actually shows on the surface of the ground. The above are some of the conspicuous surface evidences of poor drainage or the absence of it.

Where surface manifestations are not such as to show the character of the drainage of an area, first hand knowledge on this point can be gained by making a few borings with a hand auger. The water will fill the holes to its own level in the soil. If this level is found to be close to the surface, or if it is proved that the water stands for months at a time within one or two, or even three, feet of the top, or at any point higher than the depth to

which the crops to be grown would naturally extend their root system in search of plant food, the water will, as a general thing, seriously interfere with crop production. The nearer to the surface the water level stands, within the general limits suggested, the less favorable, we would properly conclude, are the drainage conditions under ordinary circumstances.

ORIGIN OF THE WILLAMETTE VALLEY

Scientists who have studied the region say that the broad depression through which the Willamette river flows was formerly covered by the waters of the Pacific, an irregular shaped arm of which extended far inland between the Coast and Cascade Mountain ranges. The boundaries of this sound, for such it was, were irregular. Doubtless many islands projected above the level of its waters and into it streams flowed from the surrounding slopes, carrying sediments of widely varying nature eroded from a watershed of vast extent. In a general way, the conditions then may be compared with Puget Sound at the present time.

A gradual tilting and elevation of the sound bottom resulted in the slow recession of the ocean water, until the very depths were uncovered and this vast fertile section of country was added to Oregon's domain. Its present surface features are, therefore, those determined chiefly by the agencies at work during its occupancy and desertion by the waters of the Pacific. Waves dashed against its shore lines, forming beaches, their incessant action wore away and determined the outlines of the islands in its midst, and from this source, as well as the supply furnished by innumerable rivers and creeks flowing into it, immense quantities of fine sediment were distributed over the bottom of this sound. The spreading out of layer after layer of sediment and the active work of the weathering and erosive agents since, have had a tendency to even up or ameliorate abrupt cliffs, so that, as we now see, the region is one of moderate relief and of gradual slopes, not of rocky ruggedness.

The present major river and its tributaries, aside from the development of relatively narrow flood-plains in places, have thus had little to do with determining the character of the present general valley floor. Its features are for the most part those of the former sound bottom, and its soils the mechanical sediments

that were washed from adjacent slopes to settle in the less disturbed regions of its depths. Lengthwise of this great valley depression there is a uniform slope to the north. Eugene, near its head, has an altitude of about 450 feet, and at Portland the elevation is 57 feet above tide. In this distance of slightly more than 100 miles there is thus a fall of 393 feet, or an average grade of near four feet per mile. This grade varies locally, both above and below this average, but a grade of less than two or three feet per mile is rarely found even in those districts where, to the eye, an extreme levelness prevails. Although it is always advisable and has proved necessary in some instances to include considerable area in one unit in order to secure a satisfactory outlet, it will rarely, if ever, be the case that an ample fall cannot be found to take care of the flow of drainage water.

Many of the smaller streams that have their courses through these flat sections of the valley flow sluggishly and frequently overflow their banks during periods of heavy winter rainfall. It is found that most of these have sufficient grade to carry even more water than ordinarily comes to them; seldom less than three, and usually more, feet of fall per mile. The annual overflow is caused from the obstructing of the channel by the growth of trees and the extension of their roots, the dams thrown across the channels by beavers and the consequent accumulation of sediment and other debris, etc. The particular streams in which such a state of affairs has been especially brought to the writer's attention are the Little Muddy and Long Tom rivers, south of Corvallis, in Benton and Lane counties; the Little Pudding river, in Marion county; the Tualatin and its branches, in Washington county. It is a common condition, however, and usually all that is necessary is a clearing out and opening up of the clogged channel of the stream to afford entire relief from overflow and the discouraging handicap which it is to the farmer in such a locality.

SOILS OF THE VALLEY

As suggested above, most of the soils of the Willamette valley have been produced by modification of the materials brought by streams and deposited in the bottom of an arm of ocean water. Doubtless those materials have been added to and more or less

intermixed, particularly along the former borders of the sound, with more recent wash from the foothill slopes. The present streams have also distributed over their flood plains the mud and silt which they carry. In places, patches of peaty soil have originated by the accumulation of vegetal matter in swamps or in the quiet waters of a pond or wet area produced in a stream course by the work of beavers. By far the bulk of the soil and subsoil strata over the more level areas in the Willamette valley which today, it is woefully apparent, are so in need of drainage are, however, according to the best knowledge on the subject, made up of the former sediments which settled to the bottom in an arm of Pacific ocean water.

The soil types represented in the general valley floor are designated as silt loams. These vary in texture somewhat and in color from black on the lower bottom lands through dark gray and gray to almost white, the so-called "white lands" occupying portions of the most poorly drained valley floor lands. In the river flood plains the soils are gray or brown, usually sandy loams, and sometimes gravelly in those portions actually overflowed by the rivers. These types pass into sticky clay loams in places and along the surrounding slopes grade into the red heavy silt loams or "shot" soils. Occasional spots of adobe, a fine-grained, sticky clay soil, occur throughout the valley. As stated there are also considerable areas of brownish "beaver dam" or marsh soils in especially the lower part of the valley.

Below the surface layer of soil proper, which varies from a few inches to three feet, the subsoil strata vary in different localities. The most common gray silt loam frequently passes into a yellow clay silt which extends to an indefinite depth. At times a bed of sticky blue clay, of from six inches to two feet in thickness, locally called "gumbo" and "hardpan," is found immediately beneath the soil. This blue clay is fine-grained, and when wet does not let water through it with readiness. A stratum of this nature customarily appears in all "white land" districts. At still greater depths a yellowish clay silt is commonly found. The "beaver dam" soils in depth become a soft brown muck, filled with partially disorganized organic matter and saturated with water. Beds of gravel at times underlie especially the black sandy loams of the stream flood plains at

sufficiently shallow depth to assist in the drainage of these soils.

Of the types names as covering important areas of the valley floor, the sandy and gravelly loams naturally drain most readily. The gray silt loams with yellow clay silt substratum, which in area are the most widespread types, permit the water to pass through them with sufficient facility to render their under-drainage by means of tile advantageously possible. The peaty marsh soils likewise yield readily to artificial drainage. The "white land" soils, largely on account of the prevailing presence of the impervious blue clay subsoil, do not yield so freely to under-drainage. But it has now been demonstrated in several places in the valley that these soils which, of all types, are most badly in need of drainage, can be successfully drained by a proper spacing of drain tile at correct depths beneath the surface. When drained they and the "beaver dam" lands both equal, if not excel, for some crops the more tractable and highly productive gray loam soil.

It is an observation which can be safely made, that any soil as yet known in the Willamette valley of Oregon can be made to yield to artificial drainage. The beneficial effects of drainage will be slower to appear in the case of the more closely textured soils, but a properly installed system, along with the application of methods of cropping and tillage that tend to open up both the structure and the texture of the surface and subsoil layers will, all experience goes to indicate, effect perfect drainage, even if soil conditions appear unfavorable at the beginning. It is a rare case, indeed, in which water can be prevented for any length of time from reaching and flowing out through lines of open drain tile in a wet field, where the soil is of any variety that can be successfully cultivated. Once a few lines of flow to the tile are established, every feature of this water movement among the soil particles, and the extension of roots to increased depths, conspire to improve the physical condition of the soil and so facilitate the passage of moisture through its mass.

WHY LANDS DO NOT DRAIN NATURALLY

It is readily conceivable that a land surface such as the Willamette valley, covered as it is believed to have been by water, would possess those irregularities which characterized

it as ocean bottom. As the ocean waters slowly left it, there would be a tendency on the part of the streams to eliminate many of the depressions either by drainage or by filling them up. A general slope was developed in the direction the Willamette now flows. As a result we find few ponds or marshy regions to which there is no natural outlet. Such as do exist are usually the result of a more recent clogging of drainage channels. So far as the general lay of the land is concerned, therefore, the slope is such that in almost every part water falling upon it would ultimately find its way into natural drainage channels. The annual rainfall in the Willamette valley varies from 35 to 45 inches. Were this precipitation distributed uniformly through the year, many lands that now become water-logged, and even submerged, would then suffer much less, if any, from an excess of moisture. This for the reason that the streams and natural slopes, never being overloaded, could then take care of the excess water falling upon the land.

While present slopes and streams might be capable of handling such a well distributed rainfall, when the same amount of water falls each winter in little over one-half the time, the case is a widely different one. The capacity of slopes, of stream channels, of porous soils are all overtaxed, and as a consequence water fills the ground for months at a time, stands upon its surface, or overflows broad tracts from streams filled beyond their capacity. These results ensue, not because drainage is absent, but because it is inadequate when large quantities of water come in so short a space of time.

In providing artificial drainage for a region, the problem is thus largely one of removing a sufficiently large proportion of the excess water which accumulates during the most rainy periods, that the soils or crops upon them may not suffer injury. For example, it would rarely be the case that any drainage system could remove as rapidly as it came, a rainfall of three inches on the level in 24 hours. With the knowledge that such extremely heavy rainfall is apt to occur in Oregon, however, and records prove that it does at times in parts of the Willamette valley, a properly designed drainage plan should provide for so rapid a removal of the water that at no point will it stand upon growing crops for over one day, or 36 hours at the outside. The

question is one to be viewed from the agricultural standpoint entirely. Protection of planted crops and care of the soil for the purpose of plant growth and the production of crops, are the primary considerations. The slopes of the land in relation to the quickness of the rainfall and its amount are thus the factors that determine the ability of a region to drain itself of surface water.

WATER IN SOILS

In its influence upon agricultural possibilities, that water which soaks into the ground, is of equal, if not greater, import than the surface water. Its disposition and movement are determined by the physical character of the soil, subsoil and underlying strata. All soils are porous, the actual open space among their constituent grains frequently being as much as, or more than, that occupied by the solid particles themselves. This means, for example, that each cubic foot of soil can take into its open spaces about one-half a cubic foot of water, or in round numbers, say 30 pounds. The fine-grained soils have a larger proportion of pore space, therefore a greater capacity for water than coarse-grained soils. Sandy, open-textured soils absorb water readily, but on account of their coarseness can contain less than the close-textured clay or clay loam soils. They also allow water to pass through them with greater ease than do clay soils.

It is apparent, therefore, that the texture of the soil and the character and arrangement of underlying layers will determine very largely the movement of the water that is absorbed. When rain falls upon the land in the autumn, water is rapidly taken into the soil. This moisture is drawn downwards by gravity through the subsoil strata until it reaches the level of the ground water. This may be a distance of a few inches or several feet, depending on the drainage conditions. In any case here, at the ground water level, its downward movement ceases, and it becomes stagnant unless this level happens to be in a porous stratum, along which water can move laterally to some natural drainage outlet. Such lateral movement is usually either absent or slight in flat regions; at any rate it is not sufficient to remove the water at a fraction of the rate that the fall rains are contributing it. As a consequence, the water level rises and continues to do so until it reaches the surface and the ground is

saturated. At this stage, every pore is filled with water, every root surrounded by it, the ground water level is at the very top of the ground and, where surface drainage is poor or lacking, continues to rise until water stands upon the lands.

The rapidity with which absorption takes place, and the opportunity for movement of the water in any definite direction beneath the surface determines, of course, the time required for complete saturation of the soils of a region. Clayey soils, or those underlain with clay subsoils, such as some of the "white lands" in the Willamette valley, take water relatively slowly in the fall, but when filled actually contain more, because of their fineness of grain, than do the silt loams and sandy varieties. They, as it were, shed the water, and pools may stand upon the surface before the ground is thoroughly filled. Gumbo, adobe, and other clay soil types act in a similar manner.

While these soils are slow to absorb they are slower to give up their moisture in the spring, either from the surface by evaporation or by natural under-drainage, until so late a date as to prevent or greatly hinder the working of them. The value of artificial drainage to such soils as just described is clear. Surface drainage prevents standing water at any time. Proper tile under-drainage, by carrying away that which sinks into the ground when it reaches a certain depth, prevents complete saturation and water-logging, and assists in maintaining a condition of readiness for spring working of the land or growth of crops as early as weather will permit; which can never be so when undrained fields stand saturated or submerged throughout the winter months.

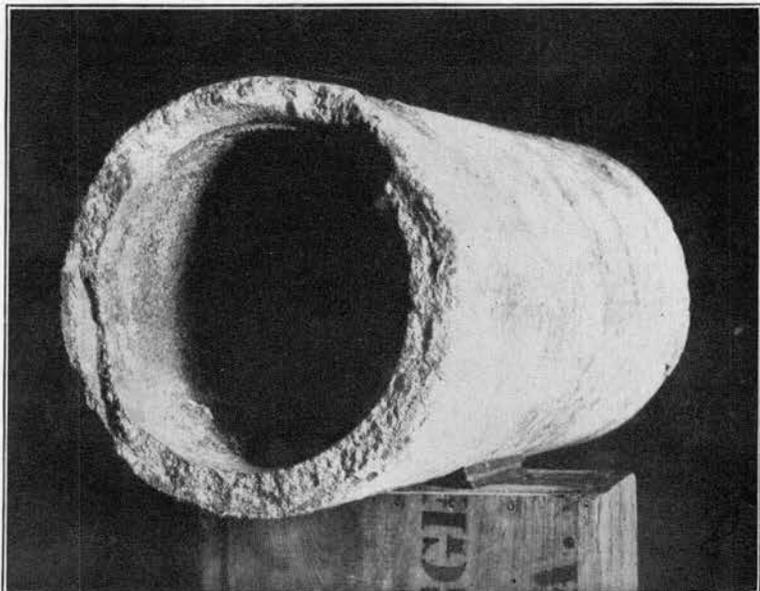
It should be explained that drainage does not remove all or nearly all of the water from soils. Of the from 30 to 60 per cent of moisture which soils can hold, it is possible to remove only about one-half by drainage. The loss of this quantity leaves open air spaces in the soil, although it still contains 15 to 30 per cent of its own volume of water. Plant growth requires as much moisture as this in the soil; more than this is too much; less is too little. We call a soil dry when plant growth ceases, although as a matter of fact it may still contain as much as ten per cent of water. The moisture so remaining, called hygroscopic water, clings tenaciously to the soil particles, and is not all removed



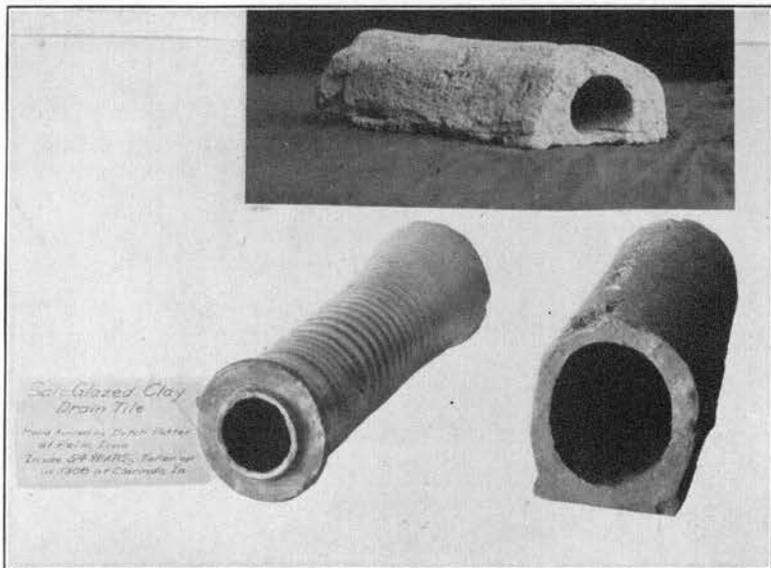
**Fig. 5. A 20-Foot Ditch Which Drains Lake Labish,
Marion County, Oregon.**



**Fig. 6. Floating Dredge in Lake Labish Drainage Ditch.
Over 1000 Acres of Fertile Beaver-dam Land Are
Already Drained by Means of This Ditch.**



Eng. Exp. Sta., Iowa State College
Fig. 7. Eight Inch Concrete Tile Taken from the Ground After About 30 Years of Service as a Drain. The Rough Edges Were Made by Breaking the Mortar Joint Between It and Its Neighbor. The Tile Is in Perfect Condition.



Eng. Exp. Sta., Iowa State College
Fig. 8. Old Timers in the Draining Business. The Upper View is a Concrete Tile After Years of Use. It Was Molded Round a Willow Root. Below at the Right is an Old Oval, Flat Bottom Clay Tile. At the Left, a Salt Glazed Clay Tile, Hand-Turned by Dutch Potters at Pella, Iowa. In Use 54 Years When Taken from the Ground in 1900.

even during the hottest, driest time of the year. That moisture in the soil which plants make use of is known as capillary water. A thin film of it surrounds each soil particle and it moves upwards from the position of the ground water by virtue of the attraction of the soil grains for it and their contact with each other. Capillary water is plant food, and in this condition only can plants appropriate it to their use; hence the very apparent detrimental effect upon growing crops of either too much or too little available water.

WHAT DRAINAGE REALLY IS AND HOW IT IS ACCOMPLISHED

As just stated in the preceding section, a condition in which the soil contains a medium amount of water, 15 to 30 per cent of its volume, is not only favorable, but essential to the best growth of plants. Drainage of wet soil is merely the adoption of measures by which the moisture content can be controlled within favorable limits for the greatest possible proportion of the year. This means the prevention of saturation for any considerable length of time during the rainy season as well as, on the other hand, the shortening or elimination of the summer period, during which the soil is too dry for growth to take place. The sum of these two influences operates to lengthen the growing season in both directions. Effective drainage acts in both these ways, as will be shown later.

