Preliminary Report on

The Improvement of Marsh Lands in Western Oregon

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IMPROVEMENT OF MARSH LANDS IN WESTERN OREGON

Summary

I. There are over 150,000 acres of marsh land in Western Oregon, including the tide, overflow and "beaver dam," or peat. Preliminary surveys by the Experiment Station indicate that drainage and improvement for most of these unimproved marshes is feasible and desirable from an agricultural, engineering, and economic standpoint. It is estimated that this land should support one family to each 40 acres, or a total of 3,750 families. The land when drained will sustain one cow to the acre.

II. Drainage district procedure under the State Drainage Law is outlined, and design and construction of dikes, tide boxes, outlet ditches, and pumping plants are briefly described.

III. The design, installation, and early operation of a tile system on the diked tide land on the Branch Experiment Station near Astoria is recorded. In designing a tile system the foothill ditch and outlet tile are the most necessary parts of a drainage system in these lands. Tile must operate in the subsoil and should be located with the aid of a soil auger in the most porous layers where water is encountered. The surveyor's level should be used on flat land, as its use in a final survey does not add 5 percent to the cost and may add 50 percent to the efficiency of the system. Aim to get the highest possible efficiency out of every hundred feet of tiling laid.

IV. Tile should have a firm bed which is true to grade, and wherever the tile base is at all soft may be placed on a plank or slab of wood. Red tile are successfully used on the Experiment Station farm, though some concrete tile was bought and installed for comparison.

V. Preliminary results from experimental sections of the tile system indicate that tile placed four feet deep with lines five rods apart will sufficiently control the excess water and water table and provide suitable drainage for staple field crops on tide lands. Where outlets limit the depth of laterals to three feet, tile lines may need to be four rods apart. For truck crops or valuable onion lands like the beaver-dam soils, spacing three rods apart is desirable, yet a depth of four feet should be maintained with this closer spacing on account of shrinkage. Silt loam having some variation in topography, like the overflow and bank land, may require only a random or natural system of interior tile to take care of water in depressions.

VI. Experiments indicate that near the north Oregon coast tide boxes should have a capacity of one square foot for each twelve acres. On the lower Columbia supplementary pumping plants which have a capacity to handle one-fourth to one-fifth inch an acre of rainfall in twenty-four hours, are satisfactory.

VII. Measurements of outflow indicate that tile may need a capacity to handle one inch an acre in twenty-four hours near the north coast of Oregon; three-fourths inch an acre near the south coast; and one-third to one-half inch an acre in the Willamette Valley.

VIII. The tile drainage system described has disposed of excess water and reduced the water table, frequently running full for several days at a time in heavy weather.

IX. Cost of the tile system as designed will average about $25.00 an acre. The first crop, 5 tons field-pea hay to the acre, was double the yield on the portion not yet tiled. This crop was worth $25.00 a ton at local prices, so the cost of tiling was repaid in the first crop. Tiling will double
the productive value of the greater part of the marsh lands in Western Oregon. Much of this land is already provided with protecting dikes for main outlet ditches, but is in need of tile.

X. The reclamation of marsh lands consists of three operations: (1) Protecting works; (2) field or farm drainage; and (3) subjugation of wild growth, breaking, and establishment of improved crops. These latter operations are described.

Crop rotation; the use of legumes and fertilizers; and periodical inspection of drainage structures is necessary to maintain and improve the structure and fertility in a way that will facilitate the passage of water through the soil into the tile and make possible maximum crop returns so that all three operations of reclamation may prove most successful.

XI. A farmer should study subsoil and soil water conditions in wet areas and then lay out a full system of drainage with the aid of a level, if necessary. The system may be installed in units, the most necessary parts first; but it is best to order tile in car lots. A farmer can make a study of drainage so that he can superintend and inspect his own work. He can watch results, and extend the system as needed.

XII. A community needing an outlet ditch should secure preliminary topographic and soil surveys and learn the feasibility and extent of the proposed outlet ditch. If it is found to be feasible, petitions should be prepared according to the State law and presented to the county court. The district officers then prepare a plan and get an estimate, after which the court appoints three viewers to assess the land in proportion to the benefit to be received. The district officers secure bids and let a contract for construction of ditches. The drainage tax may be paid in installments, which return in increased crops.

ACKNOWLEDGMENT

Studies reported in this bulletin have been supervised by the writer under the general supervision of Dean A. B. Cordley, Director of the Oregon Experiment Station. The drainage experiment work on the John Jacob Astor Branch Experiment Station near Astoria was conducted in cooperation with former Superintendent A. E. Engbreton, and later with H. R. Taylor, present Superintendent at that station.

Feasibility surveys by the Oregon Experiment Station have been carried out in cooperation with T. A. H. Teeter, Professor of Irrigation and Drainage Engineering, Oregon Agricultural College, who also edited the engineering topics included. Valuable suggestions regarding the soil work were obtained from C. V. Ruzek, Associate Professor of Soils.
THE IMPROVEMENT OF MARSH LANDS IN WESTERN OREGON

I. Introduction

Along the Pacific coast, from Southern California to Alaska, including the coast of Oregon, are large areas of land known as tide lands. Along the Columbia River and other streams leading to the coast are bottom lands, to some extent affected by tides and subject to overflow during the high water of early or late spring. Other areas of peat and muck occur in the interior valleys west of the Cascades. There are about seventy-five thousand acres of tide land on the Oregon coast and a similar area of overflow land on the Oregon side of the lower Columbia. In addition there are several thousand acres of peat and muck, locally known as "beaver dam," in the more humid section of Western Oregon. These lands are located where there is a remarkably long growing-season, and within reach of water transportation and markets. They are composed of rich, alluvial and vegetable accumulations, and when reclaimed, are the greatest forage producers in the State. The one great factor limiting their maximum production is an excess of water. The reclamation of these lands is a comparatively quick, safe, and permanent aid in increasing food production. It offers great opportunities for rapidly establishing returned soldiers in profitable agricultural enterprises.

On the John Jacob Astor Branch Experiment Station near Astoria the Oregon Agricultural College Experiment Station has some fifty acres of dried tide land for which a tile drainage system was designed in 1915, that has since been partly installed. This bulletin is written to describe the installation and operation of under-drains on this branch experiment station; to point out the best methods of marsh-soil improvement that are to follow drainage, as indicated by experiment and experience; and to advise and encourage the reclamation of these lands where feasible. About one-third of these marsh lands has been provided with the larger type of protecting works such as levees or outlet ditches. Almost no under-drainage has been provided for the tide lands, although this treatment will double the production of most of these wet pasture lands. Under-drainage, in short, will make it possible to kill out the rushes, grow legumes, and mature cultivated crops so that crop rotation can be practiced.