The control of saturation and the maintenance of an openness in the soil such that air can at all times move through it is accomplished by removing surplus water as rapidly as it accumulates. Water will not appear upon the surface until the soil is filled to overflowing. The crops cannot utilize the moisture until it has passed into the ground and has reached and surrounded their roots. The rational method of getting rid of excess water would, therefore, obviously be to take it out beneath the surface after it has passed through into and through the full depth of the soil layers. Two means are employed, either alone or in conjunction, to accomplish artificial under-drainage; the open ditch and the drain tile.

THE OPEN DITCH

The open ditch will carry away, of course, all water that

comes into it from whatsoever source. It is most efficient in draining out depressions in which surface water naturally accumulates and in taking the run-off from adjacent slopes. It is pre-eminently an instrument for surface drainage. The shallow furrow ditches which are so common a feature in fields throughout the grain growing sections of western Oregon serve only a limited purpose in preventing actual ponds of standing water. While they are about the only possible safeguard that can be employed under present conditions against the drowning out of crops, they are really not very effective in this regard. They are inefficient so far as actual drainage of the soils is concerned, and are a nuisance in the cultivation of the fields and in harvesting the crops. This method will be unnecessary and will disappear with the advent of tile drains.

The extent to which even the deep open ditch accomplishes the under-drainage of the land contiguous to it is not very great. When first made, the water seeps into it from a distance on each side about equal to the distance it would travel to a drain tile of equal depth. An increase in its width does not cause it to "draw" from a proportionately greater area of land. Its efficiency for under-drainage, especially in clay and loam soils such as ours, decreases rapidly, too, with use, so that in a few years its value for this purpose is oftentimes very low, if not actually nil. Surface water flowing through a ditch contains sediment washed from the drainage slopes. The coarser grains of the sediment, which is all composed of soil particles, is deposited in the bottom, and the finer particles distributed against the sloping sides of the ditch. A slimy coating thus accumulates with each rise and fall of water level which tends to close and to seal the exposed soil spaces and to thus impede the lateral passage of water into the ditch.

The value of an open ditch or of the ditch system of drainage is to be considered, therefore, as limited to the removal of surface water and to serve as outlet channels into which tile mains may empty. Ditches are not to be recommended unqualifiedly for even these purposes, except where the capacity must be so large that a closed waterway would be out of the question. The space occupied by a ditch and usually the heap of earth excavated from it, represents so much wasted farm land. A ditch must be

bridged and fenced, and is in the way of farming operations. It must be cleaned out and its banks and bottom kept free from weeds, obstructing roots, willows, etc. The water flowing into it cuts the banks in places and there is a constant loss of soil in the water that flows through it.

In some of the older regions where drainage has long been practiced, open ditches are being replaced by large tile, which are buried to a shallow depth, and the ditch area thus restored for cultivation. Tile as large as 36 inches in diameter, and larger in some cases, are used as mains in some Iowa drainage sections. The same is true in Illinois, Minnesota and other middle states. Two or more tile are often laid side by side in order to afford an ample flow capacity. The use of these tile is practiced because of the objections to the open ditch already mentioned, and because farmers in those states cannot afford to lose the use of so much valuable land. They can afford to close up the ditches at even a much greater initial expense.

The soils of these states, though fertile, possess a lower potential productivity because of climatic limitations than do those of the Willamette valley, with whose matchless climate that of the middle states is not to be compared. Many open ditches will be constructed in the development of drainage in Oregon. But we have every reason for predicting that fewer and fewer of them will be made as the years pass, and many earlier ones will likewise be replaced with big tile as our farmers begin to realize the necessity of putting to use every square foot of the land and of properly draining it.

THE UNDER- OR TILE DRAIN

By under-drainage is meant literally the removal of water from under or below the surface and, therefore, beneath the soil through which the water must pass in its downward course to reach an under-drain. The tendency of water is to move downwards by gravity, but, as has been pointed out, only that portion is actually free to do so which is in excess of the needs of plant growth. Capillary water normally moves upwards, and it is from the thin film of it which surrounds each of the soil grains that plants obtain their supply. It is, therefore, used up by plant growth and a part of it escapes by evaporation at the surface.

On the other hand, the surplus, which we shall call gravitational water, sinks through the soil and subsoil strata and continues, under the action of gravity, to go deeper until it reaches the permanent or ground water level, a porous stratum such as a bed of gravel or an open underground drainageway. At the ground water level it may experience a lateral movement, as it might also in coming to a bed of porous sand or gravel, but in a region such as this, where winter rains are heavy and continuous, such lateral motion is, under most flat lands, so slow that the ground quickly fills with water to the very surface.

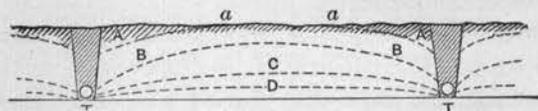
Thus the only avenue of escape is one afforded by placing open conduits at such a depth and grade that they will intercept and carry away this accumulating water. The earlier drains for the purpose were the so-called "blind" ditches, or those made by covering over with soil, poles or straw or a bed of stones laid in the bottom of a shallow ditch. Inverted V-shaped troughs of plank and board boxes were formerly used. The foregoing, which it is apparently are at best temporary makeshifts, have now been replaced and have given way entirely to the drainage tile.

Tile are made of clay and of cement concrete. Formerly they were shaped oval or round, with a flat base, but these forms have long since disappeared, except as relics, and the straight cylindrical tile is now almost universally employed. A line of round tile in the ground provides an inclosed circular channel for the flow of water. In a well tiled field there will be a series of tile lines so spaced with reference to each other that the rain water can reach them as rapidly as it falls upon the lands. Under such conditions the ground never becomes saturated with stagnant water. The upper layers are constantly losing their water downwards and are, as a result, always receptive of more, which they absorb quickly as the rains fall upon them. In the winter time they thus serve as a reservoir which, as it is intermittently replenished by rainfall, in turn constantly leaks this supply into the drain tiles below. Surface standing water is thus prevented.

GROUND WATER TABLE

At first thought it may seem that water which sinks into the ground on an area that is under-drained moves directly

towards the nearest open tile as if in a hurried effort to make its exit. This is not the case. In other words, the tile exercises no "draw" whatever upon the water above its own level. The ground water level and its position have been referred to. Figure



Elliott's Practical Farm Drainage

Fig. 9. Effect of Drains on Position of Ground Water Table.

9 illustrates the influence of consecutive lines of tile on the position and nature of the ground water surface, or water table. It will be noted that directly over the tile the water table is always lower than at points at some distance, and that it is highest midway between the two tiles. This is its position except at times immediately following excessive rainfall, when the water table may rise to the land surface at all points for a brief time. The action of the tile in such a case is to rapidly lower the water directly over it until it sinks to the level of the tile itself. At the most distant points between the tile the water lowers less rapidly, but, if properly spaced, the water table here will sink to a practical plane, as shown by B, C and D. The farther apart the tile, the nearer to the surface will the water remain beneath *a* and *a*. When it appears at the surface, or stands close below it, this area will show all of the indications of lack of drainage, which, as a rule, an additional line of tile or closer spacing will completely remedy.

It is apparent that putting the tile to greater depth would

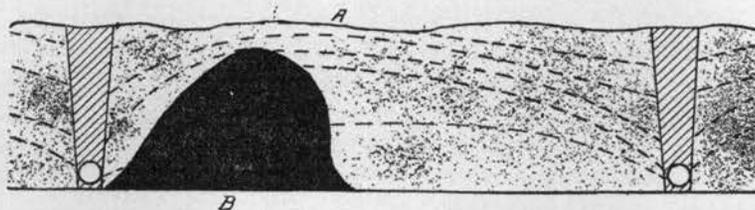


Fig. 10. Effect Upon Water Table of a Ridge of Impervious Clay (B) Beneath the Surface. Water May Stand in the Area A Comparatively Near a Drain. Short Sub-Laterals or an Additional Lateral Are Needed in a Case of This Kind.

have the effect of lowering the water table across a greater distance between tiles. Both depth and distance apart are,

however, factors that the drainage engineer must determine for individual cases or regions, since the character of the soil and the subsoil, the facility with which water will pass through them, the amount and character of the rainfall, and the grade of the tile vary in separate localities.

It will be seen that what tile drainage really does is to determine and to control the position of the upper level of the ground water in the soil, and especially during the rainy season, when it would otherwise rise to the surface or above it. It keeps the water table down to such a depth that plants can extend their roots to a greater distance than would be possible without drainage. Every opportunity to grow below ground is responded to by an increased vigor and a corresponding greater

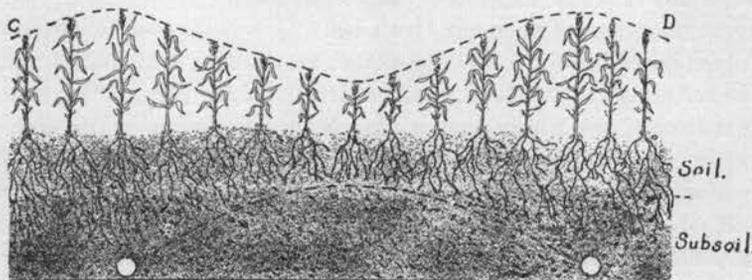


Fig. 11. Effect of Placing Drains Too Far Apart. Note That the Curve of the Ground Water Surface is the Reverse or Reflection of That Made by the Top of the Plant Growth on the Soil Above. The Reason for This is Seen in the Different Depths to Which Root Extension Can Go as Determined by the Water Table.

development of the plant above ground. This point is illustrated in Figure 11.

ROOT GROWTH

Many of the common crops, if not interfered with, extend their roots to rather surprising depths. In arid regions roots go deeper in search of water than in moist. In sandy, open-textured soils, they likewise penetrate deeper, because root enlargement meets less resistance and on account of the less freedom with which moisture moves upward by capillarity in this type of soil. In the loam and clay loam soils, such as the undrained soils of the Willamette valley largely are, the common cereals—oats, winter wheat and barley—are known to penetrate to a depth of four feet or more if unobstructed. Corn roots extend to an equal depth, while the ramifying roots of the clovers and alfalfa

and most orchard trees very frequently push their way for eight or ten feet, and in some cases double these distances below the surface of the ground.

It is to be kept in mind that such root growth is quite essential to the best development of the plant, and that it cannot take place unless the ground water level is either naturally or by drainage lowered to such depths. Every inch nearer the surface that the water level stands decreases in that proportion the opportunity for plant development and for crop production. What, then, should be expected of field crops whose root growth is limited to an upper two feet, or one foot, or much less, until May or June, or later, when they require four feet or over? It is just this very state of affairs that at present exists over wide areas of Willamette valley land, and which is absolutely limiting their producing capacity. The farmers in these sections are not only not realizing from their efforts anywhere near what the soils are capable of yielding, but the time is not very distant, if it has not already arrived, when abandonment of worn out soils will begin. Drainage is a remedy, the only remedy, and it is an efficient one.

"PLOW SOLE"

Another condition, the importance of which it is necessary for every farmer to appreciate in attempting to revive the productivity of his soil, either with or without drainage, is the existence of a more or less impervious layer at a shallow depth beneath the surface. This is due to the monotonous methods of cultivation long practiced over large areas of former grain land in the valley. A dense close-textured stratum called "plow sole" has been produced just below the depth to which the land has been plowed. This has come about by oft-repeated cultivation to about the same depth, the puddling effect of the horses' feet which have passed down the furrows year after year, and of the stock that have long pastured upon it during the muddy season. It has become so packed and its flocculated granular texture so broken down that it does not let water through it readily, and the roots of plants meet more or less resistance in pushing their way into and through it.

This is to some extent the cause of standing water on present fields where such was not noticeably the case until after years

of cultivation. The "plow sole" must be broken up before perfect drainage can be established and before a high state of tilth and productiveness can be attained in the soil. Plant roots will make their way into it to a much greater extent after drainage, and the removal of the water will also cause more cracks and joints to form by its drying out. These slower processes can and should be aided by deep plowing, subsoiling, and the use of such legume crops as the clovers, vetch, alfalfa, etc., which have the ability to more forcefully extend their root systems into even the finest grained of clay soils.

It is obvious that in order to accomplish most in this respect, deep plowing or subsoiling should not be done when the ground is wet, or so damp that there is any tendency to compact or puddle where the teams walk. In such a case, not only would the old plow sole not be broken up, but the very purpose of the deep plowing would be further defeated by the beginning production of another impervious stratum lower down. In order to be most effective, the plowing should be done in the summer, when the ground is dry, or promptly in the fall with the very earliest rains. In some localities it may be thought impossible to plow in the dry season on account of its hardness and the large lumps and clods that necessarily result from tearing up this old compacted layer which perhaps has remained undisturbed for years. It should be remembered in this connection that the more clods and lumps that can be turned up, the more beneficial to the soil will the plowing be; also that the extra effort, time and horse power expended in this work in the drier parts of the year, are certain to be fully repaid by the additional rapidity with which the tractability of the soil will improve, and its ability return to yield more abundantly.

Drainage, cultivation, correct methods of cropping. After all, these are only measures that it is essential to adopt in order to get most out of our soils, yet such as will at the same time tend to preserve and to maintain their fertility through generations to come.

SUMMARY OF EFFECTS OF DRAINAGE UPON SOILS

It will be well to summarize at this point in a systematic but brief manner the various ways in which drainage affects a

soil that has suffered from too much water. As will be seen, its beneficial effects are cumulative, one depending upon and following others from which it has resulted.

Aeration. The removal of water which has filled the pore spaces in a soil, permits air to pass into it to the depth of the drain. This air is renewed following each rainfall that sinks into the ground, and to some extent is believed to circulate between open tile and surface. Aeration is an essential condition that must be brought about before any of the following effects can take place. The presence of air in the soil determines the depth to which roots can go; it is essential to the germination of seeds; it promotes the growth and its presence is necessary to the activities of the host of nitrifying bacteria as well as those of decay, and it aids also in bringing about the decomposition of the mineral particles of the soil which liberates the needed inorganic elements of plant food. Agricultural experts place the presence and renewal of air in the soil as the most important condition of plant growth.

Increase in temperature. Soils filled with water are relatively cold soils. This is true for two reasons. First, because water heats up much more slowly than do the solid particles of the soil. Authorities state that as much as ten times the heat is required to raise the temperature of a given amount of water one degree, as is necessary to raise the temperature of the same volume of soil particles one degree. In the spring the warming up of a soil containing one-half or more of its volume of water, as many undrained soils do, will progress much more slowly than when a large portion of this water has been taken out by drainage. A cause considered to be equally important is the cooling action due to the evaporation from the ground of the larger amount of moisture in a water-logged soil. The warmer the air, the more rapid this evaporation, hence the greater its cooling effect. As a result of the combination of these two influences, differences of from two and a half to twelve degrees have been noted between drained and undrained soils. An early warm seed bed is essential to good farming, and a difference of but a very few degrees at seeding time may determine the success or failure of a crop.

Favors the work of bacteria. Those species of bacterial life which are active in rendering the nitrogen of the air and that of

decaying organic matter available for the use of growing plants are a very essential factor in soils. They require comparatively warm temperatures in which to work, and they become active and multiply in numbers only after a certain warmth has been attained. An abundance of air and some moisture are also requisite. These conditions in the soil are brought about only by drainage, and the longer the period of each year during which they can be maintained the more important will be their beneficial effects.

Renders deep root extension possible. As already pointed out, common farm crops naturally extend their roots to a depth of several feet in a soil free from excess water. They also grow laterally to a greater extent, both of which give an added vigor to the plant. These roots die and decay and leave openings in the soil and subsoil layers through which water can more readily pass to the drains, and by means of which air can reach to greater depths.

Improves the texture of the soil. The chance for water-logged soils to dry out from beneath, and the action of plant growth upon them, is such as to tend to group the individual soil grains into coarser crumbs or granules. This has the effect of rendering the soil more open-textured and easier to work, besides making it more retentive of capillary moisture, yet more easily drained of its pore water; in other words, from the standpoint of plant growth, an improved texture in every way.

Renders greater depth of soil possible. The foregoing conditions all favor a more thrifty and vigorous plant growth. The lowering of the water table by drainage permits air to reach to greater depths and roots to extend. Nourishment is thus drawn by plants from deeper layers and an enlarged area. Soil formation, that is, the decomposition and alteration of the mineral particles which render plant food elements available, takes place throughout a correspondingly greater volume of previously dormant, though potentially rich, soil and subsoil strata. Through these processes a vastly greater supply of virile food elements is opened up on which crops can draw for growth and sustenance. The bringing about of this condition is of unmeasurable importance to the present and to the future of agriculture in any region of fertile but wet farm lands. It applies emphatically to the large

areas of wet Willamette valley lands that have been pointed out.

PRACTICAL RESULTS OF DRAINAGE

As a consequence of the changes in the soil just enumerated, that may be brought about by providing adequate drainage, many practical results will accrue. The natural question asked by the farmer is, wherein will these improved soil conditions benefit me? What evidence is there that to drain my land will be profitable, worth its cost and more? The following are some of the chief practical benefits to the farmer that will be realized from drainage.*

Land is ready for seeding and cultivation earlier. The removal from below of excess water throughout the rainy season enables the soil to dry out much more quickly in spring, with a corresponding rapid increase in warmth, which, in the Willamette valley will fit it for cultivation from one to two months earlier than undrained land.

Crops begin a healthy growth at once. The proper amount of moisture and heat germinate seed promptly, the tiny rootlets find at hand oxygen from the air, plant food prepared as they need it and an open soil into which they can push their way with little resistance. Fall and winter crops will start a vigorous growth as early in the spring as the weather is favorable, and will not be held in check nor dwarfed as on water-logged soils.

Crops are better able to withstand drought. The greater depth of soil and the extended range of roots, along with the change in the texture of the soil, which renders it capable of retaining more moisture in the condition plants require and can use it, are among the causes that enable a crop to pass safely through a dry period. At first thought it may be questioned by some whether the removal of water from the soil, as by drainage, in a region like the Willamette valley, will actually place at the disposal of growing plants in a dry season more water than before drainage. It is a fact of observation that such is the case.

The principal way that a water-logged soil can get rid of its moisture is by drying out on its surface. This process causes cracks to open up and invariably in the clay loam types leaves

*In part from "Practical Farm Drainage," by C. G. Elliott.

a more or less hard crust through which evaporation takes place much more rapidly than through a granular or pulverized surface layer. This is a fact taken advantage of by the dry farmer, in fact, is largely the basis of the success of dry farming methods. Drainage takes the water out from below, no opportunity for crust formation appears, and the entire mass is left more open. As a result, the moisture from the permanent water level rises higher by capillarity and keeps the upper layers constantly more moist than in soils allowed to become saturated and to dry out by evaporation.

It is upon this principle of capillary movement that sub-irrigation is accomplished and it is not overstating the facts to say that effective under-drainage for the removal of water is at the same time in many cases an adequate means of supplying needed moisture to growing crops in times of drought. Irrigation as such, may be of great assistance in occasional dry seasons in sections of the Willamette valley which are troubled with too much water in the winter time. But in many instances it will be found that drainage alone will prove doubly serviceable in that it will equalize and apportion soil moisture more suitably for the use of plants by carrying away excess when not needed, and by dealing out a carefully hoarded supply as plant growth demands it.

There is no loss of crops from heavy rains. A sufficient number of drains of proper size, accurately laid, will carry off the heaviest rainfall so rapidly as to prevent serious injury to a crop. Water is thus not allowed to accumulate or stand on the land nor does the soil become saturated with and plant roots surrounded by stagnant water. From our familiarity with the water holding capacity of soils, we know that a common soil dry to a depth of three and a half feet can absorb as much as 15 inches of rainfall. An ordinary agricultural soil in good tith drained to the same depth is able to take up at least six inches of rainfall. This means that a drained soil can drink in this amount of water before saturation is reached and without any run-off whatever from its surface. If but two-thirds of this amount of storage is assumed, the soil is still capable of holding four inches of rainfall.

Considering the amount of precipitation in the Willamette valley, it will probably be found necessary to design tile drainage systems to carry at least one-half inch of rain in 24 hours.

This is a point which must be determined by actual measurement, however. In one week, three and one-half inches of water could thus be handled by the tile drains and this with, say, four inches that the soil can contain, makes seven inches and over of combined storage and drainage capacity. This is greater than Oregon conditions demand as between six and seven inches is nearer the average monthly than weekly winter rainfall. These facts are brought out to show that drained farm land constitutes a vast storage reservoir which can take care of as heavy rainfall as ever comes, discharge the excess through submerged tile, yet retain a sufficient amount to supply the requirements of plants throughout all seasons of the average year.

Crops make a much more vigorous growth. This is due to the fact that all the conditions for plant growth are most favor-



Fig. 12. Section of Drained Farm Road.

able, the right amount of air, moisture and heat; extended root range; availability of fertile elements; increased activity of beneficial bacteria. All of these so aid the plant that it makes a maximum growth.

Roads and walks are bettered. The ground in walks and roads is rendered more firm and will support a permanent improvement and sustain travel better. Drainage is an essential pre-requisite to permanent good roads in the Willamette valley. It is necessary that the exceeding importance of this fact be appreciated in the present active campaign for good roads. Perfect drainage of the road-bed must be secured before permanent construction can be made. Proper road drainage in many flat,

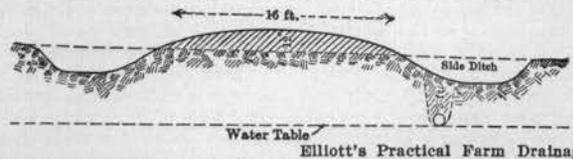


Fig. 13. Section of Public Road With One Underdrain. A Drain at Each Side is Frequently Advisable.

wet sections of the state is not possible until the lands themselves are drained; and land drainage can be largely brought about only

by district organization on account of the low grades and the securing of an adequate outlet. Drainage and good roads are contemporaneous problems in substantial development, the one, however, a necessary pre-requisite to the other.

Sanitary conditions are improved and the attractiveness of farm premises is increased. The removal of stagnant water by drainage lessens the danger of disease and promotes a satisfactory state of dryness around barn yards and farm buildings. Gardens and grounds can likewise be kept in much better shape and the appearance of home surroundings, therefore, improved.

The profits from the land are greatly increased. Drainage makes hitherto waste lands highly productive. It doubles and sometimes trebles the yield per acre on cultivated lands. It lessens the expense of cultivation because crops are no longer drowned out, and there is no waste of time and labor in cultivating irregular fields. From every standpoint the farmer is aided in obtaining larger returns from his labors.

HOW TO SECURE DRAINAGE FOR A DISTRICT.

Most of the states in which there are drainage problems of importance have passed drainage laws that are designed to answer and to equitably control the drainage questions that arise. A summary of Oregon's drainage laws is given herewith.*

PETITION TO ESTABLISH DRAINAGE DISTRICTS.

Whenever twenty-five per cent of the owners of any body of land susceptible of one system of drainage desires to drain the same for the public benefit for sanitary purposes, for the improvement of agriculture or to prevent overflow from flood waters or any possible rise of the level of the sub-surface waters thereof, they may present to the county court of the county in which the lands or the greater portion thereof are situated at a regular term of court a petition praying for the organization of a drainage district. Such petition shall contain a description of the boundaries thereof, the approximate number of acres in the proposed district, the name or number proposed for the same, the names and owners of each tract of land included therein separately owned, and a description of such separately owned tracts, and the names of three persons to serve as trustees for the first year and until their successors are chosen and qualified. Such petition shall also contain a general description of the route and character of the proposed drainage system, and the necessity for such drainage. It must be verified by affidavit of one of the petitioners, and must be published for four weeks next preceding the date designated in the petition for the hearing thereof in some newspaper published in each county in which the lands included in said district are situated, and must be posted for the same length of time on bulletin board in the county court house of

*Water Laws of Oregon, 1913, State Water Board, Salem, Ore.

each such county; and a copy thereof shall be served on each record owner and person in possession of such lands if to be found within the county or counties in which such proposed drainage district may be located.

DISTRICT PARTLY IN DIFFERENT COUNTIES, MANNER OF PROCEEDING.

When a district is situated partly in different counties, the trustees must, after the petition has been granted forward a copy thereof to the county clerk of any county in which any portion of the district may lie, and the court to which the same is forwarded must not allow another district to be formed within such district unless with the consent of the trustees thereof.

APPROVAL OF PETITION BY COUNTY COURT.

Any person owning lands within the district or whose lands are affected by the drainage thereof may appear at the hearing to support or oppose the petition. If a remonstrance against the granting of the petition be filed at the hearing, or at such further time as may be granted by the court, signed by two-thirds of the owners of the property within the district, the petition shall not be granted. If no such remonstrance be filed and the court find that the district is of public utility and importance, and that the benefits to be derived from the proposed drainage will exceed the cost thereof, that no land is improperly included in or excluded from the district, and that the system of drainage in general meets with their approval they shall note their approval upon the petition and cause an order to be entered in the county records approving the same. The court may, however, by order, alter the boundaries of the district or prescribe in general terms a different system of drainage. If such alteration shall affect any lands not affected by the first petition, notice shall be given in like manner to the owners of such land for such time as the county court may prescribe, not less than two weeks, and a hearing shall be had at a subsequent term to be fixed by the court by order. From and after the entering of such order the district is duly formed, and the persons named in the petition or such other persons as the county court may designate in such order are directors for the first year and until their successors are elected and have qualified.

PETITION TO BE RECORDED.

The petition shall then be recorded in the records of the county commissioners' court.

PETITIONERS MAY MAKE BY-LAWS.

After the approval of the petition by the county court the directors shall cause a meeting of the residents of the district to be held, at a convenient time and place, and upon reasonable notice to the owners of lands within the district, for the purpose of adopting such by-laws as they may deem necessary for carrying out the purposes for which the district was organized. Such by-laws shall prescribe the manner of election of trustees, of the acquirement of real and personal property for the purposes of the district, and for the construction, maintenance, and operation of the drainage system. They may also make provisions supplemental to those contained in the law for the assessment and collection of liens upon the lands embraced in the district, for the construction, operation, and maintenance of the drainage system, and for the issuance and sale of bonds secured by the lands within the district to provide money for the purposes thereof. Such by-laws shall not be operative until they are approved by the county court, which approval shall be noted upon a copy thereof to be kept on

the files by the county clerk, and the court shall have power to modify or amend said by-laws by and with the consent of the land owners of the district at a meeting called upon such reasonable notice as may be prescribed in such by-laws.

POWER AND AUTHORITY OF DRAINAGE DISTRICT BOARD.

The board thus formed shall have power to elect one of its number president thereof and to employ engineers to survey, plan, locate and estimate the cost of the works necessary for the drainage of the lands in such drainage district, and such board shall have power to estimate and determine the amount and value of land needed for the right of way for such drainage system; and all lands which may be necessary and convenient as an outlet for such drains and ditches, although no part of the same may be marshy or wet, may be included in the drainage district provided for by this Act; and in all cases where the owner of any lands which may be necessary or convenient for such right of way is unwilling to convey the same to the trustees of such drainage district for the sum estimated by them to be its fair value, the owner of such land shall appoint one disinterested householder, and the trustees of such drainage district one householder, who shall appoint the third householder, and the three so chosen shall arbitrate the amount to be paid for the right of way, and the award of such arbitrators shall be final, and the amount of such award shall be first paid before the right of way shall be appropriated, and if they cannot agree on a reasonable price within ten days from the time the same is submitted to them, then such trustees, in their name and for the use of such drainage district, may maintain an action at law for the appropriation of so much of such land as they may deem necessary for the uses aforesaid before the circuit court of the county where such land is situated in the same manner and with like effect as is provided in Chapter I of Title XLV.

DRAINAGE DISTRICTS MAY BRING ACTION TO CONDEMN LANDS.

All drainage districts organized in the State of Oregon, and those that may be hereafter organized, are hereby authorized in case they cannot agree with the adjacent owners of the land, between their drainage districts and some suitable outlet to a stream or place where the district may be properly drained, to bring an action at law in the circuit court of the proper county, for the purpose of determining the damage of the person, persons, corporation, county, or whomsoever may be the owner of the land sought to be appropriated for the purpose of securing a suitable outlet in order that the district may be properly drained.

ACTIONS TRIED AS OTHER CONDEMNATION PROCEEDINGS.

All such actions may be tried in the same manner and form as like actions are now tried by other corporations authorized to conduct like actions, and the same law shall apply to the practice and method of procedure as the statutes now provide for in the cases last mentioned.

BOARD MUST REPORT TO COUNTY COURT.

The board of trustees must report to the county court of the county or if the district is situated in more than one county, then to the county court of each county in which the district or any portion thereof is situated, the plan of work and the estimates of the cost, together with the estimates of the incidental expense of superintendence, repairs, etc.

COMMISSIONERS TO ASSESS CHARGES AND BENEFITS.

The county court by which the district was formed shall appoint three viewers, disinterested taxpayers of the county in which the district, or some part thereof, is situated and such viewers must view the lands situated

in the district and make upon such lands an assessment of the benefits which they may derive from the work. Such assessment shall be reported to the county court, which shall review and consider the objections to the same at a subsequent term to be fixed by its order, and of which notice shall be given by posting the same on the bulletin board in the county court house in each county embraced in the district, and in such other manner as the county court may prescribe. After such assessments shall have been reviewed and equalized by the county court, if it shall find that the same are just and that the amount produced by the same will be sufficient to carry out the proposed system of drainage, it shall by order cause the sums so assessed to be entered either upon the general assessment roll or a separate roll to be provided for by the court, and thereupon such assessment shall become a lien upon the lands therein described, and shall be collected in like manner as general taxes are collected, or by civil suit or action, as the county court may direct. The court may by order direct that such assessment may be paid by installments, and bonds issued against the same, in the manner provided by Chapter 5 of Title XXVI, Lord's Oregon Laws, being Sections 3245-3253 thereof. The county clerk shall perform the duties devolved upon the auditor, the county judge the duties devolved upon the mayor, and the county treasurer the duties devolved upon the city treasurer by such Act.

WARRANTS TO BE PRESENTED TO COUNTY TREASURER.

The warrants drawn by the trustees must, after they are approved by the county court, be presented to the treasurer of the county, and if not paid on presentation, indorsement must be made thereon, and they must be registered in like manner as county warrants. If a district is situated partly in different counties, the charges must be paid into the treasurer of the county in which the said district was originally created.

ORIGINAL ASSESSMENT INSUFFICIENT, ADDITIONAL ASSESSMENT

If the original assessment is insufficient to provide for the complete drainage of the land of the district, or if further assessments are from time to time required to provide for the protection, maintenance, and repairs of the works, then the trustees must present to the county court by which the district was formed a statement of the work to be done and its estimated cost; and the court must make an order directing the commissioners who made the original assessment, or other commissioners to be named in such order, to assess the amount of such estimated cost as a charge upon the lands in the district, which assessment must be made and collected in the same manner as the original assessment.

LIST OF CHARGES ASSESSED AGAINST EACH TRACT TO BE MADE.

The commissioners appointed by the county court must make a list of the charges assessed against the lands of each district, and the list must contain a description of each tract assessed, the number of acres in each tract, and the names of the owners of the lands in each tract, if known, and if unknown, the amount of charges assessed against each tract.

FILING LIST OF CHARGES, LIEN ON LAND CONSTITUTED.

The list so made must be filed with the county treasurer of the county, or if the district is partly situated in different counties, then the original list must be filed in the county in which such district was originally created, and copies thereof, certified by the commissioners, must be filed with the treasurer of each of the other counties. From and after the filing of the list, or certified copies thereof, the charges assessed upon any tract of land in said drainage district constitutes a lien upon said tract of land

in the county in which said drainage district, or portion thereof, is situated. The list thus prepared must remain in the office of the county treasurer thirty days, or longer if ordered by the board of trustees, and the board of trustees may extend the time of the payment of the charges assessed against the tracts of land in said drainage district from time to time to conveniently meet the expenses incurred in constructing said drainage system, or keeping the same in repair, and during the time the list so remains, any person may pay the amount of the charges against any tract to the treasurer, without costs, or if so ordered by the trustees, said payments may be made by installments, and the time of paying said installments may be extended from time to time as hereinbefore provided; and if, at the end of thirty days, or of any longer period fixed by the trustees, all of the charges, or all of any of the installments ordered by them, have not been paid, the treasurer, when ordered by the board of trustees, shall return the list, having designated thereon the various tracts, against which there remains unpaid charges, the amount of charges unpaid and the names of the owners thereof, to the district attorney of the county, in which said drainage district is situated, who shall at once proceed by suits in equity to foreclose the liens against the various tracts of land on which there are unpaid charges. The suits to foreclose said liens shall be commenced in the name of the drainage district, the complaints shall be verified by the president, or in his absence by the secretary of the board of trustees, and the procedure shall be the same as in the foreclosure of mortgage liens against real property. At the sale of said tracts the drainage district shall have the right to bid thereat a sum or sums not to exceed the lien charges and costs of foreclosure and sale against any particular tract. The tracts thus sold shall be subject to redemption within the time, manner and provisions of law governing the redemption of real estate sold on execution. In the event any of the tracts sold shall be purchased by the drainage district, and shall not be redeemed as herein provided, then the drainage district may sell and convey said unredeemed tracts, in the name of the drainage district, by order of its board of trustees using the ordinary scroll seal for its signature. Upon the sale of any tract, or tracts, if there be any overplus, after paying all assessments, charges and costs of foreclosure and sale, the overplus shall be deposited with the county treasurer, to be paid by him by order of the court, to the party or parties entitled to the same.

WORK DONE UNDER DIRECTION OF BOARD.

The work must be executed under the direction and in the manner prescribed by the board of trustees.

BOARD MUST KEEP ACCOUNTS.

The board must keep accurate accounts of all expenditures, which accounts and all contracts that may be made by them are open to the inspection of the county court and every person interested.

TRUSTEES MAY ACQUIRE PROPERTY.

The trustees may acquire by purchase, all property necessary to carry out and maintain the system of drainage provided for.

OWNERS MAY DRAIN ON THEIR OWN RESPONSIBILITY, WHEN.

Whenever any district susceptible of one mode of drainage, entirely owned by parties who desire to drain the same, and to manage such drainage without the intervention of trustees or the establishment of by-laws, they may file the petition provided for in preceding Sections, and must state therein that they intend to undertake such drainage on their own responsibility. If the petition is granted the owners of the land have all the

rights, immunities and privileges granted to the boards of trustees, and in all proceedings the names of the owners may be used instead of the names of the trustees.

PENALTY FOR INJURING OR REFUSING TO KEEP DRAIN OPEN.

If any person or persons shall wilfully fill up, injure, or destroy any drain constructed as herein required, or wilfully prevent or delay the construction of any drain in the manner provided in this Act, or shall neglect or refuse to keep the same open, as required by this Act, such person or persons shall be deemed guilty of a misdemeanor, and on conviction thereof, for the first offense shall be fined, in a sum not less than \$25 nor more than \$100; and for the second offense shall be fined in a sum not less than \$50 nor more than \$200; and for each subsequent offense shall be confined in the county jail for not less than thirty days nor more than one year.