The climate of Western Oregon is coastal in character. In the Southern coastal region of the State the precipitation averages about 70 inches a year, and it gradually increases to 100 inches or more near the north coast, in the vicinity of Astoria. Following up the Columbia River there is a decrease in precipitation with a normal of about 45 inches yearly precipitation at Portland. The bog lands in the Willamette Valley are in a section where the climate is somewhat more seasonal, but like the coast climate, is characterized by rainy winters and fair summers of moderate temperature with comparatively high relative humidity. The growing season between killing frosts in the Willamette Valley is about 200 days, while on the coast it is nearer 250 days, a remarkably long growing season. The region is free from high winds and much more free from injurious frosts than are most marsh lands.

II. Marsh Soils

Marsh soils usually contain a large amount of organic matter, giving them a peaty character. Such soils, therefore, are usually light in weight, dark in color, and very spongy. They take up two or three times their weight of water and shrink upon drying. When dry, such soils usually possess a loose, dusty character.
Tide Land. Tide lands occur as deltas or flat bottoms along the rivers and estuaries influenced by tide water. The rise and fall of tides causes these streams to back up and overflow at high water, when their sediment is deposited along these bottoms. The coarser material is deposited first, or near the stream, giving rise to what is locally known as "bank land." Such land may be built up to the extreme high-water mark. Mud flats about the deltas are built up until they are exposed to the air part of the time, and water-loving vegetation gains a foothold. When this land attains an elevation above mean tide it may be considered for agricultural reclamation. The vegetation before diking consists of tussocks, rushes, sedges, sphagnum moss, and various other water-loving growths. These lands are usually cut by very irregular tide sloughs, leading from the low parts of the tide flat out through the bank lands into the open water.

The soil of typical tide land is a silty muck, containing usually about 30 percent organic matter in addition to some inorganic material in the form of fine sandy silt. Fine sandy streaks may be encountered in subsoil at depths of four or five feet, forming favorable layers in which to lay drains. Layers of vegetable matter from former sphagnum moss may be encountered in the subsoil, while the surface soil usually has a fibrous peaty structure.

Overflowed or Bottom Land. At some distance from the coast, as a slight elevation is attained, the effect of the tide is of minor importance and the soil grades gradually into silt loam. Dark silt loam is the prevailing type on the Columbia River bottom and other stream bottoms of that region, but there is fine sandy loam on some of the river-bank land, and occasional layers of silt are encountered in the beds or margins of shallow ponds, lakes, or sloughs. Some bodies of peat occur, as they do near Clatskanie. The undrained land of this type may contain 20 percent of open water, though under average conditions these ponds are found to recede to small dimensions in dry weather. Perhaps 15 to 25 percent may be covered with spruce, vine maple, willow, steeple brush, and other growth that requires clearing and grubbing before being cultivated.
In the unreclaimed state this land is utilized for pasture from about the first of July until November. In normal times it pays interest on $40.00 to $60.00 an acre valuation. The same land when reclaimed should yield four tons of field peas and oats or an equal tonnage of alsike and timothy hay as well as good crops of cereals, corn, potatoes, etc. The soil is deep and fertile, and, when utilized for forage crops in connection with dairying, it will safely pay interest on a valuation of $150.00 to $200.00 an acre. Under favorable conditions, especially near Portland, there will be an increasing demand for this land for truck crops, which may pay interest on twice the valuation that dairying would justify.

Peat and Muck or “Beaver Dam.” Peat and muck bogs occur in small areas aggregating several thousand acres, mainly in the lower Willamette Valley. The central portion of these bogs is usually filled with peat of medium to good depth. Shallow peat, loam, or silty clay loam, may occur around the margin of these bogs. The central part or marsh area commonly has considerable in-wash in the surface layers so that a fairly well-balanced soil has developed. The peat soil is rather free from raw, coarse peat material and rapidly becomes finer with cultivation. Cat-tail and bullrushes may occur on the deep peat in the native state, while the growth on the silty peat or muck is likely to be a mixed growth of willow, vine maple, alder, and hard-hack. The land in the raw state is therefore of very low productive value, but when reclaimed and brought into full production it is very valuable for onion growing and general truck or forage production.

Chemical Composition. The total supply of organic matter and nitrogen is usually high in these soils, although the nitrogen may be somewhat unavailable in new land. The phosphorus content is about the average, though in some soils it seems to be a little below the average and rather unavailable so that super-phosphate is used commercially by truck growers on the “beaver dam” soil. There is a good supply of potash in much of this soil on account of the large amount of silt in-wash. Some of the soils have shown indications of responding to potash fertilizers, which might be used with success on the deep peat under certain conditions in normal times. The chemical reaction of most of these soils is somewhat acid. With good drainage, however, the organic acids are removed or their
accumulation prevented so that very abundant crops are secured without liming. Tide lands in the vicinity of Astoria have responded to liming where Alsike clover was grown while the “beaver dam” soils, in some instances, have not responded to the treatment. Numerous specific tests of the overflow land indicate that lime is not badly needed on this land, where thorough drainage is provided, at least during the first years after reclamation.

Altogether these soils are deep, generally free-working, and possess high usable water capacity. The total supply of plant food is good and fairly well balanced for peaty soils and they are generally very productive when drained. The results of several analyses by the chemists of the experiment stations made from representative samples of the marsh areas above described are given in the following table:

**TABLE I—CHEMICAL COMPOSITION OF MARSH SOILS**

<table>
<thead>
<tr>
<th>Locality</th>
<th>Soil</th>
<th>Total Nitrogen</th>
<th>Phos. (P₂O₅)</th>
<th>Potash (K₂O)</th>
<th>Reaction or Loss on Lime Requirement A. ft.</th>
<th>% Loss on Ignition</th>
<th>Sulphuric Acid (SO₃)</th>
<th>Authority</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coquille (overflow)</td>
<td>Peaty soil surface</td>
<td>.14</td>
<td>.75</td>
<td></td>
<td>3,000 lbs.</td>
<td></td>
<td></td>
<td>U. of Cal. (acid anal.)</td>
</tr>
<tr>
<td></td>
<td>Silt muck surface</td>
<td>.14</td>
<td>.71</td>
<td></td>
<td>Very acid</td>
<td></td>
<td></td>
<td>U. of Cal. (acid anal.)</td>
</tr>
<tr>
<td>Astoria Tide Land</td>
<td>Exp. Sta.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Surface</td>
<td>.65</td>
<td>.28</td>
<td>2.14</td>
<td></td>
<td></td>
<td></td>
<td>Ore. Exp. Sta. (tot. anal.)</td>
</tr>
<tr>
<td></td>
<td>Subsoil</td>
<td>.43</td>
<td>.20</td>
<td>1.98</td>
<td></td>
<td></td>
<td></td>
<td>Ore. Exp. Sta. (tot. anal.)</td>
</tr>
<tr>
<td>Clatskanie Projects</td>
<td>Peat</td>
<td>1.05</td>
<td>.25</td>
<td>1.55</td>
<td></td>
<td></td>
<td></td>
<td>Ore. Exp. Sta. (tot. anal.)</td>
</tr>
<tr>
<td></td>
<td>Subsoil</td>
<td>.90</td>
<td>.22</td>
<td>.49</td>
<td></td>
<td></td>
<td></td>
<td>Ore. Exp. Sta. (tot. anal.)</td>
</tr>
<tr>
<td>Tillamook Tide Land</td>
<td>Peaty muck surface</td>
<td>.78</td>
<td>.31</td>
<td>1.05</td>
<td>15,840 lbs.</td>
<td></td>
<td></td>
<td>Ore. Exp. Sta. (tot. anal.)</td>
</tr>
<tr>
<td></td>
<td>Second foot</td>
<td>.33</td>
<td>.22</td>
<td>1.37</td>
<td>2,160 lbs.</td>
<td></td>
<td></td>
<td>Ore. Exp. Sta. (tot. anal.)</td>
</tr>
<tr>
<td>Beaver Dam</td>
<td>Virgin</td>
<td>1.56</td>
<td>.26</td>
<td>.14</td>
<td></td>
<td>63.95</td>
<td>.23</td>
<td>Ore. Exp. Sta. (tot. anal.)</td>
</tr>
</tbody>
</table>
Feasibility Surveys. The length of dike per acre enclosed is less for compact areas or where only part of the boundary requires embankment. Feasibility of a project depends on location, demand for land, time and cost of reclamation, soil fertility, and probable agricultural value, as well as practicability of engineering features.