A special set of regulations governing the establishment of drainage districts in Washington county is provided in the Oregon law. They differ in some respects from the drainage laws given which apply to other portions of the state.

RESUME OF DRAINAGE LAWS

No attempt will be made to discuss these laws in their entirety. For the purpose of indicating the method of procedure in the establishment of a drainage district, by which means doubtless much of the Willamette valley drainage will necessarily be accomplished, the essential steps will be pointed out.

a. Twenty-five per cent or over, (in number, not acreage) of the land owners in a drainage system must apply to the County Court for the organization of a district. The petition must give a description of each separately owned tract, its acreage and ownership, boundaries and general character of the proposed drainage system, and name three persons to serve as trustees for the first year.

b. The County Court, at a regular term, will consider, grant or disapprove the petition unless a remonstrance be presented signed by two-thirds of the property owners in the district. The court may alter the boundaries or prescribe a different drainage system.

c. After approval of the petition by the court the trustees shall by due notice call a meeting of all residents of the district to adopt a by-laws. The by-laws will define the method of electing the board of trustees and of administering the business of the district, and must be approved by the County Court.

d. The drainage board shall have power to employ engineers, determine cost of the work, the land affected, and to adjust dam-

ages and benefits to land required for outlet right-of-way. The drainage district may condemn rights-of-way across property outside of the district.

e. The board of trustees must report for approval the plan of the work and cost estimates to the County Court.

f. The County Court shall appoint three disinterested taxpayers, living in the same county but outside of the proposed district, as viewers, to assess the benefits upon each piece of land within the proposed district and to report to the County Court. The court will review, hear objections and equalize such assessments and cause such sums to be entered upon general or a special assessment roll, which amounts become a lien upon the lands and shall be collected as are general taxes.

g. The court may direct that assessments may be paid by installments, and bonds issued against the same. Otherwise a certified list of assessments must be filed in the office of the county treasurer, where the list must remain for 30 days, or longer if ordered by the board of trustees, during which time any person may pay the amount of the charges against his land. The board of trustees may determine and extend the time of payment of assessments to meet the expenses of carrying on the work. If payments are not made as directed by the board the district attorney of the county will be authorized to proceed by suits in equity to foreclose liens against tracts on which there are unpaid charges.

h. Private parties may petition the County Court as provided in a to undertake drainage on their own responsibility.

PURPOSE OF THE LAWS

A review of the Oregon drainage laws will show that it is their intent merely to provide an opportunity for drainage to any section of the state desiring it. Drainage districts are organized for the purpose of rendering available an outlet for the drainage of every farm within the district, and in order that farmers may co-operate to secure adequate drainage. The engineering and construction work and maintenance referred to in the law, plainly cover only the building of mains and such lateral ditches or tile lines as will enable each tract or group of tracts in the district to drain into them. An opportunity for

drainage is thus provided, as is the apparent intent of the law, but the actual drainage of individual farms constitutes a set of problems by itself to be solved by each owner when he is ready to take advantage of the opportunity opened to him. Unforeseen legal questions will arise at all steps in the process of district organization and in the application of the drainage laws, whose interpretation and solution will require the counsel of a competent attorney, and which can be solved in no other way.

To date there has been, so far as the writer is aware, but one drainage district organization effected under the present laws in the Willamette valley section of the state. This district covers over 1,000 acres in Louisignout lake, in Washington county. A number of other district projects are in process of organization. Sufficient progress has been made in several instances to disclose some questions for which the law appears to make no specific provision. One question that seems not to be covered by the law in a satisfactory way is that of the payment of preliminary expenses incurred before the formal organization of the drainage district is effected, and before it is legally capable of transacting business as a corporation. In some of the other drainage states, clauses in the law provide that such expenses are to be met by special assessment, and in others they become a lien upon the property within the district and are collected the same as or a part of, the regular taxes and assessments made after the district is formed. The Missouri drainage statute, adopted in 1913, and referred to as perhaps the most equitable and satisfactory set of drainage laws in the United States, stipulates that "The board of supervisors of any drainage district. . shall, as soon as elected and qualified, levy a uniform tax of not more than 50 cents per acre upon each acre of land within such district. ., to be used for the purpose of paying **expenses incurred** or to be incurred in organizing said district," etc.

The more complete drainage statutes of other states have been evolved through years of experience in their application. Shortcomings have been corrected and desirable provisions added by successive legislatures, as will doubtless be the case with the Oregon laws as attempts to apply them show wherein they are lacking.

DESIGN AND CONSTRUCTION OF DRAINAGE SYSTEMS**THE OUTLET**

In the design of a drainage system the outlet is first to be determined. In some cases natural depressions or stream channels may be taken advantage of. But where there are few streams and the slope of the country is slight, it will more often be necessary to construct a ditch whose course may lie in part outside of the district to be drained in order to secure the required fall. Ditch laterals, too, will constitute an essential part of the system.

The size of the outlet ditch must be proportioned to the amount of water it is to pass and to the grade. The water that will drain into it can be gotten at only by measurement of the amount of run-off from the area to be drained. Drainage engineers now employ a "drainage coefficient," to express the run-off from a region, which is the depth of water in inches that must be removed in 24 hours. This factor can be determined by stream gagings of the entire flow from a watershed in its relation to precipitation. Or, where drainage systems have been installed, can be more directly gotten at by actual measurements of the flow from drain tiles or in ditches. Until such data are actually collected for the drainage areas in the Willamette valley, the proportioning of the outlet to the work it is expected to do will be left entirely to the judgment and experience of the engineer. In older drainage countries it is found that until definite figures for run-off were secured, no two systems in the same region were designed alike. As a result, some systems had capacity greater than necessary, while others were too small; difficulties which should, if possible, be avoided in Willamette valley drainage installations.

The controlling factors in the building of a ditch are the capacity required, the nature of the ground and the grade to which it is to be dug. A ditch will be more efficient the higher ratio between volume of flow and "wetted perimeter" can be made. That is, within well known limits, the deeper the water in relation to the width of its surface the better. The half circle would be the limit in this direction. Friction between the moving water and the sides and bottom tends to retard flow and the more the water is spread out, that is, the shallower the stream, the greater this frictional retardation will be. The cross section

of the ditch should be as deep and as narrow as the grade and character of the ground will allow, and the slope of its banks such that they will not cave nor yet be so flat as to especially favor the growth of weeds, etc., above water level or on the sides

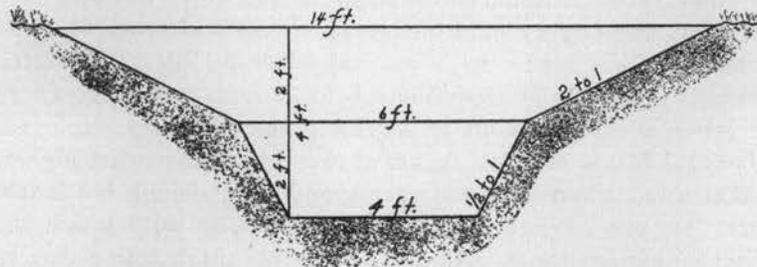


Fig. 14. Cross-Section of Ditch with Upper Side Slopes Less Steep.

in low water times. These are considerations which affect the economy and ease of maintenance as well as the flow of water.

Elliott* states that "ditches as deep as four feet should ordinarily have side slopes of one foot horizontal to one foot vertical and a bottom width of three feet. They can be made by teams with plows and drag scrapers by using runways for the teams when the bottom half of the ditch is excavated. A form requiring the removal of more earth, but one more easily kept in order is that having slopes two to one for the upper two or two and a half feet of depth, and one-half to one for the lower part" as shown in Figure 14.

For the larger ditches a side slope of one to one is very commonly employed. If the nature of the material is known, it is regarded as good practice to excavate the ditch to a width enough larger than required so as to allow the sides to cave and to establish their own position of stability. Excavation of small ditches is done by hand and with teams, plow and scraper. For ditches of larger size, ditching machines are used. The floating, the combined floating and walking, and the traction dipper dredges are types of these. The drag-line excavator and the hydraulic dredge are employed on the larger projects. Each has to be adapted to the particular job in hand.

The cost of digging ditches will vary largely with the char-

*"Practical Farm Drainage." Page 24.

acter of the materials to be excavated. By the hand and team method the work is more expensive than by machines, where it is possible to use the latter. To handle such earth as clay, silt, soil, sand and gravel, contracts are usually let at so much per cubic yard. In some states small ditches, those not over five feet deep, are dug by hand and team at costs of from 10 to 15 cents per cubic yard. In Iowa and other middle states ditch contracts are made at from about 6 to 10 cents per yard, where the grade is low, the country level and the dredge is employed. Labor and fuel in our own region at present are somewhat higher, so that ditches here will cost correspondingly, though not much, more. On one project in the Willamette valley with which the writer is familiar the excavation of a 20-foot ditch with a dredge through rather difficult ground, cost about 17 cents per yard. Contractors state that 10 cents per yard is an average price for ditch work on large projects.

DRAINAGE OF INDIVIDUAL FARMS

While, doubtless, most of the drainage in the Willamette valley will be accomplished in large units by the organization of drainage districts, some drainage has been and will be done independently on individual farms. This is possible only where a suitable outlet is available. At times it will be necessary for two or more neighbors to co-operate in order to secure fall and an outlet for their drainage; which is, after all, only the application of the drainage district plan on a lesser scale.

In a much larger number of instances, though, and we hear of many of them, farmers are prevented from draining by the disinterest of those whose land lies next to them; not because they have not a legal right to a right of way across any land to an outlet, but because of the prohibitive expense of securing that right of way. Where natural streams, creeks or gulches are available, these may serve as outlets in the same way as do artificially dug ditches. In any case the layout and installation of the individual drainage system constitutes a problem which must be worked out for each farm. The essential steps in its solution are: A preliminary view of the area to determine the general location of the drains; taking levels for the establishment of grades; determining upon the position of mains and laterals;

construction of the drains, including trenching, laying the tile and filling.

Mr. C. G. Elliott, in "Practical Farm Drainage," says:

"The observing farmer or cultivator who has acquainted himself with his fields during his labors upon them through successive seasons will have noted the location of parts on which an excess of water at certain times occasioned a partial or total failure of crops. He also will have marked the direction taken by surface water after the ground was saturated in a heavy rainfall, as well as the points at which overflow from low places, ponds and swales occurred. Knowledge of this nature is of first importance in the location of a system of drains that shall relieve his lands of all excess of water.

"If in addition he has looked below the surface and observed whether the soil structure is characterized by parallel layers or is close and compact, if he has dug post holes or pits when the ground was wet, and has noted the freeness with which water oozed and trickled from the sides, and how quickly it filled the hole; if he has been still more observant and noticed whether the water spouted from little crevices or formed on the walls of the hole in an almost imperceptible film, and whether the walls began to slough off as the water increased or remained smooth and intact; if he has sunk the hole still deeper and ascertained whether there is sand, gravel or hard clay at a depth of from five to seven feet; if in short, he has become familiar through his field operations with the composition, structure, texture and drainage properties of the soil and subsoil of his land, he has acquired data of utmost value as a preliminary to the proper placing of his drains.

"When about to begin actual work in this direction he must supplement this general knowledge, which has been accumulating year by year, with more exact information, gained by a detailed examination of the area under consideration, having the precise location of the drains definitely in view. Here he should bear in mind that what may seem commonplace and trivial matters are often important determinants in the establishment of a drainage system.

PRELIMINARY LEVELING

"In this final study of the fields, a level, either in the hands

of the farmer or of an engineer accompanying him, will always be of great assistance, and is often absolutely necessary. While occasionally the slopes are well marked and the best location of the lines quite apparent to the eye, thus making the use of the level at this stage seemingly superfluous, it is much more frequently the case, so deceptive are slopes and distances, that grave errors of eye or judgment are quite possible, and should be avoided by taking accurate observations with the level. There should be a sufficient number of such levels taken to indicate the height of the principal depressions and elevations in the tract of land under surveillance, that by a comparison of these, the outlet point, the watershed, and the direction of main and important minor slopes may be ascertained.

“In addition to keeping the necessary level notes during this part of the work, a preliminary level sketch should be made to accompany them. This should be constructed on the field by the proper notations at each station as the work progresses. It should show when completed the approximate location of the stations, with the elevation of each, the direction of the slopes, indicated by arrows, and the course of any natural water channel which may be made the outlet or any part of the drainage system.

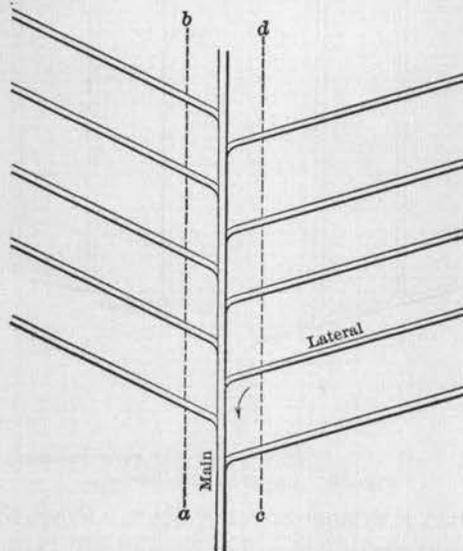
LOCATING THE DRAINS

“The engineer, or farmer, if the latter is undertaking the work alone, is now ready to locate his drains; to determine from the facts secured where the lines shall be laid most effectively and economically to do the work desired. At this point, in addition to the use of the knowledge acquired relative to the situation, the exercise of discretion and good judgment is imperative. Previous experience is, of course, a valuable aid here, but thought and painstaking in the application of the data secured will, in a great measure, compensate for its lack. Too much emphasis cannot, however, be placed upon the need of guarding against errors in location which shall either impair the efficiency of the drains or add unnecessarily to their cost. Though it may be the intention to construct at first only a part of the drains necessary for the thorough drainage of the field, the entire system should be decided upon at this time and recorded, so that to the work now done other portions can be added later, and when all

are finished a complete, well-arranged drainage system will be in operation.

ARRANGEMENT OF DRAINS

“While the location of drains must necessarily depend largely upon the contour of the field, there are certain recognized systems of arrangement which are more or less closely followed by



Elliott's Practical Farm Drainage

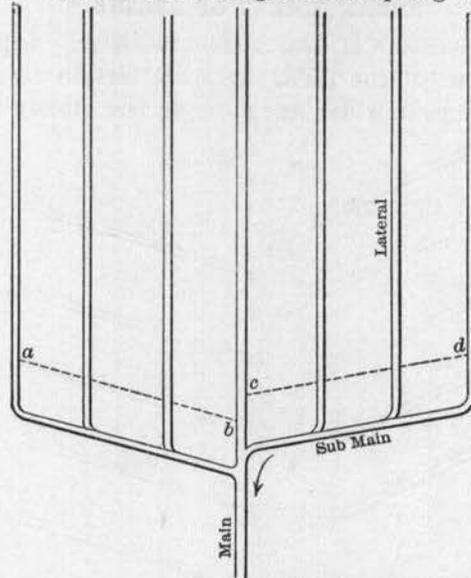
Fig. 15. The Herring-Bone System of Laying Out a Tile Drainage System.

drainage engineers. The herring-bone system (Fig. 15), or a modification of it, is well suited to ponds or basins which have a considerable slope toward the center, by reason of which surface water sometimes accumulates rapidly in the lowest ground, and its removal is hastened by the action of the large number of drains there. The plan also meets the conditions where it is necessary to extend some of the branches farther than others to reach spots that should be drained. While an efficient system, it is not an economical one except in the locations just mentioned, for the reason that the portion of the branch drains between *a-b* and *c-d* (Fig. 15) are unnecessary, that strip of land being drained by the main ditch.

“The gridiron system (Fig. 16) is adapted to level land where there is no concentration of surface water, and where all of the

soil within range of the lines appears to require equal drainage.

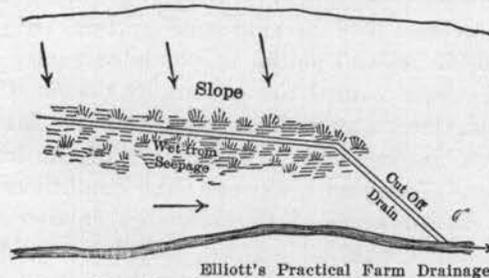
“There are cases where a single intercepting line may be of



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Fig. 16. The Gridiron System.

more service than a system of many lines. From the office performed, this arrangement is called the cut-off system (Fig. 17), and is employed where it is necessary to protect a strip of land



Elliott's Practical Farm Drainage

Fig. 17. The Cut-Off System.

from saturation produced by water oozing from a slope or higher level. The depth of the drain in this system is an important consideration, for if it does not reach the plane of the water-bearing stratum, the water which produces the boggy or spouty condition will not be intercepted. . . .

"Across-the-slope system has come to have a recognized place. Slopes do not usually lie as a plain, with only one definite inclination of the surface, but either upon the surface or in the sub-soil they are broken by slight valleys which concentrate drainage water in a small measure, suggesting the running of drains down instead of across the slope, and this method is the one generally practiced. Close observation of old drainage systems, however, shows that in some instances this plan may be profitably modified by placing the lateral drains either diagonally to or nearly across the slope. The occasion for the adoption of such a plan is furnished when the slope is a plain, devoid of the corrugations or draws before alluded to, to such an extent that water in its natural course will pass in straight lines directly down the slope instead of being deflected laterally into little valleys. . . .

"Often it is advisable to use two, or even more, systems or modifications of them in the drainage scheme of one field or tract of land. Sometimes, also, in place of sub-mains it is expedient to have two or more drains discharging into the outlet stream or ditch. It is, however, desirable to have as few such tile outlets as is consistent with the system or systems employed, as they must be protected and kept in order for all time. The plan of

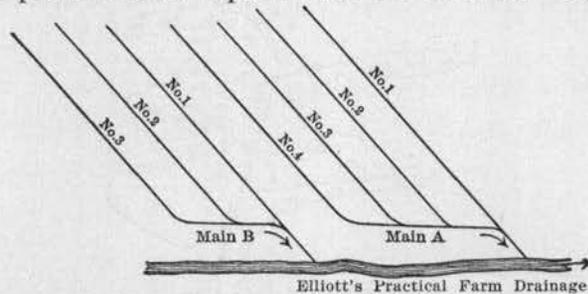
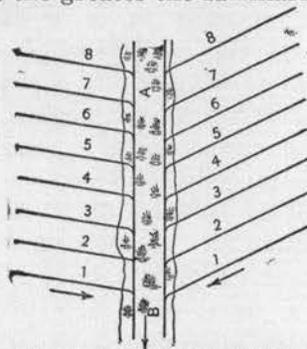


Fig. 18. Modified Gridiron System.

a modified gridiron system, shown in Fig. 18, reduces the number of exposed outlets to a minimum and requires no additional cost but that of the necessarily increased size of the pipe for the main.

"When long parallel lines can be employed, the cost of drainage of land directly affected is less than where short lines must be used. Natural conditions of soil and surface are, however, controlling factors in the arrangement of drains, in whose results

efficiency holds first, and economy second place, and it will readily be seen that the greater the familiarity of the land owner

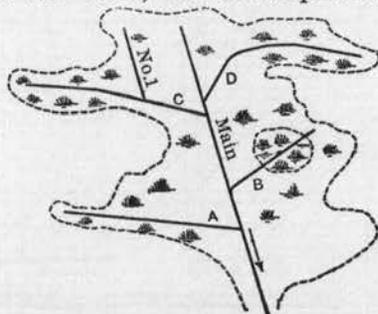


Elliott's Eng. for Land Drainage

Fig. 19. Method of Draining a Broad, Flat Slough by Placing a Main on Either Side.

with the surface and peculiarities of his fields, the better able will he be to determine what method is best adapted to meet the requirements.

“As the most practical method of offering helpful suggestions for this part of the work, the development of” a drainage

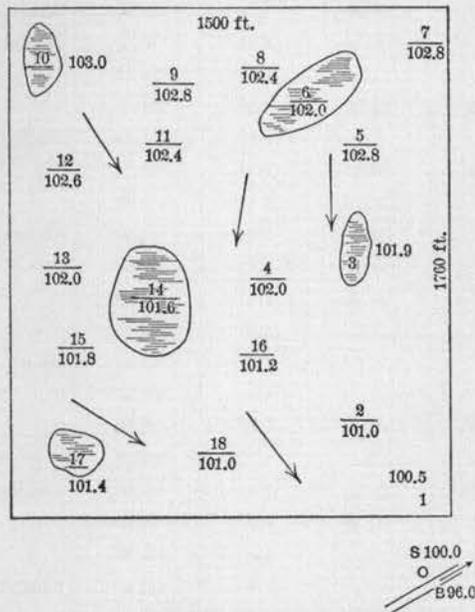


Elliott's Eng. for Land Drainage

Fig. 20. The “Natural” System of Draining Ponds and Rolling Land.

plan for a field is given as an example. This field “consists of sixty-one acres which is seemingly quite nearly level. A small creek, three hundred feet distant from the field line, and on the land of a neighbor, is the only outlet available. Beginning at the point o, on the bank of the creek (Fig. 21), assume for it an elevation of 100. Find the elevation of the bottom of the creek, which latter point will control the location of the outlet for the field. Select points upon the field as shown on the sketch map

(Fig. 21) and record their elevations in the notes. The level notes to accompany this sketch will appear as shown on page 50. The station numbers and accompanying elevations in the notes cor-



Elliott's Practical Farm Drainage

Fig. 21. Sketch Map of Field to be Drained.

respond with those upon the map. A small stake should be set at each point where a level is taken and numbered to agree with the station recorded in the notes. From the numbers in the column headed Elev. can be computed the height of all the points indicated, above the bottom of the creek. It will be noted that the circuit is made and the levels closed upon station No. 1, so as to prove the accuracy of the levels.

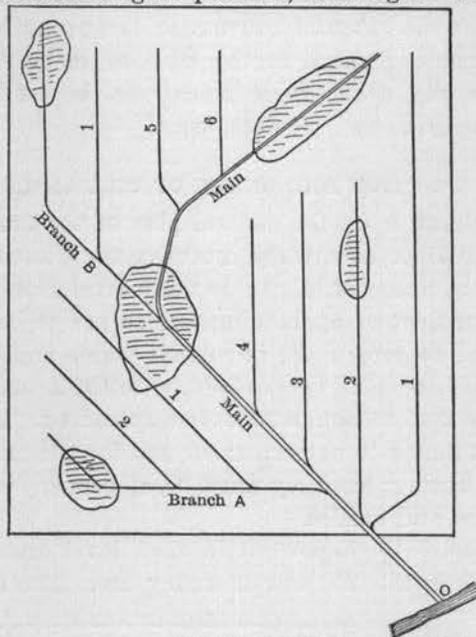
“The sketch map places the facts which have a bearing upon the location before the eye in a collective form so that the topography of the entire field can be seen at a glance. If the knolls and slopes were more pronounced, the levels taken would be confined to the lower sections of the field. Having before him, then, this map, which is on a page of the level note-book and need not be copied unless it is desired to use it for some other purpose, the farmer or engineer can indicate the plan of draining by

PRELIMINARY LEVELS AS SHOWN ON SKETCH MAP, FIGURE 21.

Sta.	B. S.	H. I.	F. S.	Elev.	Remarks
O	4.20	104.20	....	100.00	Bank of creek.
B	....	.....	8.20	96.00	Bottom of creek.
1	....	.....	3.70	100.50	
2	3.60	104.60	3.20	101.00	
3	....	.....	2.70	101.90	Shallow pond.
4	5.23	107.23	2.60	102.00	
5	....	.....	4.43	102.80	
6	5.42	107.42	5.23	102.00	Shallow pond.
7	....	.....	4.62	102.80	
8	4.30	106.70	5.02	102.40	
9	....	.....	3.90	102.87	
10	....	.....	3.70	103.00	Pond.
11	....	.....	4.30	102.40	
12	5.10	107.70	4.10	102.60	
13	....	.....	5.70	102.00	
14	....	.....	6.10	101.60	Flat pond.
15	4.80	106.60	5.90	101.80	
16	....	.....	5.40	101.20	
17	....	.....	5.20	101.40	Small flat.
18	5.10	106.10	5.60	101.00	
1	....	.....	5.50	100.60	Check on Sta. 1 (Error, .10 Ft.)

sketching in the lines approximately, if he chooses, but the better method is to locate them upon the ground. Fig. 22 represents the plan which is made in accordance with the conditions ascertained by the survey. The creek is four feet deep, which will permit the outlet of the drain to be three or three and one-half feet below the surface of the bank. One of the principles of drainage is that in general mains should follow the lowest ground, and pass through the natural depressions. This principle should be applied here. There will be but one outlet. The main extends from the point o to point 14, and thence to point 6 (Fig. 22), all of these being lower than the surrounding land. There are other depressions shown, and the question arises whether it is now desirable to lay out a system which will secure uniform drainage,

or place drains in the low lands only. In case the latter is decided upon, drains would be laid through points 3, 10 and 17 (Fig. 21) and drain No. 2 and branches A and B (Fig. 22) would accomplish the purpose. The more complete system would consist of parallel lines as long as possible, running in the direction of



Elliott's Practical Farm Drainage

Fig. 22. Location of Drains on Field Shown in Fig. 21.

the slope, as represented in Fig. 22. Branch No. 5 is joined to the main as shown, in order to shorten the line and lessen the acuteness of the angle which it makes with the main. The angles at which most of the laterals join the main are necessarily sharper than is desirable. The lines can be staked out as represented with the assurance that the fall on each, though slight, will be sufficient. Whatever the distance between the drains, the plans as to location of the main and the direction of the laterals will remain the same.

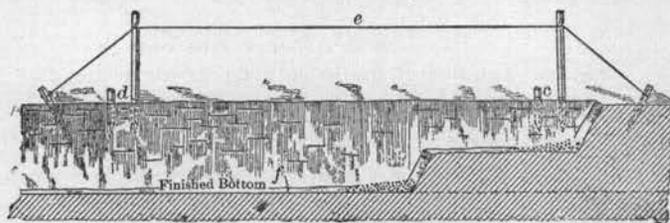
“The outlet and three hundred feet of the main being on the land of another owner, it will become necessary for the respective owners to enter into some agreement mutually satisfactory, regarding the right of way for the drain and its cost. . . .

“In working out the plans upon the ground the course is walked over and guide poles set at each important point as it is decided upon, as the outlet, changes of direction, entrance of branches, etc. This is equally necessary when the proposed system has first been outlined in pencil on the preliminary sketch, as some prefer to do. Actual canvass of the proposed course may suggest desirable changes in the plan as mentally determined upon, and in any event guide poles must be set by which the staking of the drain shall be done later.”

POSITION AND GRADE OF TILE LINES

After deciding upon the general plan of the drainage system, the next step is to accurately establish the position and grade of the different lines of tile. To do this a level should be used and careful record kept of all readings which are to be platted on a map and used to profile the important mains and laterals. The importance of care in all details leading to the actual construction of a drainage system cannot be over-emphasized. Drainage is an improvement that is to be permanent and the tile must themselves not only be lasting, but they must be of proper size and laid to correct depths and grades.

This is especially important in such level areas as much of the wet lands in the Willamette valley are. The farmer cannot



Elliott's Eng. for Land Drainage

Fig. 23. Use of the Guide Line in Digging the Trench.

and should not try to put in his lines of tile by eye. More reliance may be placed in personal judgment when slopes are steeper, but even then the additional cost of laying out and constantly checking up with the level will always be more than justified. In this general treatise the details of procedure in doing the necessary instrument work for drainage lines will not be gone into. It can be done by any one who understands the use of the engineer's

level. The main steps only will be indicated. Complete statements of the methods to be pursued may be found in C. G. Elliott's works already referred to and in other drainage publications.

Leveling is begun at the lowest place on the farm, that is, where the proposed outlet is to be, and lines run and measured for each main, sub-main and lateral. Stakes are set on which is marked distance from outlet and elevation measured from some assumed datum plane. From these figures the grade is established which the workman follows in digging the trench. Each branch is carefully run out in the same manner. A branch drain should join the main somewhat above the grade line of the main, the amount varying with the size of the tile. The proper distance above is about one-half the diameter of the main tile. This is known as the "drop" and guards against the clogging of the laterals and avoids backing up of water from the main when it is running filled.

On the adjustment of grades, Elliott* says, "There are three elements which will control in the adjustment of grades: the minimum gradient which may be used, the general depth which it is desired to have, and points where gradients should change if more than one gradient on a line is used. The least grade allowable is measured largely by the accuracy with which the construction work will be done, since tile drains will operate successfully and be permanent, in clay or other firm soils, if accurately laid on a grade, however slight. Grades of .04 feet or approximately $\frac{1}{2}$ inch in 100 feet, are as light as can be made in practice. If the soil is soft, full of fine silt or sand which will enter the drains, more grade should be given the line, especially for the drains of smaller size, as a greater velocity of flow will be required to free them from silt which enters. A grade of $\frac{1}{2}$ inch to $2\frac{1}{2}$ inches to 100 feet may be regarded as the minimum.

"Where the ground does not have uniform slopes it is necessary to change grades at various points. Some practice is required before the amateur can do this with dispatch and precision. The subject of proper depth of drains . . . enters into this matter. The surface elevations will indicate to the eye the profile of the ground. These figures may show a gradual rise

*Practical Farm Drainage, pp. 72 and 74.

for a distance and then drop back into a pond, or continue level for some rods. This condition will require that a deeper cut be made through the higher ground than at any other place, and it may be wise to change the grade just below the rise to avoid unnecessary cutting.

"It is frequently asserted that the grade of a drain should increase as the outlet is approached. This is desirable, but is impracticable in farm drainage, except where natural slopes make it permissible. We must make the best adjustment possible consistent with efficiency and economy. Lack of grade may sometimes be offset by additional size of drain in order that the relative efficiency of the different parts of the drain be maintained. It is desirable that a little additional grade be given at the bends, unless they are long. A careful arrangement of the grades of drains is of great value, and is one of the advantages to be derived from a survey, the best tile drain for the least digging being obtained. Definite points for securing accurate construction are also fixed, and it is known from the beginning how the drainage of the field can be best effected."

DISTANCE BETWEEN AND DEPTH OF TILE

Attention has been called to the effect of drain tile on the position of the ground water level. Underdrains first take the water from the land directly over them, and the water table here first descends to the level of the tile. Each way from the tile the ground is dried according to the ease with which water can pass through the soil layers. A clay soil resists the passage of water more than the silts, and much more than the sandy soils. Naturally, therefore, water will be able to make its way a greater distance laterally to a drain through an open textured soil than through the clay types of soil. Reference to Fig. 9 will recall the relation of drains to ground water.

The character of the soil thus determines largely the distance between drains. The depth to which the tile are placed also influences the distance apart. As a very general rule, the deeper the tile the farther apart they may be and still provide adequate drainage. This is only true, however, when the soil is fairly uniform in character at different depths and when it is sufficiently open to allow the water to freely pass to considerable depths.

The depths of drains will more often be adjusted according to the relation between soil and subsoil layers. It is frequently the case, as has been pointed out for Willamette valley lands, that less porous clay subsoil strata occur at varying distances beneath the surface soil. At times, a permeable bed of sand, sandy subsoil or joint clay comes in at moderate depth which the water can reach, but this is the exception. The drains should be placed at the line between the impervious bed and the more porous soil in the first case, if this line is not closer to the surface than two and a half feet; while with a more porous bed below, the tile may go three, four, or even more feet down.

In judging the drainage propensities of a soil, what appears to be an impermeable subsoil may prove to possess a structure such that when it dries water can readily pass through it. The finer grained clays sometimes shrink in drying to such an extent that the stratum will separate into small blocks by cracking and opening of joints, akin to the action of the "joint" clays. Definite knowledge as to thickness and character of soil and subsoil and of the rooting habits of the crops to be grown are therefore necessary in order to correctly place the lines of drain tile. This can be obtained only through careful experiment, observation and experience.

Some drainage has been done in the valley on the different types of soils. It has proved necessary to place the tile as near as 35 or 40 feet, with a depth for the laterals of from 30 inches to four feet on the "white lands"; while for the more open soils, the clay and silt loams, spacings of from the figures given up to 100 feet or over have been found to give satisfactory results. The depth of mains will be somewhat greater than that of the laterals, but should, of course, be regulated by the lateral system. While these general figures are quoted as our best knowledge at the present time, it does not necessarily follow that future experience will not modify them. In fact, it is to be expected that correct data on depth and distance for different soils will come only as a result of drainage experience in this region.

SIZE OF DRAINS

Since the purpose of drains is to remove the surplus water from the soil before injury to crops results, they must be propor-

tioned so as to carry away this excess during periods of greatest rainfall. Unless they do this they fail to accomplish what they are designed to do. This means that the size of tile must be such that their capacity will not be overtaxed during even the heaviest and most continuous winter rainfall, unusual storms excepted. The speed with which water should be removed by drains depends upon the length of time the soil may remain saturated without detriment to it or to crops growing upon it. Its removal is regulated by the storage capacity of the soil. As a rule, for ordinary crops water should not show above ground for longer than 36 hours after a rain and, to be safe, a drainage system should be designed to effect its disappearance in 24 hours.

The mains should, therefore, be of such size as to pass all of the water collected by the laterals and their size should be correctly proportioned to the amount of rainfall and the area and slope of the land. It has been previously pointed out that the correctly designed system must be based upon accurately made observations of actual flow from tile in the particular region. In the absence of such data, judgment and experience must be relied upon. In most sections of the country where the annual rainfall is 35 to 45 inches drains are designed to remove one-fourth inch in depth of water in 24 hours. Experience in some of the middle states, however, whose average rainfall is below the lower figure given, tends to indicate the desirability of assuming a larger daily runoff than one-quarter inch.

With an annual rainfall in the Willamette valley of from 40 to 50 inches, and a comparatively uneven distribution through the year, it seems best to design drainage systems capable of removing as much as one-half inch of water in one day. Experience may show, when data on this point are to be had, that for some localities, less than this will suffice, while in others a still larger removal will have to be provided for.

In the determination of the proper sizes of mains to serve known acreages engineers make use of formulae that involve a knowledge of the grade, head of water and velocity of flow, and the length of the drain to the outlet, besides the openness of the soil to the circulation of water through it. In the following table is shown the number of acres mains of different diameter will drain. A 1,000-foot main is assumed in making these computa-

tions, also that one-half inch of water is to be removed in 24 hours.

NUMBER OF ACRES DRAINED BY TILE, REMOVING ONE-HALF INCH RAINFALL IN 24 HRS.