The Oregon Experiment Station, at the request of land owners has made preliminary agricultural and engineering surveys to determine the feasibility of most of the marsh reclamation proposed in the State or undertaken during recent years. This work has been handled by the department of Soils in cooperation with the department of Irrigation and Drainage Engineering. The U. S. Department of Agriculture topographic maps, or harbor and river maps, are available covering much of this region and these, together with the ownership maps and other data in the local county records, were used as a basis for field work. High- and low-water marks, definitely established bench marks, and tide tables were referred to as well as the weather bureau data for the areas. The Engineering field work usually consisted of selecting the location for the outlet ditch or protecting dike, and then running a survey over the route and developing data for estimates, for protecting works such as dikes, sluice boxes, pumping plants, and outlet ditches.

The Agricultural survey is usually carried out at the same time to determine the kind and extent of various soils in the area, the composition of the chief soils, their drainage qualities, or amount of field and under-drainage required, suitable types of agriculture, and probable agricultural value of the land when brought into full production. The entire cost of the improvement as compared to the total productive value of the land with and without drainage is considered in arriving at conclusions concerning the question of feasibility. These surveys help to establish credit for meritorious projects and have led to the organization and construction of numerous feasible projects. Assistance has frequently been given in drainage-district organization through the Extension Service of the College.

Constructed Projects. Perhaps one-half of the reclaimable marsh lands in Western Oregon have had the larger protecting works, such as levees and outlet ditches constructed. There are numerous other feasible projects contemplated or under process of organization. In fact, nearly all
the above-mentioned areas of marsh lands are reclaimable. The lands already diked are in need of further interior drainage and in many cases some supplemental pumping to perfect their reclamation.

Diking by hand began in the vicinity of Astoria as many as thirty years ago. About 12,000 acres has been diked in Clatsop County. Old levees are found also in other parts of the coast where dredges have been used for dike construction for many years. Several thousand acres have been enclosed by the dikes established near Clatskanie. Some interior drainage and pumping plants are in use there. Outlet ditches have been built on two districts containing some 3,000 acres of overflow land in Coquille Valley. A project of 2,300 acres near North Portland is being diked, and was partly protected and planted to crops for the first time the past season. A tract of 2,200 acres near Troutdale has also been closed in, and is being rapidly brought into intensive cultivation.

**New Projects.** Between these two projects is an area of about 7,000 acres of dikeable land which is organized, and authority has been finally secured to proceed with the construction of its protecting works. This land is similar to the Sauvie Island Project twelve miles below Portland, which is estimated to cost $30.00 an acre, and would reclaim some eleven thousand acres of overflowed land. The Deer Island Project contemplates constructing a levee near the edge of Deer Island extending around the island and also including a fine body of mainland which would be enclosed by a semicircular dike. Pumping plants will be required for most of these projects. The total cost of the Deer Island Project is estimated at less than $30.00 an acre. These lands have paid interest on perhaps $40.00 to $60.00 valuation for late pasture. Perhaps 10 to 20 percent of these areas is open water, and a similar area is brush or uncleared land. The remainder is practically ready for the plow. These lands when reclaimed should produce four tons of peas and oats, or of alsike and timothy hay, as well as good yields of cereals or cultivated crops. The soil consists of deep, dark, and fertile alluvial deposits. If used for forage crops in connection with dairying, these lands when reclaimed should safely pay interest on a valuation of $150.00 to $200.00 an acre, and, as nearby markets develop,
would become more valuable in favored locations for garden truck, and because of the rather free-working, early character of the soil, particularly on the high ground adjoining the sloughs. Water can be pumped from these sloughs for supplemental irrigation late in the season with the same works that control the seepage during the June freshet. There are numerous other areas of marsh land in Multnomah, Columbia, Clatsop, Coos, and the other counties which can be reclaimed or doubled in production by drainage. A large part of this land is capable of being brought into a good state of production in one or two years after drainage. (2)

IV.—DRAINAGE DISTRICT PROCEDURE

To secure a community outlet ditch or dike where many owners are concerned it is necessary to have a practical district drainage law and to organize into a drainage district the locality to be benefited. Such a law has for its object the construction of outlet drains for the community through cooperation of the owners benefited and of meeting the cost by equitable assessment.

The principles involved in the undertaking are: (a) it must be cooperative and optional, (b) it must be for the public welfare, (c) the assessments must be adjusted in proportion to benefits, (d) the right of way must be paid for, (e) the owner must have the right to appeal and secure equitable assessment, (f) the right of outlet must be perpetual and attached to the land title, (g) the drainage tax should be a first lien on the land.

Oregon Drainage Laws. A modern drainage district law was adopted in Oregon in 1915. The principal features of the law are as follows:

(a) The owners of 50 percent or more of the acreage in the proposed district must petition the county court, which has general supervision of the drainage districts, for the organization of a district. The petition must contain the name of the district, approximate acreage, and the names of land owners within the district. It must indicate the general plan of reclamation and state that the drainage proposed is regarded as feasible.

(b) A formal notice of petition and of hearing must be sent by the county clerk to all the land owners. The county court then considers the petition and any objections filed, and thereupon establishes the district or dismisses the petition.

(c) After approval of the petition the county clerk calls a meeting of the land owners for the purpose of electing a board of three supervisors who are land owners in the district, to have general charge of the enterprise, and to hold office as determined by lot from one to three years or until their successors are elected and qualified.

(d) The board elected has power to appoint a drainage engineer and to levy a tax of not over a dollar an acre for the purpose of paying expenses
incurred or to be incurred in organizing the district. The board files with the county clerk a plan of reclamation prepared by the engineer and may petition the county clerk to alter the boundaries of the district. The board is required to keep a record of its proceedings.

(c) The county court appoints three commissioners, who are disinterested land owners, to make the assessments of benefits and damages and file a report with the county clerk.