Diameter of Tile Inches	Grade Per 100 Feet in Decimals of a Foot and Approximately in Inches.													
	0.03	0.04	0.05	0.08	0.10	0.12	0.16	0.20	0.25	0.30	0.40	0.50	0.75	1.00
	$\frac{3}{8}$ In.	$\frac{1}{2}$ In.	$\frac{5}{8}$ In.	1 In.	1 $\frac{1}{8}$ In.	1 $\frac{1}{4}$ In.	2 In.	2 $\frac{1}{2}$ In.	3 In.	3 $\frac{1}{2}$ In.	4 $\frac{1}{2}$ In.	6 In.	9 In.	12 In.
Acres of Land Drained														
4	2.0	2.3	2.6	3.2	3.6	4.0	4.6	5.1	5.7	6.3	7.3	8.1	9.9	11.5
5	3.5	4.0	4.4	5.6	6.3	7.0	7.9	8.9	9.9	10.8	12.5	14.0	17.2	19.8
6	5.4	6.2	7.0	8.8	9.9	10.8	12.5	14.0	15.6	17.1	19.8	22.1	27.1	31.2
7	8.0	9.2	10.3	13.0	14.5	15.9	18.3	20.5	22.9	25.1	29.0	32.3	39.8	45.9
8	11.1	12.8	14.4	18.2	20.3	22.3	25.7	28.7	32.1	35.2	40.6	45.3	55.5	64.0
9	14.9	17.1	19.2	24.2	27.1	29.7	34.3	38.3	42.8	46.9	54.2	60.5	74.2	85.6
10	19.4	22.4	25.1	31.7	35.4	38.8	44.8	50.1	56.0	61.3	70.8	79.2	96.8	112.0
12	30.3	35.0	39.1	49.4	55.3	60.6	69.9	78.2	87.4	95.7	110.6	123.4	151.2	174.8

The size of laterals depends upon their length and grade. Three and even two-inch tile were formerly much used, but in most places and especially where grades are low, tile less than four inches are not recommended. Larger than this are better, rather than smaller. In long laterals of uniform grade the size may be decreased up grade. Their size is to be estimated by the acreage and nature of the land to be drained and no attempt should be made to have the capacity of mains and sub-mains equal

LIMIT OF SIZE OF TILE TO GRADE AND LENGTH.

Size of Tile in Inches	Minimum Grade in Feet per 100 Feet	Limit of Length in Feet
3	.10	800
4	.06	1,600
5	.06	2,000
6	.06	2,500
7	.06	2,800
8	.05	3,000
9	.05	3,500
10	.05	4,000
11	.04	4,500
12	.04	5,000

to the combined capacity of the laterals. The table, taken from "Engineering for Land Drainage," by C. G. Elliott, indicates the advisable lengths of laterals of different sizes and grades.

Of ordinary drain tile, uniformly spaced, the following lengths will be required per acre for the laterals.

	20 feet apart, 2,178 feet per acre.			
25	"	"	1,742	" " "
30	"	"	1,452	" " "
33	"	"	1,320	" " "
40	"	"	1,089	" " "
50	"	"	872	" " "
66	"	"	660	" " "
80	"	"	545	" " "
100	"	"	436	" " "
150	"	"	291	" " "
200	"	"	218	" " "

THE TILE FOR DRAINAGE.

CLAY TILE.

It has already been mentioned that both clay and concrete tile are used for this purpose. Clay tile are made in every region where drainage is necessary. This fact of itself suggests that no special type or quality of clay is required for their manufacture, and that is true. The qualifications a clay must possess to be suitable for tile are a sufficient degree of plasticity when wet that it can be forced out through a circular die in the shape of a cylinder, and an ability to dry and burn without serious checking or cracking. Many common clays possess these characteristics and it is rare that such clays, when burned to a proper hardness, do not make serviceable drain tile.

In some places the surface clays taken to a few feet in depth do very well for tile, while in others it may be necessary to make a fixture of clays not found in the same opening. As a rule the deeper layers are more plastic, that is, they will work more smoothly in the hands or through a die and the surface soil layer is mixed with it to control its shrinkage in drying and color and density when burned. The most plastic clays, such as we find at depths up to 10 or 12 feet over large areas in the Willamette



Fig. 24. Drain Tile Factory, Salem, Ore.



Fig. 25. Layout of Tile Drainage System, Willamettedale Farm, Benton County.

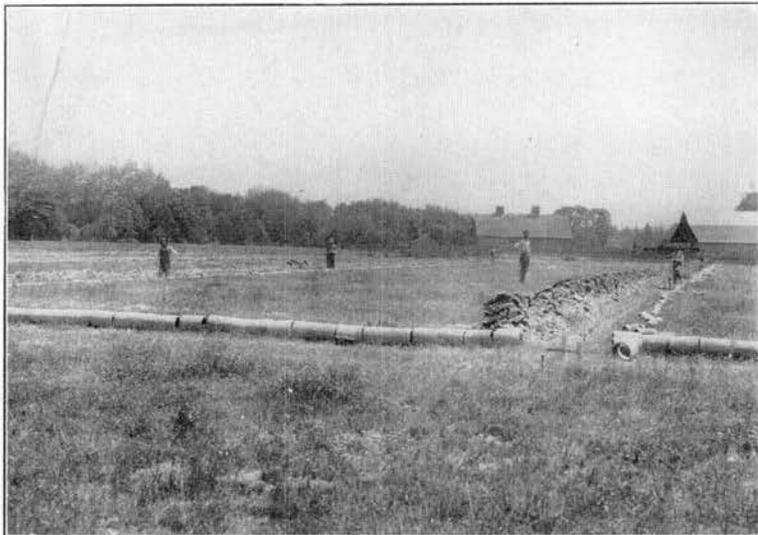


Fig. 26. Concrete Tile Main and Laterals, Willamettedale Farm, Benton County.

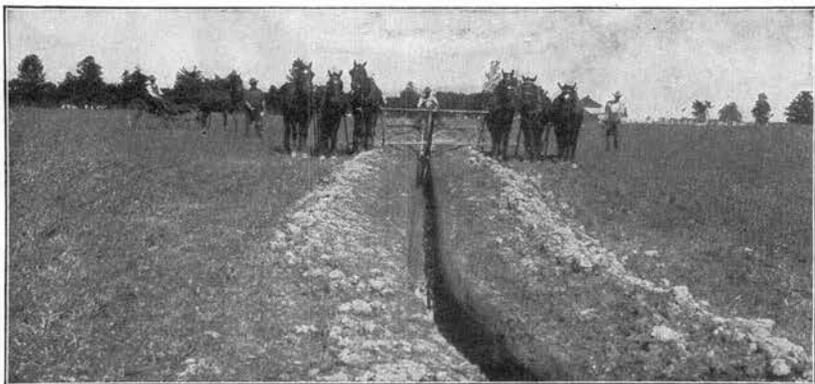


Fig. 27. Jeschke Mfg. Co. Cyclone Tile Trenching Machine at Work.

valley, are rarely satisfactory used alone. They are apt to shrink and crack in drying and in extreme cases to have a shelly structure. This last is a defect common to many very smooth working plastic clays. It is produced by the auger of the machine in which the tile are made and is known as laminated or auger structure. It can often be corrected and a better article made by a mixture of clays or the addition of sand or a sandy clay to the more plastic one.

Besides the surface clays, shale clays are used for making drain tile. These frequently require grinding and usually a more thorough working than the softer varieties of clay, but produce ware of equal and often better quality. Most of the larger sizes, say above ten inches, are made of the shale clays on a steam driven pipe press instead of an auger machine.

The common tile is red in color and varies in density from quite porous to the thoroughly vitrified condition. The walls of a porous tile will absorb water quickly until saturated, while those of the vitrified tile are nearly impervious to water. Even in the previous case, however, no appreciable amount of water goes through the tile walls when it is laid in a drain. The water passes in entirely between the ends of the individual tiles.

From the standpoint of durability and service in the ground, therefore, it is safest to use the hard burned and the vitrified tile whose walls are largely impervious to water. It is apparent that this is a consideration, though, of much greater importance in regions where frost is apt to reach the tile in the ground than in one of mild climate. The mere presence of ordinary soil water in the walls of a porous tile can exercise no detrimental disintegrating effect, so far as we know, providing the tile is well burned. On the other hand, it is well known that a wet tile is weaker than a dry one. When a tile is placed beneath the surface it is subjected to a weight of earth above it depending on its size and depth. The tile must, of course, be amply strong to bear any load that will come upon it in the ground. Instances are known where porous tile showing no signs of deterioration have been taken up after years of service in drainage systems. If the tile when they are laid are of undoubted quality no question can later arise as to their permanence in use.

To briefly sum up, therefore. Both common and shale clays

are suitable for drain tile making, the former more particularly for the smaller sizes, the latter for all sizes. The best vitrified tile are made of shale clays. Unused clay should be tested in a practical way before a plant is built for tile manufacture. The Oregon Bureau of Mines and Geology is prepared to investigate new deposits of clays that show promise of value and to make practical tests of them where it is apparent that the results of such tests will aid in the development of drainage or the drain tile manufacturing industry.

While a set of standard requirements for clay drain tile have not yet been formulated to meet Oregon conditions, tile users should insist upon well burned tile that have a decided tone or "ring" when struck lightly with a hammer. They should not be too porous or show signs of crumbling. Tile should run fairly even in size, should be round and not distorted in shape, and the inside should be smooth so the flow of water through them will not be impeded.

CONCRETE TILE.

Concrete tile have come into use in more recent years. They are made of a proper mixture of sand and Portland cement. For the larger sizes gravel, or crushed stone and sand, are employed. The smaller sizes, up to 10 and even 12-inch, are in most factories now made on a machine. The larger sizes are made in molds in which the cement-aggregate mixture is placed and tamped by hand. The tile are then cured, either by steam, in a moist atmosphere, or are sprinkled, by which means they are kept saturated and harden for a considerable period before they are ready for use.

On account of the newness of concrete tile for drainage on a large scale, we do not have the basis of long continued use to determine their adaptability as we do in the case of clay tile. A few old drains have been taken up in different parts of the country in which the concrete tile after as long as thirty years in the ground are in perfect condition. On the other hand, some concrete tile drains have failed after but a short period of service. The same has happened with clay tile.

It has been argued that concrete tile will yield rapidly to the solvent action of the water which passes into their walls. So far, this has not been proven to be an important item in the case of or-

dinary land drainage, nor of swamp drainage in humid regions. The failures of concrete tile so far observed, as is also true of clay tile, have been due rather to raw materials of poor quality, poor or ignorant workmanship, or improper treatment in process of manufacture. Without the experience of years to guide us in this matter, it may therefore be said that according to our best knowledge, concrete tile will prove entirely suitable for underdraining, providing they are properly made of the right proportions of good sand, gravel or stone and cement, are properly cured and properly laid in the ground.

Both clay and concrete tile of the larger sizes have been known to fail by crushing due to the weight of the ditch filling. This, of course, emphasizes the importance of first making the tile sufficiently strong, and second, of properly bedding them in laying so they will have an even bearing. A considerable number of measurements of loads on tile in ditches have been made recently by the Engineering Experiment Station of the Iowa State College. A discussion of the results cannot be entered into here, but a bulletin on the subject may be obtained by writing to the Director at Ames, Iowa.

Concrete tile are as a rule somewhat more porous than the best clay tile. This should not be regarded as unfavorable to them, however, providing they measure up to the standard of strength, and compare in other desirable qualities.

TESTING OF DRAIN TILE.

The American Society for Testing Materials is now drafting a set of specifications to which drain tile should conform. These specifications will be based upon the results of a large number of tests and the experience of the most capable drainage engineers. The required tests will include breaking to determine strength, and absorption of water, to determine porosity. The first may be made by loading the tile with known weights until it fails or by the use of a simple machine, one of which is shown in Fig. 28. Absorption is easily determined by weighing a piece of the broken tile before and after soaking or boiling thoroughly in water.

As the result of a large number of tests of both concrete and clay drain tile and determination of the loads to which they are subjected when in the ground the Engineering Experiment Station of the Iowa State College recommends that tile meet the follow-

ing strength and absorption requirements, the tests to be made by the Iowa method. Tile less than 15 inches in diameter should

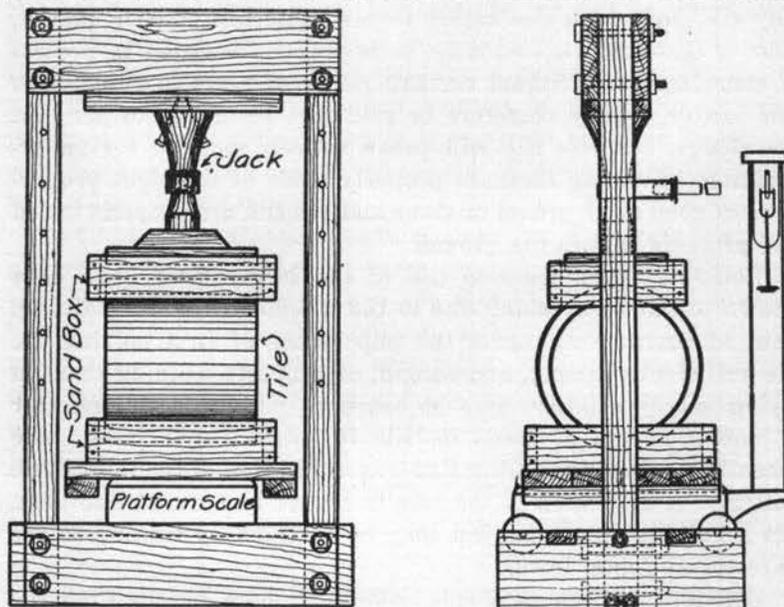


Fig. 28. The Ames Junior Tile Testing Machine.

Eng. Exp. Sta., Iowa State College

have a bearing strength of at least 1,000 pounds per lineal foot; those from 15 to 20 inches, 1,250 pounds; 21 to 27 inches, 1,500 pounds; and from 28 to 36 inches, 1,850 pounds per foot of length. Absorption should run from 6.5 to 9 per cent for concrete tile, and from 6 to 7 per cent for clay drain tile.

CONSTRUCTION OF UNDERDRAINS*

“While it is desirable that the construction of underdrains should be carried on at a time when it will least interfere with regular farm operations, this is not always practicable, since the condition of the ground is an even more important consideration, affecting as it does the amount of labor required, and thus the expense of the undertaking. The farmer will find it to his advantage to choose a season of the year for his drainage operations when digging can be most easily done, and to haul and distribute his tile when the roads and land are most favorable for

*Practical Farm Drainage by C. G. Elliott, p. 89, et seq.

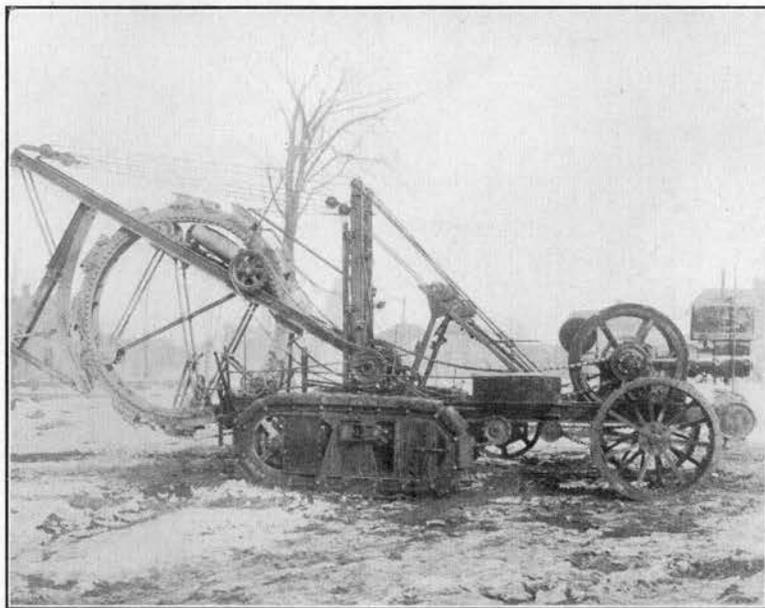


Fig. 29. Buckeye Traction Ditcher Co. Tile Ditching Machine.

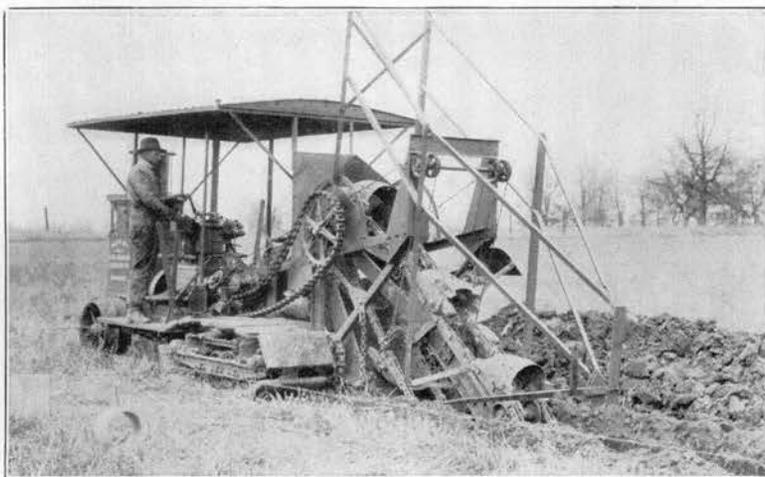


Fig. 30. F. C. Austin Drainage Excavator Co. Tile Trenching Machine.



U. S. Department Agriculture
Fig. 31. Tools for Tile Drainage Work.



Fig. 32. How the Guide Line Is Used to Bring the Trench to Grade.

such work. Swamp land is often more easily manipulated during some parts of the season than others, and land which is periodically wet may at times be too dry to be excavated at a reasonable cost.

“The construction of underdrains consists of four distinct operations, not always undertaken by the same contractor. These are excavating the ditch, grading the bottom, laying the tile or other material used for the drain, and backfilling the ditch.

EXCAVATING THE DITCH

“There are so many kinds of land which may be profitably drained that no one method of digging ditches will apply to all. Some soils contain roots, stones and tough clay; others are soft, mucky and unstable; while others are free from all those properties so difficult for ditchers to contend with, being friable loams and clays which can be dug with ease and dispatch.