(f) Property owners are notified of this report by publication and may file exceptions with the county court.

(g) The drainage board must levy the assessments, let contracts, secure the construction of all drainage work; they must issue bonds and collect the assessments in annual installments. They may also levy maintenance tax and define terms whereby existing drains may be connected to the ditches in the district.

The new law places the important work in the hands of the land owners who are directly interested. It is believed by good attorneys that the new law will be found adequate and clear in the methods of organization, administration, and maintenance of reclamation districts, and it is proving thoroughly practical.

The law provides that bonds may be issued to distribute the expense of providing outlet ditches over a period of years, during which time the increase in yield from drainage should be ample to provide a sinking fund for retiring the bonds.

Where a few persons all agree to drain, they may petition the county court and undertake drainage on their own responsibility.

A Successful Drainage District. The Tillamook district was the first to be organized under the 1915 law, and since it has been carried to completion, is used herein as an example. At the request of parties interested, through their County Agriculturist, the writer, accompanied by Mr. G. A. Hart, Engineer of the U. S. Office of Drainage Investigations, made a preliminary examination of the districts on May 15, 1915. The tract, a mile or so wide and a mile and a half long, shown in Figure 23, is located just south of the City of Tillamook and includes a marshy area too wet to afford much pasture. The soil below the tenth contour is peaty muck underlaid at a depth of five or six feet by blue clay. Silt loam covers the remainder of the bottom land, while a gravelly loam extends over the bench. The rainfall is perhaps seventy-five inches a year. Preliminary levels and soil examinations were made to determine the feasibility of the drainage and a canvass was also carried out to determine the sentiment of owners in regard to the organization of the district. Very little opposition was encountered, and as the soil and topographic conditions were favorable it was decided to make application for the organization of a drainage district.
Organization. A petition was prepared and notice of hearing issued under the district law. (8)

In June, Mr. Hart returned and made the field survey, with assistance furnished by the district, and prepared a plan of reclamation indicated on the map of the district illustrated in Figure 23. Poor drainage and the shallow water table were due to lack of outlet. The present purpose of the new drains is to remove the winter flood water quickly in the spring and supply outlets for the individual tracts. The main ditch and the several laterals were laid out with a mean depth of about six feet.

Construction and Cost. In the Tillamook district there were 698.81 acres, each acre of which was assessed the number of drainage points corresponding to the amount of benefit. The total drainage points as shown by the assessment list for the district were 41,302. These were assessed five cents per point; raising $2,065.10. The total cost of installing the outlet drains amounted to $1,612.57, leaving a balance of $452.56 in the treasury to be used for maintenance. The construction work was carried to successful completion in the summer and fall of 1915. The various items of expense were as follows:

<table>
<thead>
<tr>
<th>Item</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Attorney fees for drafting petition</td>
<td>$ 50.00</td>
</tr>
<tr>
<td>Engineer and helpers</td>
<td>$ 38.19</td>
</tr>
<tr>
<td>Advertising</td>
<td>$ 50.00</td>
</tr>
<tr>
<td>Excavating new ditch and repairing</td>
<td>$ 890.88</td>
</tr>
<tr>
<td>Old ditch used by drainage district</td>
<td>$ 463.50</td>
</tr>
<tr>
<td>Three commissioners, one day</td>
<td>$ 15.00</td>
</tr>
<tr>
<td>Clerk, one day</td>
<td>$  5.00</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>$1,612.57</strong></td>
</tr>
</tbody>
</table>

Results. The secretary of the Tillamook Drainage District writes that they have found the new law adequate and practical. The increased crop yields of the district returned the total cost of the improvement during the first year. As the cost was only about $3.00 an acre, the expense was handled on a cash basis without issuing bonds. Several owners in the district have completed their field drainage by supplementary under-drains since the outlets have been provided.
V.—DIKE LOCATION AND CONSTRUCTION

Cooperation is important in order to get the largest enclosure with the shortest dike. Dikes should be located on land of relatively good elevation where possible; should run at right angles or parallel to the stream; and should have a wide fore-shore, or strip of land on the outside to break the force of the stream. Natural brush protection can be taken advantage of if a hydraulic dredge is used. Soft slough bottoms and deep peat or coarse sand are not desirable materials for making embankments. A location can frequently be selected that will avoid running the embankment through such formations. Heavy silt or silty clay are desirable embanking materials.

Construction. It is generally recommended that the top width of a levee should be twice the square root of the height, and that it should be carried three feet above mean high tide. The side slope for good silt should be three of run to one of rise on the water side. In sandy soil or under windy locations, four to one is better. Fine sandy loam or muck can be used for embankment successfully where it is sluiced in with a hydraulic dredge or deposited in a saturated condition with a dipper dredge. It is desirable, especially with peaty surface soil, to provide a muck ditch, by removing the original earth from the center of the dike line to a depth of two or three feet, and then start to build the dike with excavated subsoil material so that the dike is keyed in at the center. Logs, sod, and vegetation should be removed, and it is desirable to plow and remove the surface soil ahead of the embankment construction. The muck ditch can frequently be dug by means of the dredge dipper where all vegetation and logs have been removed, and scalping off the surface soil may be neglected. Where the hydraulic dredge is used it may be desirable to clear a muck ditch and leave the growth on the sides of the proposed levee to protect against erosion. In crossing an old slough it is desirable to remove the muck in the slough and form the sides at the base of the new levee with piling. Shrinkage of the dike should be allowed for in any case. This will be greater in peat than in silt. Peat may shrink as much as 25 to 33 percent. Where there are numerous tide sloughs, and the seepage is anticipated, a barrow pit may be provided inside the dike to intercept seepage and lead small streams to a sluice box, thus reducing the number of boxes.

The earliest dikes constructed in the vicinity of Astoria were built by hand labor, and a good spade man was considered capable of building a rod a day. Most of these dikes have been strengthened by dredge work since
that time. The floating dredge with a boom 80 to 100 feet long is desirable; it should puddle the levee in depositing saturated material. Some contractors on the coast prefer the dipper dredge, where small stumps are to be handled. In normal times the common price for this work has been about ten cents a yard. Suction dredges have been used on the Columbia River during recent years at a considerable saving per yard over the floating dredge fitted with boom and dipper. The illustrations (Figures 6 and 8) show the two types of dredges. Both represent dredges in use on the lower Columbia.

Maintenance. The embankment can be smoothed down with scrapers and in two or three years can be seeded over so as to afford good pasture. The presence of stock will tend to keep out rodents and pack the embankment, while the sod will protect from erosion. Where the embankment is subject to wave action, rip-rapping with stone or lining with rows of piling to which a chain of logs is attached will usually afford protection.

Tide Boxes. The primary consideration in providing a tide box is to allow ample capacity. Failure to do this has resulted in dissatisfaction and loss. Inquiry into the capacity of tide boxes in the vicinity of Astoria and a study of the areas served by boxes considered of ample capacity, developed the fact that an area of about 12 or 13 acres was being drained for each square foot of tide box. These sluice boxes should be strong, tight and firmly placed. They should be located on a firm foundation and be provided with piling to which mud sills are bolted at mean low tide. Wing walls should be provided extending well into the levee banks. The gate should be counterweighted to move easily and should seat tight. Tongued and grooved piling can be used to coffer-dam the water while the pit is being excavated for a small tide box which can finally be set at the time of low tide. The larger boxes can be installed with the aid of a dredge at the time of favorable tide. It is recommended that the gate be made to fit tightly by use of good rubber belting, that the hardware used be galvanized iron or hard brass with link hinges for the gate. Where the fall is more than the amount needed, and the land within the area served by the sluice boxes is low, it is frequently desirable to allow the turbid hill water to spread out over the low area and deposit silt. Water can then be siphoned off, by having the upper end of the sluice box carried above the surface of the ground so as to draw off only the clear water, as illustrated, Figure 14. Creosoting will protect lumber from deterioration.
Outlet Ditches. Marshes on the coast and the lower Columbia do not frequently require any extensive amount of interior open ditches. An upland stream may enter and spread out on the marsh or traverse it in a meandering course. A large stream may require dredging to straighten or banking of the sides to carry the water across the marsh to the open water on the outside. A small foothill ditch will frequently serve to pick up the hill water along the margin of the marsh, and deposit it by gravity or through a separate sluice box at the end of the dike. In such a ditch settling basins may need to be provided for deposition of silt brought in from the hills. Some marshes in the Willamette Valley require an outlet ditch through the trough of the marsh and smaller foothill ditches around the marsh borders. Outlet ditches should be made of ample depth to provide for the discharge from tile and should have broad side slopes. They should be reasonably straight, and have as uniform a grade as practicable. The size of the ditch may depend somewhat on the grade. In most of the marsh land the fall will be limited and the size will depend mainly upon the amount of water to be handled. This is affected by amount and distribution of rainfall, weather conditions, topography, the size of the watershed area, the nature of growth, and kind of soil. The dredge used for the embankment will generally be used for interior ditches, unless perhaps a smaller one is required. A dredged ditch can not be made narrower than six to eight feet. Attention should be given to these interior ditches to guard against erosion or caving and injury by stock.

Pumping Plants. The mean tidal fluctuation on the Pacific Coast is but five to seven feet. On the lower Columbia only a few hours occur between the tides during which sluice boxes may operate. Again, much of the marsh land is within three feet of the mean water level outside and complete drainage for such conditions requires some pumping. The
A centrifugal pump is most used for this purpose, as it is light, simple, and handles large quantities of water. Pumps for drainage should be set as low as possible while still keeping them above water. A concrete base should be provided bearing threaded anchor bolts with nuts below base plates for leveling up before completing the concrete work. The suction and discharge pipes should have few turns and these should be of large radius. The pipes should be no longer than necessary and should discharge at as low an elevation as possible to save power. The supply ditch will usually be a large tide slough which provides some storage capacity and this should be screened at the approach to the intake pipe. Modern pumps have double suction and split casing; provision should also be made for priming. The capacity required may vary from one-fifth to four-fifths of an acre inch to the acre in twenty-four hours. One-fifth to one-fourth of an inch has been found ample capacity for diked bottom land in the vicinity of Portland. The capacity may be somewhat less for meadows than for crops that require complete drainage for maturity, such as potatoes and onions. Where electricity can be obtained at a moderate rate, a direct-connected motor in conjunction with the centrifugal pump makes a very satisfactory installation and requires very little attention. Where electricity can not be obtained, gasoline or distillate engines may be employed. A small portable pumping outfit may be located on a barge and used for drainage or supplementary irrigation.

Cost of pumping includes (1) fixed charges, such as interest and depreciation on the first cost of the plant; (2) operating expenses, including labor, fuel, and lubricating oil, which collectively make up the total annual cost. This cost distributed over the area would give the total annual cost per acre for pumping. Pumping plants will be used more and more in connection with drainage and supplementary irrigation on the peat and overflow lands of the Portland district, and as a supplement to the sluice boxes to provide complete drainage near the coast.

Very little interior drainage has been provided in diked lands and almost no under-drainage has been employed. On the tide lands an occasional box under-drain has been installed. The tile drainage system on the Branch Experiment Station at Astoria is, so far as can be determined, the first thorough tile system to be installed on tide land. The experimental part of this drainage system is shown in Figure 15. In order to illustrate the problems to be encountered in draining such land and to explain the
preliminary results of the experimental part of the system, its installation will be described.

In laying out this drainage system the existing sloughs were all sketched, and these were taken into consideration in laying out the system for the main body of the farm in a random or natural system of drainage applicable to ordinary farm conditions. A soil auger was used to study the subsoil and ground water conditions, so as to locate drains where they would serve most efficiently.

Excess water on this tide land comes from (1) run-off from the hills and related springs near the base of the uplands; (2) seepage through the dikes; (3) excess ground water due to precipitation on the low land itself. It was decided to run a main drain along near the inside of the dike to intercept seepage that appeared to be taking place there. This also led to small tide sloughs which had been closed off in constructing the dike, and contained standing water all summer, due to lack of outlet. Laterals were arranged to take up these sloughs, and a foothill ditch and under-drain were arranged to intercept the water from the upland. Additional laterals were placed at fairly regular intervals to serve the remainder of the low interior fields.

**Design of Under-drains.** The first step in designing a drainage system should be an examination or preliminary survey with the aid of a soil auger and level. The object of the examination is to learn the subsoil and ground-water conditions; to determine the lay of the land and location of outlets; to aid in design of a drain system. In arranging interior tile systems for tide land, where the field is broad, and low in the center, the main may be run through the center of the marsh and laterals may be brought to it from both sides. Where low near the hill, and subject to seepage from the levee, drains of good capacity can be put along the edges of the marsh near the dike and at the base of the hill, and the laterals led to these mains. In the Branch Experiment Station drainage system, a section was arranged to determine the best depth and distance apart for laterals by experiment.

In designing field drains for overflowed land, it may be necessary to carry an open ditch or tile along inside of the levee to collect seepage, and connect up the small depressions and sloughs leading the excess water to the pumping station or sluice box. Where there is little seepage, the interior drainage on the overflow land will usually be only a random, or natural, system of drains to take care of the swales and depressions.

The ordinary beaver-dam bogs will require an outlet ditch through the trough or center of the bog and a foothill ditch or tile line around each side. From these, parallel laterals may be run in such directions as will
FIG. 15.—EXPERIMENTAL SECTION OF BRANCH EXPERIMENT STATION DRAINS

thoroughly drain the interior or remainder of the bog most economically, with the least expenditure for junctions, double-drainage, or outlets. While the outlet ditch and foothill ditch may give sufficient drainage for pasture and meadows, if augmented by an open ditch at intervals of 300 or 500 feet, this will not permit complete drainage. To grow such crops as onions and potatoes properly, and draw off the water quickly in the spring, so that early planting can be accomplished, additional laterals three to five rods apart, arranged in parallel series, will be needed in such land.