“While various plows and machines are now put forward to take the place of hand labor, and in some instances are valuable aids, they are limited in usefulness by reason of the exceedingly variable conditions of land which requires drainage. While it is

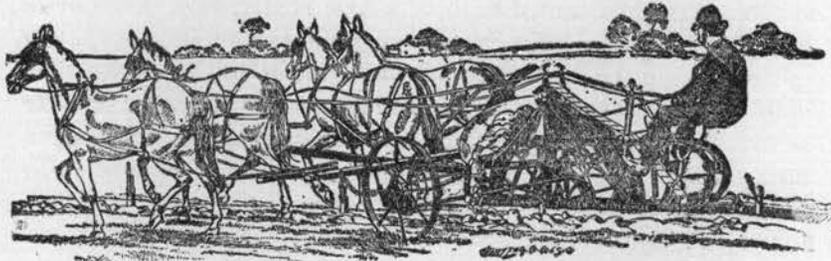


Fig. 33. The H. L. Bennett & Co. Tile Ditching Machine.

hoped and confidently expected that machines will materially assist in performing a large part of the trenching for drains, the skillful ditcher, with his simple tools, will always be in demand, and the excellent manner in which he performs the work will never cease to be the criterion in the making of farm drains.

“The long-winged ditching plow is successfully used by some to start the ditch, and to loosen and partially remove the top 15 inches of earth. This will lessen the cost, especially where unskilled labor is employed. It is not possible, however, to get a neat line at the bottom of the ditch where the plow is used, because

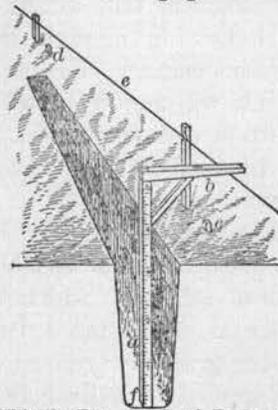
the furrow will lack the straightness which is secured by the hand-made ditch when dug by a line.

“The tools required in hand work are two steel ditching spades, with blades 18 and 20 inches long respectively, the blades being slightly concave, $6\frac{1}{2}$ inches wide at the point and $5\frac{1}{2}$ inches wide at the shoulder; two round-pointed shovels with long handles; a drain scoop for preparing the bottom; two lines, 100 feet long, one a $\frac{1}{4}$ -inch rope for lining the trench, and the other a small cord for a grading line; a gage with arm; a pocket rule; a small hatchet, and a tile hammer. If the land is gravelly, stony or has hard clay, a mattock and steel handbar should be added to the outfit.

“Assuming that the land to be drained is free from stones and sufficiently soft to permit the use of the spade, and that the lines for the drains have been staked out, proceed as follows: Start at stake o, stretch the guide line on the ground at one side of the stakes, making deviations from a straight line where needed by swinging the rope until it takes an easy curve. Mark the line on the ground by cutting the turf about six inches deep with the spade. It is important that this be done neatly, as it is the dress line of the ditch. Begin by removing the earth with the shorter spade, making the ditch twelve inches wide on top when the ditch is to be three feet deep, and fourteen inches wide when it is to be four feet deep. The former depth can be reached at two spadings. Where the ditch will be deeper, it is best to remove sufficient depth of earth from the top to permit finishing the ditch at two full drafts of the spade. The spade should be thrust into the ground a little quartering, instead of square across the ditch, so that the sides will be partially cut instead of being wholly broken. The curve in the blade of the spade facilitates this, the skill of the workman being shown by the small amount of loose earth he leaves after each spading. The line side of the ditch should be kept dressed by a light side cut of the spade as the work proceeds, and the top earth be dropped on one side of the ditch, and the second spading on the other so that the soil can be readily replaced when the ditch is filled. The first spading is followed by the shovel, which removes the loose earth and leaves the ditch clear. This is the base from which the workman operates to complete the ditch ready for the tiles.

GRADING THE BOTTOM

“Place the grading line in position as shown in Fig. 35, setting it at a convenient height above the surface, and at a constant distance above the bottom of the proposed grade line, being certain that at each stake the distance measured above the hub to the line, added to the depth of ditch at that point, equals the distance at which the line is set above the bottom of the ditch, which in the illustration is $4\frac{1}{2}$ feet, the arm of the gage rod being set at the same distance. Various devices are used for obtaining the grade indicated by the survey. In some cases the line is set high above the center of the ditch; in others crossbars are set for testing the grade by line of sight; but in all methods the principle is the same. While all are correct, and have their advocates, it has been found that the line and gage method is well adapted to



Elliott's Eng. for Land Drainage

Fig. 34. One Style of Guide for Grading the Trench.

farm use, and can be employed by workmen who do not succeed in using some of the others.

“The workman now takes out the bottom draft, or “spading” as it is commonly called, taking care to leave as little loose earth in the bottom as possible, and not to cut deeper than the grade line of the ditch. When a stretch of about four feet has been dug, the workman, without moving from his position, removes the loose earth, or crumbs, with the drain scoop, and proceeds to cut the bottom to a smooth grade just wide enough to receive the tile it is proposed to lay. He tests the accuracy of the grade by means of the gage, the arm of which should touch the cord which has

been previously set at the side of the ditch and drawn tight. This stretch of the ditch should not be passed until it has been dressed

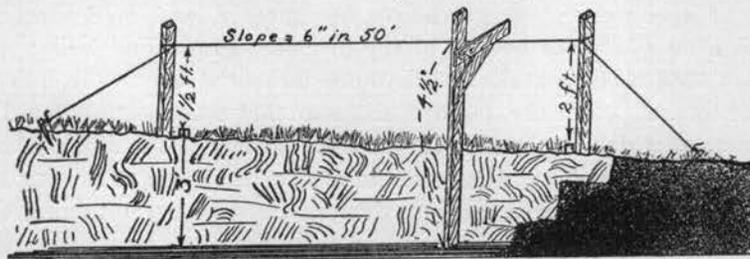


Fig. 35. The Use of the Guide Line and Gage for Bringing the Bottom of the Trench to Grade as it is Dug.

down to the correct grade. If the earth is free from pebbles, the bottom can be easily made as true as the line parallel to it by which it is tested. Ditches for tile eight inches in diameter, and under, can be made in this manner. Larger ones, as well as board, brush and stone drains, will require a wider ditch, which must be finished on the bottom with the shovel, the workman walking in the bottom of the finished trench. The method of testing the grade remains the same.

"It may be that the line has not been marked by continuous levels, but sufficient measurements and levels have been taken to determine the rate of fall upon which the drain may be laid between certain points, as, for instance, two, three or six inches per hundred feet, or the grade per rod, as the case may be. The bottom may then be graded by a drag level, shown in Fig. 36, which consists of a wooden bar (A in the Fig.) of the dimensions shown, upon which a small spirit level, D, is mounted, and to which a handle, C, five feet long, is attached. The fall per rod, or for one hundred feet, having been ascertained, compute the fall for five and one-half feet (one-third of a rod) and attach

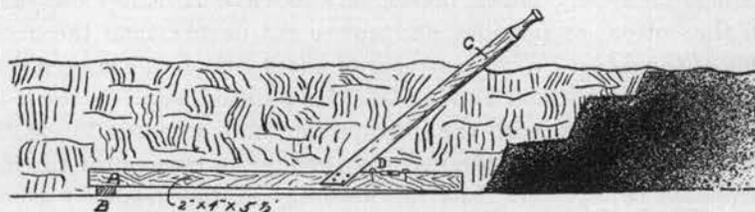


Fig. 36. Grading by the Use of the Drag Level.

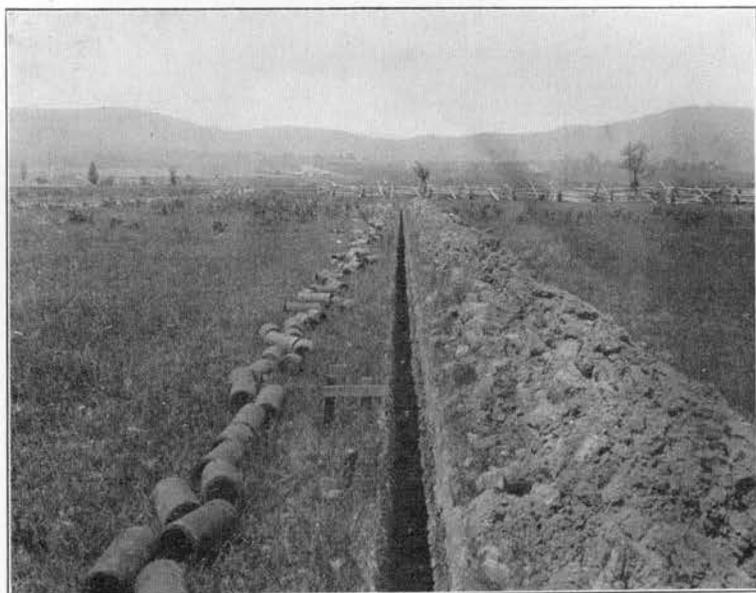


Fig. 38. Tile Trench Showing Excavated Earth at One Side; Guides for Grading and Clay Tile Distributed Along the Other Ready for Laying. Willamettevale Farm, A. J. Johnson, Benton County.



Fig. 39. Filling the Trench After Tile Are Laid.
U. S. Department Agriculture



U. S. Department Agriculture

**Fig. 40. Clay Tile Wye for
Junctions.**



**Fig. 41. Unprotected Main Tile Outlet, Subject to Under-
mining and Displacement.**

a block, B, equal in thickness to the fall in the length of the bar. Place the bar upon a plank or floor previously made level, and adjust the small level, D, so that the bubble will stand in the center. The bottom of the ditch is tested by the workman, who pulls the bar along as he completes the ditch, the bubble indicating the accuracy of the bottom. A little water in the soil and ditch is always desirable, as it lessens the labor of digging, and facilitates the grading of the bottom. Inexperienced ditchers make the trenches needlessly wide, and fail in that dexterous handling of the spade and draining scoop which distinguishes the professional workman from the common laborer.

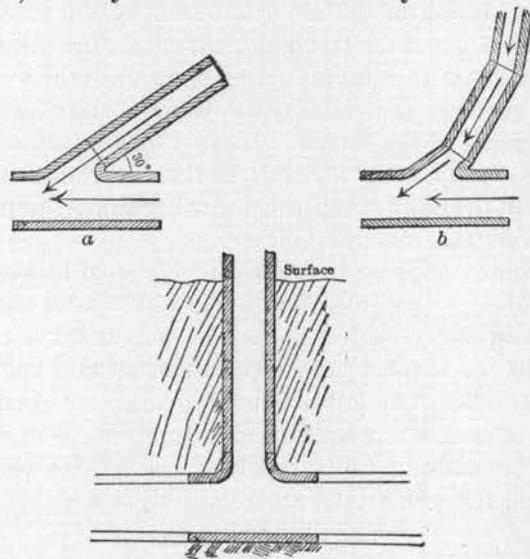
“The drain scoop, a most useful tool, shown in Fig. 31 (some forms of which are patented), is made with blades varying from three to seven inches wide. It may be purchased with a handle adjustable at the shank by means of a ratchet and bolt, or with a stationary handle. The latter is usually more satisfactory. Similar scoops of larger size or with greater strength in some of the parts, may be made by a blacksmith if needed, for scooping mud from a ditch, for which they are admirably suited.

LAYING THE TILE

“If the bottom of the ditch has been perfectly prepared, the tiles can be easily and rapidly put in place. Sizes up to eight-inch can be more readily laid with a tile hook, the workman standing on the bank and putting the pieces in place from the outlet up grade, turning each tile until the ends fit closely on top. If the bottom has been poorly prepared, the workman should stand in the ditch and, taking the tile which have been strung along the bank within convenient reach, lay them in place, backing up the ditch as he proceeds. Any rough places in the bottom which prevent the tile from lying firmly, and joining properly, may be removed with a hand trowel or with the drain scoop, a work which he cannot conveniently do when standing upon the surface using the hook. All large tile and box drains should be laid in the same manner. Ordinarily the ends should be joined closely, but when the tiles are surrounded by stiff clay, it is better to join the several pieces quite loosely to facilitate the entrance of soil water, especially in lateral drains. No injury to the drain in such soil need be feared from the entrance of silt. . . .

“Junctions of branch or lateral drains with their main should

be made by the use of junction tile, which should be put in place when the main is laid. Not all manufacturers make junction tile, or junctions, as they are called. Some only make a hole in the



Elliott's Practical Farm Drainage

Fig. 37. Horizontal and Vertical Junctions.

side of a straight pipe, the drainer being obliged to make the junction by fitting the lateral to it, while others do not make even this helpful provision. Properly shaped "Y" and "T" junctions are made at many factories, and should be secured when possible. A badly made junction will greatly impair the efficiency of both lateral and main to which it is joined. The angle between the lateral and main should be about thirty degrees, as shown at *a* in Fig. 37, which is known as a "Y" in distinction from a "T" in which the angle between the two is a right angle. In the former, the currents from the two pipes unite with the least possible resistance, so that the flow of neither is materially checked. It is frequently necessary to have the general direction of the laterals at right angles with the main, but the joinings can be made with "Y" junctions in the manner shown at *b* in Fig. 37. "T" junctions are used on the larger mains in making stand pipes from the main to the surface, for inspection purposes, or for making surface inlets for admitting free water to the drain. This

is shown at *c* in Fig. 37. All junctions, and the tiles which connect with them, should have the earth carefully tamped about them so that they cannot be displaced. . . .

“Blinding is fixing the tile in place by chipping moist earth from the side of the ditch so that it will distribute itself about the tile. This earth should be carefully but lightly tamped about the tile so as to hold them firmly in place, after which sufficient earth should be sliced off the side of the ditch to cover them six inches deep.

FILLING THE DITCH

“The drain having been properly blinded, the balance of the back-filling can be done in the most convenient manner. Earth can be removed more easily if moderately dry, and the filling may occasionally be deferred until the excavated earth becomes sufficiently dry to handle. But large mains located in low ground, and liable to flooding before the drainage system has been completed, should be filled with as little delay as possible. The plow is commonly used to fill ditches on cultivated land, but should not be used on meadow and pasture land, as it plays havoc with the sod. An “A” shaped winged scraper, with the wide end behind, drawn by two teams of horses, one walking on each side of the ditch, is efficient, leaves the sod intact, and ridges the earth nicely upon the trench, an important matter in ditch filling. The earth-moving wing of the scraper is held in position by a guide plank, which extends into the trench, and prevents the wing from sliding away from the bank of earth to be moved.”

ESSENTIAL PRECAUTIONS IN DRAINAGE WORK

In the earlier portions of this paper attention has been drawn to the importance and necessity of farm drainage in the Willamette valley. This section of the state has been particularly referred to not because it alone is in need of drainage, but because the need is here most evident and urgent, if indeed large portions of it have not already reached the stage where drainage is the only means of saving it from actual decadence, speaking from the agricultural standpoint. Some detail has been entered into in discussing the legal and practical procedure in securing adequate drainage and installing drainage systems.

It is to be seriously appreciated by every resident of the

Willamette valley that drainage is to be a permanent improvement, one on which not only this but succeeding generations must depend. In order that it may be so, it is not only unfair to ourselves but more so to posterity if anything short of the highest degree of care and skill is exercised in all drainage installations. Precision must be practiced in all engineering work, first-class tile and other structures must be used and these accurately put into the ground. Extra precaution will be necessary in the establishment and maintenance of grades in a region where the fall, though ample, is so small as it is over many square miles in the most important farming sections of the Willamette valley.

It seems well, therefore, that there be given at this point a resumé of the principles on which successful tile drainage depends. In a way, what follows amounts to a set of suggestions which, it is believed, it will be well worth the while of every one who contemplates draining to bear very carefully in mind. The material for these suggestions comes from the experience of competent drainage engineers and from the testimony of many farmers who have drained their lands of water. A fuller statement of these "cardinal" principles by A. Marston, of the Iowa State College, may be found in the sixth annual report of the Iowa Drainage Association, on which the writer has largely drawn, in part by quotation, though applying the principles to Oregon conditions.

PRINCIPLES OF TILE DRAINAGE

1. **A capable engineer should always be employed to plan, lay out and supervise the construction of a tile drainage system.** Many hundreds of dollars have been wasted by farmers through the disregard of this principle. It is an exceedingly grave mistake to assume that the farmer and ditcher can do this work. Engineering knowledge and experience are essential.

2. **The drainage engineer should furnish to the land owner a complete map, profiles and description of all drains for a permanent record.** This is highly important to the farmer, as this knowledge may save him much time and money in later years when repairs or modifications are needed.

3. **Plan for a complete and regular drainage system.** It may not be possible to put in the entire system at first, but sooner or later this will be done, so mains and submains of ample size

should be put in at the start; and as a matter of dollars and cents, the whole laid out in a systematic manner.

4. Use every effort to arrange laterals in parallel lines as straight and as long as possible up to a safe maximum length for the size of lateral used. Many feet of tile may be saved by a regard for this rule.

5. Plan a system of main drains so arranged as to take the discharge of the laterals as soon as the safe maximum length of the lateral is attained, yet one that has as few junctions as possible. At every junction the branch line must pass through a few rods of ground that is already drained by the other tile which is a waste so far as draining is concerned. The junctions themselves are also expensive.

6. For a grade of less than 0.5 per cent use 5-inch tile as a minimum size for laterals, and for 0.5 per cent and steeper do not use smaller than 4-inch tile for laterals. Experience has proved that this is an important and safe precaution to observe.