Experiments Relating to Depth and Distance Apart. As the under-drainage of tide land is comparatively new, it seemed desirable to arrange a section of the drainage system on the Branch Experiment Station into an experiment to determine the proper depth and distance apart for placing laterals in tide lands. Laterals were accordingly arranged at a depth of about four feet and spaced 100 feet apart; others were placed three and one-half feet deep and seventy-five feet apart; while still other laterals were placed three feet deep and fifty feet apart. Sufficient laterals were placed in each trial to provide one interior or guarded lateral, the discharge of which could be measured. It was planned to measure the discharge of

19
FIG. 16.—METHOD OF USING GRADE LATH

each of these guarded laterals, together with the outflow from the entire experimental system, and also the distance to which these tile lines, placed at different depths and distances apart, would affect the water table in a reasonable length of time after heavy rains. The water table is being studied by means of a row of observation wells extending across the tract at right angles to the experimental laterals. The tract is divided into plots in order to determine the yields of crops grown on the plats having laterals at greater and lesser distances apart. The preliminary data obtained are given in Table IV.

From the preliminary results at hand, it appears that fairly good drainage will be provided where the tile lines are placed four feet deep and five rods apart. Where this depth of outlet can not be obtained, it may be necessary to put the tile lines three feet deep and four rods apart to accomplish the same purpose.

In the overflow land, parallel laterals are not likely to be needed. Here, only a random system of drains will be needed, running through the main swales and ponds at a depth of three to three and one-half feet.

In the peat, or beaver-dam land, fair drainage for grasses may be provided with open ditches from 300 to 500 feet apart and five feet deep. To enable early planting, however, and to bring this land into full production, or to obtain complete drainage for the ripening of crops such as onions and potatoes, it has been found desirable in practice to have laterals three and one-half to four feet deep and three to four rods apart, and in addition, to take care of any seepage or spring water not collected by such parallel laterals. Four feet is a good minimum depth, as peat soil may shrink one-fourth of its volume, due to more rapid disintegration following drainage. If the water table recedes below the tile base, such shrinkage is more apt to interfere with the grade of the tile line. Flash boards may be used to raise the water in drains and cause sub-irrigation at intervals.

Studies Relating to Size and Grade. The size and grade for tile are closely related to the depth and distance apart, and are affected mainly by (1) character of soil and subsoil; (2) amount and distribution of rainfall; (3) topography and amount of run-off; (4) kind of crops; (5) prevalence of underground water, and (6) the grade. Experiments by the experiment stations in the Willamette Valley and on the coast, where the outflow from different tile systems has been measured, have developed a standard of one-half inch to the acre in twenty-four hours as providing good drainage capacity under Willamette Valley conditions, unless there is additional spring water or some unusual condition to contend with. Pumping plants on the overflowed land having capacity to handle one-fourth inch or one-fifth inch of water in twenty-four hours are considered to have fair capacity where operated regularly and for sufficient intervals of time. From preliminary data at hand, it appears that the main tile on tide lands on the
North coast of Oregon should have capacity to handle an inch to the acre in twenty-four hours. On the South coast, three-quarters of an inch to the acre in twenty-four hours should be a reasonable capacity, on account of the lesser rainfall.

The following table shows the number of acres from which one-half inch of rainfall will be removed in twenty-four hours. If one inch capacity is desired, the area may be reduced one-half.

**TABLE II—CAPACITY OF MAIN DRAINS (1,000 FT. IN LENGTH)**

<table>
<thead>
<tr>
<th>Tile, Diameter, Inches</th>
<th>Fall in Feet for Each 100 Feet</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.00</td>
</tr>
<tr>
<td>Acres of Land Drained</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>8.8</td>
</tr>
<tr>
<td>6</td>
<td>14.6</td>
</tr>
<tr>
<td>8</td>
<td>28.8</td>
</tr>
<tr>
<td>10</td>
<td>50.0</td>
</tr>
<tr>
<td>12</td>
<td>76.1</td>
</tr>
</tbody>
</table>

Where laterals are of considerable length, or where they encounter sloughs or springs, they should be made of five-inch tile. The length of such laterals may be as much as 800 to 1,000 feet. Four-inch tile may be used for short laterals where there is plenty of fall, or where laterals are arranged in parallel lines and placed true to grade on solid ditch bottom.

**Grade.** The greater the fall, the greater is the capacity of the tile line. Lateral tile of four- and five-inch diameter must have a fall of one-fourth inch to the rod. Usually the fall should be twice this amount, or two-tenths of a foot for each hundred feet. A lateral run across a springy slope to intercept the water should have four to six inches fall to each hundred feet, in order that the water will go through the tile instead of with the slope of the land. When a grade is carefully fixed with the leveling instrument, which should always be used when the fall is less than three inches for each hundred feet, large tile may be laid with a fall of as little as one-
eighth of an inch to the rod, or five-hundredths of a foot, to each hundred feet. It is desirable to avoid changing from a steeper to a lesser grade, but if such a change is necessary, a silt basin should be installed. On the tide land there may be no slope in the land surface, and the grade for the drain may have to be obtained by placing the tile deeper at the outlet and shallower at the head. In the experimental tile system at the Branch Station near Astoria, the main drain is practically six feet deep at the outlet, while the upper end of the most distant lateral is less than three feet deep. The elevation of the land near the outlet is about one foot higher than in the most remote parts of the drainage system, which are at a distance of 1,200 feet. The fall used for the main drain is .16 of a foot for each hundred feet, and the laterals have a fall of .2 of a foot for each hundred feet.

VII.—CONSTRUCTION OF UNDER-DRAINS

Underdrainage on marsh land can best be installed in the dry season, except where special conditions make other seasons suitable for the work. The whole system should be designed with the aid of a soil auger and a surveyor’s level at a time when the excess water can be observed.

Accurate data and good construction are necessary to secure the highest efficiency in a drainage system, and unless there are several inches fall for each hundred feet, levels should be run for each line. In permanent surveys for drains, stakes are set every hundred feet, beginning at the outlet, so that tile can be carefully laid to calculated grade. Where a small amount of leveling is needed, a carpenter’s level provided with sights may be used, or a piece of garden hose with a glass tube fastened at each end may be used, and sights taken across the water level in these tubes fitted into the upturned ends of the filled hose.

Getting the Tile. The survey should determine accurately the number of feet of tile required. Size can be determined, a tile bill prepared and bids secured. It is best to order in carload lots, and haul directly from the car to the point of use by wagon or boat.

Digging the Ditch. A cord should be stretched along the side of the stakes, so that the ditch may be started in a straight line. The use of the plow for opening the trench is advisable only in tough sod. A three-foot ditch can be made by two spadings with an 18- or 20-inch square-pointed tile spade; the ditch should be eleven to twelve inches wide at the top. A round-pointed tile spade may be used for the last spading, and care must be taken not to dig below grade. The shovel and tile scoop are then used, leaving a firm, smooth tile base that is true to grade.
Use of Grade Line. A line is placed over the grade stakes where elevations have been obtained, and grade is calculated at a uniform or even distance above the proposed tile base. If the grade line is five feet above grade, the ditch should be trimmed out until five-foot gage sticks will just reach from the string to the bottom of the trench when held in a vertical position. To set the grade lath at a proper height, therefore, subtract the depth of the cut at a given station from the length of the gage to be employed. Gage laths may be set across the ditch or at one side, with a cross-arm extending out even with the edge of the trench. A No. 18 galvanized wire makes a good gage string, being light, strong and durable. In cutting through high ridges, a longer gage may be required. The gage line should be kept tight. The following table will be helpful in changing the survey figures from decimals of a foot to inches:

| TABLE III—EQUIVALENT VALUE OF INCHES AND DECIMALS OF A FOOT |
|-----------------|---------|---------|---------|---------|---------|---------|---------|---------|---------|
| Inch            | 0       | .01     | .02     | .03     | .04     | .05     | .06     | .07     | .08     |
| 0               | .00     | .01     | .02     | .03     | .04     | .05     | .06     | .07     | .08     |
| 1/4             | .25     | .26     | .27     | .28     | .29     | .30     | .31     | .32     | .33     |
| 3/8             | .38     | .39     | .40     | .41     | .42     | .43     | .44     | .45     | .46     |
| 1/2             | .50     | .51     | .52     | .53     | .54     | .55     | .56     | .57     | .58     |

As the drainage system on the Branch Experiment Station at Astoria is practically the first thorough tile system on such land, and as numerous difficulties are encountered in tiling tide lands, it seems desirable to describe the installation of this system in some detail. The drainage system was designed by the writer, and installation has been in charge of former Superintendent A. E. Engbretson, who describes the construction work as follows:

"The tide land has buried in it large amounts of logs and debris, especially in the older portions of the land. In digging, these are often met with and require considerable time in cutting. All logs should be cut entirely in two, even if partly below the tile base. In deep ditches, such as required by the main, the tile should be laid as soon as possible because of the fact that after a heavy rain the sides will move toward the center, thus making it very narrow. All tools should be sharp so as to cut the fibrous roots in the land."
"The tile base is of such a nature that it is inadvisable to stand on it while laying unless it be done promptly and in very dry weather. There is generally some water present and any walking will make the base soft and uneven. It is also unsatisfactory to stand on the tile while laying. This will cause them to be uneven and improperly placed. In order to avoid these difficulties a plain board 1 in. x 8 x 36 in. was beveled at one end and a strap for the toe was nailed on top. When laying tile, a person stood on this board and worked it back as the tile was laid. This left a smooth base on which tile could be properly laid.

"There are places in the tide land that are very soft. These are perhaps old slough beds that have been filled. Tile can not be laid on this soft bed. A plank 2 x 12 in. is sunk below the tile base so that it forms a solid, even base. Where these spots are not wide the ends of a plank should rest on firm ground. If they are wider, and two or more planks are necessary, blocks should be placed under the ends so that there will be no sinking. All places that are soft and seepy should be provided with planks underneath the tile base so that there will be no settling below grade."

All tide sloughs having water should be taken into consideration. For short, irregular tide sloughs a slab drain can be employed. Rails and tussocks can be placed in old sloughs after which they may be plowed full. For all the main drains where land is valuable it will be cheaper in the long run to use tile even though a slab has to be laid underneath to keep the tile in place.

Laying the Tile. Tile laying should begin at the outlet and proceed upgrade just as soon as the trench is finished to grade. A carefully finished trench facilitates laying the tile. Tile should be placed in a straight line and true to grade with ends fitted snug on top and flush at the inside lower edge. Openings of more than one-eighth inch should be covered with pieces from a broken tile. Tile may be rotated to fit, and imperfections may be taken advantage of in making slight turns. Curves may be fitted in by chipping off the inside edge of the tile with a chisel and hammer. The
Y’s for junctions can be constructed but it is best to buy them ready made. Use a board or plank under the tile wherever the tile base is in the least unstable. Guard against obstructions and disturbance of the tile by blinding in each evening during construction.

Filling the Trench. After the tiles are blinded in or partly hidden with loose earth it may be desirable in fine-textured soil to cover them with a layer of rushes, straw, or sods to facilitate the entrance of water into the drains. Rushes or sod placed over the tile will be very slow to decay and will prevent the joints from filling up with clay or silt. The trench can then be back filled by plowing off the sides with a plow equipped with long eveners so as to allow one of the horses to walk on each side of the trench.

Details of Construction. Outlets should be walled up and screened, or, if liable to inundation, should be provided with a flap gate, counterweighted so it will close out a back current. Laterals should be brought into the main drain with a curve and slight fall. Silt basins and surface inlets should be three feet in diameter so a person may enter to clean them out, and should be covered or screened.

Sub-irrigation. Flash boards may be provided in open ditches or tile lines where it is desirable to check the outflow for a couple of days every two weeks in the earlier part of the dry season to provide sub-irrigation.

VIII.—OPERATION OF EXPERIMENT SYSTEM

H. R. Taylor, the present superintendent, describes the operation of the completed portion of the drainage system as follows:

“Water Table. The difference between the effect of experimental laterals 380 ft. long and (Lat. B) 50 ft. and (Lat. C) 100 ft. from their neighbors was studied by means of borings or wells.

“Readings were taken during the last week in September before the fall rains. At that time the water table was at a depth of more than five feet. Wells were bored to a five-foot depth. Readings were made October 5, 1918, after a two-day rain, and on November 27, 28, and 29, during and after a storm period. Weather—October 4 and 5, rain; November 25 and 26, rain, heavy showers during the week previous; November 27, frost followed by clear weather; night of November 27 and 28, heavy showers; November 28, cloudy; November 29, clear. Readings in the following table are in feet and inches.”
In adjacent fields there was a considerable amount of water standing in pools on the surface. There was no water on the surface of the drained field.

Data for November 28 will also apply with fair accuracy to November 26 and November 27, as the outflow for those days was quite constant.

"Yield. On the drained field a crop of oat and pea hay yielded 5.1 tons to the acre. The best growth was made nearest the drains and the plants were shorter and the number was less per square foot in proportion to the distance from the drains. Adjacent to the main drain, the plants reached a height of over 6 feet; at the point farthest from the main, a height of 4 to 5 feet. An undrained field of oats and vetch adjacent to the drained field yielded approximately 2½ tons of hay to the acre but was a little 'patchy' on account of wet spots during the early spring."
Cost and Profit. Cost of drainage varies with kind of soil, size of tile, thoroughness of drainage, method of construction, and labor conditions. Box drains may be used for moderate-priced land and even open ditches may be used while the land is being reclaimed; but for good agricultural land tile will generally be most permanent and satisfactory.

After the tile system is designed and measured out, a tile list should be made. Table V shows the approximate normal price, and the weights of different sizes.