7. Use as little as possible over one-fourth mile as a maximum safe length for 5-inch and 4-inch laterals.

8. Make all mains for farm tile systems large enough to remove at least one-half inch depth of water in 24 hours from all land in the drainage area that will ever be drained. This is a tentative recommendation which, it is believed, will be safe for Willamette valley conditions. Mains should be amply large, for farmers almost invariably desire to extend their systems to drain land not included at the beginning. More and more of the higher slope lands will be drained as benefits appear.

9. Before making plans for the system, study carefully the character of the soil and the source and direction of movement of ground water in all land that will ever need draining. This measure has everything to do with the working of the drainage system when installed.

10. Where there are slopes, laterals and mains should be so arranged as to intercept the seepage of ground water at the highest point on the slope where it ever shows. If this principle is carefully regarded, one tile may often be made to do the work that it would otherwise require several lines to accomplish.

11. In draining draws, locate a drain on each side of the draw at the foot of and parallel to the steep side slope, so as to intercept

the ground water from the higher land. This method is far better than short laterals at an angle with the slope.

12. In draining ponds or other areas from which surface as well as ground water must be removed, the capacity of the mains for farm tile systems should be 100 per cent greater than for ground water only.

13. In draining ponds and other areas from which surface water must be removed, use catch basins to admit the surface water to the tile; or where feasible put in enough greater length of laterals to admit the surface water without delay by seepage through the soil. The provisions of 12 and 13 are only those that

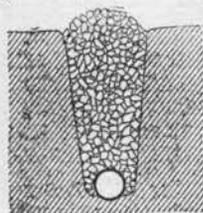
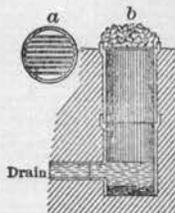


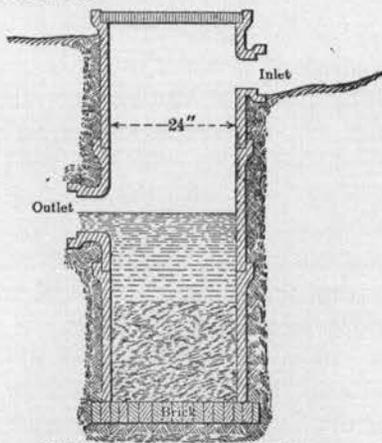
Fig. 42. Surface Inlet Filled with Crushed Rock.



Elliott's Eng. for Land Drainage
Fig. 43. Surface Inlet, Iron Grating Covered with Broken Stone to Prevent Silt from Washing Into Drain.

experience has proved necessary for promptly getting rid of the surface water before it has injured the crop.

14. If catch basins are used, cover the grating with several inches of fine stone or pebbles or broken tile to keep silt from washing into the drains.



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Fig. 44. Silt Basin for the Removal of Earth Carried in the Tile.

15. In all ordinary soils the movement of the water from the surface of the ground is, first, straight down through the soil to the ground water table; second, sidewise through the soil to the tile in a curved path which is not appreciably longer for four feet than for three feet depth of tile. The whole body of ground water, even that below the tile, participates in this sidewise movement. A clear conception of the movement of water beneath the surface of the ground will aid very materially in determining the spacing and depth of drains. Drains provoke this lateral movement in regions of stagnant ground water, then intercept its flow. Water enters the tile from the bottom instead of from the sides and top.

16. Laterals should be put as little short of four feet in depth as experience in the particular region proves will make an efficient drain. Deep drainage has proved most satisfactory wherever it has been used. In close textured clay and clay loam soils it may be that shallower depths must be adopted. In all soils, however, where drains will operate satisfactorily at four feet, nothing less should be considered. It remains for drainage investigations to show the best depths and distances apart for drains in the principal types of soils in the Willamette valley. For the present the judgment of the drainage engineer should be accepted on these points.

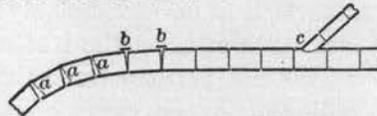
17. Tile mains should be laid enough deeper than the laterals to permit the laterals to discharge into the main above the center line. This precaution will guard against backing up of water in the laterals from the main.

18. The drainage engineer should set solid grade stakes as often at least as every 50 feet. Every drain should be laid to a carefully established grade indicated by the engineer's grade stakes. These stakes should be firmly driven even with the surface of the ground and the position of each preferably marked by a lath.

19. The harder burned the clay tile and the stronger and more impervious are both clay and concrete tile, the better they are. It is unnecessary for the walls of the tile to be porous. Water does not pass into the drain through the walls of the most porous tile. It enters between the ends and there only.

20. Every tile should be laid by measurement to the grade line given by the grade stakes, preferably by the guide line

method. In most soils the tile should be laid as closely as possible to each other and openings on the outside of a curve should be covered by pieces of broken tile.



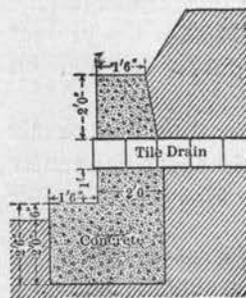
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Fig. 45. Protection of Tile in Curves. Junction of Main and Lateral.

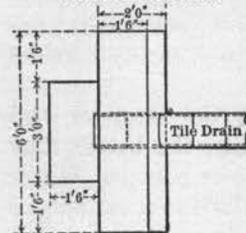
21. Special wyes and tees should be used for junctions and these laid with great care.

22. The land owner should inspect the tile as soon as they are laid, after which they should be promptly blinded with about six inches of top soil to hold them in position. In some instances instead of top soil it may be advisable to use straw or brush, or gravel if available, next to the tile. These materials merely prevent the tendency of some clay soils to pack down and to seal over the openings before lines of flow of water to the tile have become established.

23. Before the ditch is refilled, the drainage engineer should thoroughly inspect the entire system and make frequent tests of the drains with a level to determine whether they have been correctly laid to grade. He should uncover the blinded tile occasionally to ascertain the quality of laying and in general take every precaution to see that good work has been secured.



VERTICAL SECTION



PLAN

Elliott's Eng. for Land Drainage

Fig. 46. Bulkhead for Protecting Drain Outlet.

24. Refilling in ordinary soils may be done with a team and plow, or some form of V-shaped drag, or a scraper.

25. Great care must be taken to construct safe and satisfactory outlets with free discharge and with the end of the tile held solidly in place to protect it from danger of undermining. It may often be necessary to excavate a shallow ditch for a distance below the outlet. The end tile should be held in place by a bulkhead preferably of concrete, or stone or brick masonry, extended far enough below the

tile to insure against possible undermining and made thick enough to be safe against overturning. A screen of coarse mesh wire fencing placed over the end of the outlet tile is frequently serviceable in preventing clogging of the drain by the entrance of field rodents that build their nests in the tile.

26. **After the entire system is constructed, it should be given proper maintenance each year.** Outlets should be kept open and in repair. Gullying or pits along the line of tile should be prevented and carefully repaired when discovered. The tile map furnished by the engineer will enable the owner to locate and to watch the working each year of every line in the system.

27. **The best results from tile drainage must not be expected, nor will they appear the first year.** Tile drains properly installed effect great changes in the soil and these changes operate to better its condition and to improve it for many years after the drains are constructed.

COST OF DRAINAGE AND PROFITS.

At the very outset, it is apparent that the drainage of farm lands is not an inexpensive operation. Its exact cost will vary with the character of the soil and the flatness of the grades; and therefore with the amount and size and price of tile necessary; which is the same as saying that costs will be determined by the conditions existing in each particular drainage section. In a region such as this, costs will often vary from farm to farm on account of differences in the character of the soil and nearness to an outlet and on separate parts of the same farm as well.

It may be said in general that the higher the grades, that is, the more rolling or sloping the land, and the more open textured the soil, the less the expense of draining will be. In the table on page 57 it will be noticed that the acreage a main of given diameter will drain increases quite rapidly as the grade at which the tile are laid becomes higher. The same general principle holds also for each lateral drain. Since laterals must be laid closer in the finer textured soils, from this standpoint drainage will cost more in the flat lowland parts of the Willamette valley where a clay loam soil predominates than in the less level areas. Drainage of "white lands" or of those regions where soils are of similar type will thus be about the most expensive of any in the valley.

It is not difficult to estimate very closely the cost of draining in individual cases after the preliminary work has been done and depth, distance apart and sizes of the tile decided upon. The exact knowledge of this cost does not, however, mean much to the farmer unless at the same time a fairly accurate idea of the profit to be expected from drainage can be given him. In order to be worth while, it must be proved that drainage is to bring about such an increase in land value, or a sufficiently greater productiveness, to pay a large rate of interest on the total drainage expense. Merely legal rates of interest are not sufficient, but it must be convincingly clear to the land owner that within a reasonable number of years the benefits will cancel the drainage debt, or counter-balance the investment.

The extent to which drainage has been done in the Willamette valley of Oregon is not such as to conspicuously bring before its inhabitants in general the far-reaching importance of it. A few farms have been thoroughly drained and many rods of drain tile have been laid here and there to take away seepage water in draws, to control the flow from springs, to remove standing water in ponds, etc. The history of the beginnings of drainage in many other states where it is now an established practice is precisely identical. All those who drain become ardent enthusiasts. In other states the contagiousness of this enthusiasm has been such at times that not only were drain-tile factories taxed far beyond their capacity, but the supply of tile ditchers and responsible drainage engineers and contractors also much below the demand.

Such has been the story of drainage in Indiana, Illinois and Michigan, and such is the drainage evolution that is now in progress in Missouri, Iowa, Minnesota and the Dakotas. These states are in the lead. Drainage has proven indispensable to them. Their soils are no better and they need drainage no worse. Their climate does not compare with that of Oregon, nor does the variety of crops they grow. These states have drained their wet lands because they could not afford to farm them without draining. Most of them were as slow to see the light as Oregon has been, but none have pushed forward in the drainage movement more rapidly than, we have every reason to predict, will the people of all sections of this state when once the contagion of drainage

really takes hold. Oregon farmers will soon learn that drainage of their wet lands is not only profitable but indispensable. The day is not distant when farmers on Willamette valley low lands are going to scramble for the privilege of an outlet into a district drainage ditch, rather than oppose and even obstruct the process of legal organization for its construction, as some of the unprogressive and short-sighted now do.

Since systematic drainage has progressed so little here, we must draw in part upon experience and records of both cost and benefits in other states and other countries. In the matter of cost fairly accurate figures are obtainable that will apply to Oregon conditions.

COST.

The cost of open ditches has been alluded to in an earlier chapter. The principal factors of cost in the construction of tile drain systems are engineering, the tile themselves, digging the trenches, laying the tile and filling the trenches. The prices of the drain-tile available at Willamette valley points by the time they are delivered in the field range from about 26 dollars for four-inch tile and 75 for eight-inch to about 175 per thousand feet for 12-inch tile in car lots. Trenching is usually done at so much per rod, including the laying of the tile. The price runs from 30 to 50 cents per rod for small tile. Filling the trenches costs around five cents per rod when done with team and plow, more if done by hand. If to these items we add the cost of engineering work, which is variable, and calculate the total per acre, it is found that the entire cost of securing drainage for wet lands in the Willamette valley will be from 25 to 50 dollars per acre. These estimated figures are borne out in the few cases where drainage systems have been installed.

PROFITS.

It has already been pointed out that within the limits of the region under consideration not much systematic drainage has been done. All localities were visited where many drain-tile have been used in the past 25 years. It is rare that records of costs have been kept, as the drains have been put in at odd times and as a rule only to drain draws or ponds here and there in the wettest fields. It is the universal opinion, however, that drainage is not only a necessary improvement, but it is proven by those who have

done any amount of it to be the most profitable investment they could make. Were such favorable experiences rare, or even occasional, rather than universal, one might properly question the value of the more widespread drainage proposed in this paper. But when within the Willamette valley, as in neighboring and more distant states, every one who intelligently drains his land becomes enthusiastic over the results and an advocate and practitioner of thorough drainage, there can longer remain no legitimate question that it is and is to become the salvation of the owner of wet farm lands.

In order to present in a more pointed manner the value of and benefits from drainage, a few concrete examples will be cited. It is to be recalled that there are two classes of lands that will be benefited by drainage, those already under cultivation and, second, lands so wet and swampy as to be worthless or nearly so without drainage. In the latter case, drainage actually produces the value of the land, while in the former the benefits come from an added return in produce from each acre.

EXAMPLES

In the Camas Prairie district, Klickitat county, Washington, within the watershed of the Columbia, about 15 miles of main ditch and connecting laterals have recently been completed. These ditches drain approximately 6,600 acres of land. The total invested in the project is 93,000 dollars, slightly over 14 dollars per acre. The benefits accruing from drainage in this particular locality was determined by a jury. The total assessed value of the lands before drainage, as quoted by the drainage engineers, was \$167,947.50; after the completion of the ditches, \$416,492.50, an increase in value of about 37 dollars per acre. And this without any tile drainage whatever, merely open ditch drainage.

To cite a specific instance from this locality: A tract of 40 acres was sowed to oats in the fall of 1911 before the land was drained and yielded 46 tons of hay on the 40 acres. In 1913, after drainage, the same piece of oats harvested 120 tons, a gain of almost 200 per cent.

Another field of 60 acres which was formerly marsh and, therefore, worthless agriculturally, gave a yield the first season after draining of 120 tons of timothy hay, two tons per average acre, while four and one-half acres of this tract yielded 16 tons

of hay. Every one within this district pronounces drainage a success and a paying investment.

Four miles east of Creswell, in Lane county, Oregon, Mr. F. J. Woodward has recently drained 80 acres of prune land. The soil is an alluvial formation irregularly underlain by gravel and clay. To illustrate its immediate effect, Mr. Woodward states that of 5,000 trees set out in 1912 before the drains were laid, 1,500 trees were lost because of too much water. In 1913, before the system was entirely completed, from a new planting of 7,400 of the same trees, on another portion of the identical field, a loss of but 300 trees was sustained.

Somewhat over two miles southwest of Forest Grove, in Washington county, Mr. John Forbis has put in several carloads of drain tile on his ranch of 100 acres. Six and eight-inch tile were used for mains and four-inch for laterals, the latter being placed about three feet deep and from 60 to 100 feet apart. Mr. Forbis' land is all rolling. The foreman on this ranch states convincingly that "Nothing could be better. Although the tile have been in less than a year, the ground is in shape much earlier this spring. Drainage was the only thing for this ranch and will prove a highly paying investment."

Ten miles east of Salem, in Marion county, Mr. Alfred Hersch has drained about 15 acres of slope land. A good portion of the land was formerly swampy from seepage, but is now in an excellent state of cultivation and yearly produces abundant crops.

On the Agricultural College farm Professor H. T. French 25 years ago tiled out completely 40 acres, 30 of which were typical "white land" and worthless. The mains are six and eight-inch clay tile with three and four-inch laterals spaced 70 feet apart emptying into them. The laterals were laid about 36 inches deep. The fall varies from one inch to six inches in 100 feet. From the beginning the results were highly satisfactory, and the efficiency of the tile has improved with years. Ground that before draining was not firm enough to be worked until June is now cultivated in March. Professor French states that "Drainage lengthens the season at least two months." Last season nearly six tons of clover hay per acre were produced on this land. The drains have paid for themselves many times and are more effective now than ever.

Mr. Thad Sweek in February, 1911, tiled 14 acres of his farm at Tualatin, in Washington county. The soil is of the heavy clay loam type. Four-inch tile were used. The tile are spaced 100 feet apart, are laid from 30 to 36 inches deep and empty directly into a drainage ditch. Trenching, laying the tile and covering cost 50 cents per rod. On the 14 acres 2,300 feet of four-inch tile were put in at an average grade of two inches in 100 feet. The tile cost 19 dollars per 1,000 feet, thus making the total cost about eight dollars per acre exclusive of the outlet. Mr. Sweek's land has been farmed for 50 years. He says: "Before tiling the land was very wet. Now we get on the ground at least six weeks earlier in the spring. Crops formerly averaged 25 to 30 bushels of oats per acre. In 1913 nine acres produced 50 bushels per acre, and nine bundles from one corner of the field that took first prize at the State Fair were bought by L. W. Hill as the best oats grown in Oregon. The soil over the whole piece is loosening up in good shape. I plowed under a crop of clover in 1912. This year I have every reason to expect 75 bushels of spring oats per acre."

In 1908 the Government completed the installation of a complete drainage system on 72 acres of principally "white land" one mile south of Albany, in Linn county, on the farm of Mr. J. A. Howard. The tract was typical worn-out and practically abandoned grain land and portions of it were so poorly drained that no attempt at cultivation had been made for a number of years. From three to ten-inch clay tile were used, the smaller in the laterals and the larger tile as mains. They were laid from three to four feet in depth and at distances apart for the laterals of from 60 to 150 feet. Grades ranged between 0.2 or one and one-fifth inches, and 0.5 or six inches in 100 feet. The entire cost for the 72 acres was \$1929.80, or \$26.80 per acre.

The success of this system has been very pronounced and satisfying to the owner. One hundred and thirty-three acres, including the drainage tract, were originally purchased for \$6,000, 45 dollars per acre. The whole then rented for 120 dollars per year. The owner, Mr. Howard, states: "The work of the drains has improved the longer they are in. No water stands on the land now in the winter time. In 1913 thirty acres went 56 bushels of oats an acre. Very heavy yields of clover and vetch have been

obtained. The land is actually worth now for farming purposes four times what it cost. I have refused 400 dollars per acre for portions of it. I am thoroughly convinced that the "white land" soils can be made the most productive in the valley if they are properly drained and the right farming methods are employed."