<table>
<thead>
<tr>
<th>Size in inches</th>
<th>Price per 1,000 ft.</th>
<th>Weight per ft. in lbs.</th>
<th>Average carload in feet</th>
<th>No. of ft. per ton</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>$24.00</td>
<td>4 1/2</td>
<td>7,500</td>
<td>400</td>
</tr>
<tr>
<td>4</td>
<td>29.00</td>
<td>6 1/2</td>
<td>6,500</td>
<td>334</td>
</tr>
<tr>
<td>5</td>
<td>40.00</td>
<td>9</td>
<td>5,000</td>
<td>250</td>
</tr>
<tr>
<td>6</td>
<td>52.00</td>
<td>11 1/2</td>
<td>4,000</td>
<td>182</td>
</tr>
<tr>
<td>8</td>
<td>75.00</td>
<td>18</td>
<td>2,400</td>
<td>111</td>
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<tr>
<td>10</td>
<td>100.00</td>
<td>25</td>
<td>1,600</td>
<td>80</td>
</tr>
<tr>
<td>12</td>
<td>130.00</td>
<td>33</td>
<td>1,000</td>
<td>60</td>
</tr>
<tr>
<td>14</td>
<td>220.00</td>
<td>43</td>
<td>500</td>
<td>56</td>
</tr>
</tbody>
</table>

In soil such as the silt loam on the overflow land lateral tile is commonly installed in Western Oregon for forty to sixty cents a rod, a price which frequently includes filling the trench. This is the price for a four-inch lateral placed three feet deep. For larger diameter of tile the price will increase five cents an inch, and for each additional foot of depth the price will increase about twenty cents.

The cost of tiling tide land is perhaps higher than on most other lands, due to the soft condition of the soil most of the year, the roots and logs encountered, and the lack of skilled labor for this work, which ordinarily must be done by hand. The time required to dig, lay and blind-in the main drain at the Branch Experiment Station for the average depth of 5 feet ran from thirty-two to thirty-five man-hours for each hundred feet. The laterals required twenty-one man hours of labor for each hundred feet of tile, placed at an average depth of three feet.

The profits from drainage come in increased yields, greater convenience in operation and higher land values. Diked lands in the drainage districts near Portland, which formerly were suitable only for late pasture, and which cost from forty to sixty dollars per acre to dike, produced this year the first crop after reclamation. The yield per acre from various crops was ten or twelve tons of corn fodder, thirty bushels of wheat, fifty bushels of oats, and truck crops which contracted at $100.00 an acre. This land when subdued rents for $30.00 or $40.00 an acre for truck farming where within the reach of Portland. Beaver dam land used for onions frequently rents for $40.00 an acre.

Drainage systems designed by representatives of the Experiment Station and Extension Service of the College in the vicinity of Tillamook have made it possible to change from the wild marsh growth to crops of hay yielding four tons an acre. The owners in different cases have reported that the increase in crop value the first year more than paid the entire cost of drainage.

Cost of the tile system as described will average about $25.00 an acre. The first crop, 5 tons field-pea hay to the acre, was double the yield on the portion not yet tiled. This crop was worth $25.00 a ton at local prices, so the cost of tiling was repaid in the first crop. Tiling will double the productive value of the greater part of the marsh lands in Western Oregon. Much of this land is already provided with protecting dikes for main outlet ditches, but is in need of tile.
A muck bog near Troutdale, containing seven acres, was drained, and the following costs submitted by the owner:

- Tile—5,000 feet of 3, 4, and 5-inch costing: $129.00
- Freight bill: 12.00
- Hauling of 12 loads at $2.00 per load: 24.00
- Digging 306 rods at 30¢ per rod: 91.80

Total: $256.80 or $36.70 per acre.

The owner states that until they drained the land they did not work the field on account of wet places. The drainage system was installed in 1912, and during the following winter the main ran full for several days at a time. The next year, according to the owner, the field produced $76.00 worth of potatoes to the acre. In 1914, the same field threshed out 64 bushels of oats to the acre. A stand of clover was obtained after drainage that had proved impossible before drainage. The owner says that the first two crops returned fully the cost of the improvement.

IX.—MANAGEMENT OF DRAINED MARSH LAND

Reclamation of marsh lands consists of three operations; namely, (1) construction of community dikes and outlet ditches, (2) field or farm drainage, and (3) subjugation of wild growth, removal of foreign material and preparation of the soil for cultivation. The normal average cost of these operations for wet soils of the United States according to government estimates, is $4.00, $8.00, and $5.00 an acre, respectively.

Our wet, marsh, and overflowed lands offer comparatively safe lines for development to increase food production or provide homes for returned soldiers. To be most successfully reclaimed such lands should be brought into a good state of production promptly to avoid accumulation of interest.
charges and to facilitate operation of tile. Frequently such lands return the entire cost of reclamation with the first crop.

Subduing the Land. Time, labor, and expense are required to eliminate trees, stumps, brush, stones, tules, or even coarse weeds from about 25 percent of these wet lands. Drainage may render saw timber or stove wood accessible and the sale of this material may help pay the cost of clearing. Brushing with an ax and bush scythe and stock may be practiced at times while stumps are decaying, and grass may be seeded in and the stumps allowed three to five years to decay before their removal. Stumps can then be removed by a stump puller or engine and cable, or they may be burned by directing the fire through an auger hole or pipe, as in a char-pitting furnace. Dynamite, carefully used, will crack the stumps and jar dirt loose after pulling, then they can be piled into tall, compact piles with a hoist, to facilitate burning.

The rank growth of tules or swamp growth may be subdued by carefully burning over the surface when the soil is wet so that fire will not extend below the surface. This overcomes the rawness of the soil; adds some available plant food; tends to prevent growth of moss and helps expose roots and logs, which may need to be removed before the land is cultivated. Open ditches for laterals will frequently be used during this process, and as the marsh settles, more permanent under-drains may be put in. These under-drains can be extended as needed to perfect the drainage, so that more intensive crops can be grown where climate and market facilities permit.

Cultivation. The use of a rush cutter or sled to which knives are attached, Figure 22, will aid in scalping off rushes on low lands. These can then be bunched up and burned before the land is plowed. A plow with a broad, sharp share should be used in breaking marsh sod. A twenty-four inch plow drawn by a caterpillar engine has been in use on marsh land at the Wisconsin Experiment Station. This outfit inverts the furrow more than in ordinary plowing, covers rubbish, and firms the soil so as to aid decay. Thorough disking is necessary to prepare a seedbed on new breaking. Peaty soil is loose when dry and a compactor, such as the double corrugated roller or multipacker, is necessary to firm the soil and bring moisture to the seed bed. Grasses should be seeded fairly early in the spring. A grass mixture can be seeded and brushed in on stump land to attract stock and afford pasture while stumps decay.

Choice of Crops. On peat land a mixture of alsike clover and timothy has been successful where seeded in the ashes after marsh vegetation is burned. Feeding out clover hay on the land has established alsike in some marsh meadows, without plowing up. A fairly permanent meadow can be established on low, wet areas by using a mixture of grasses such as blue grass, English rye grass, timothy, bent grass, and white and alsike clover.

On better-located areas after the first breaking, rank feeding crops like oats, barley, flax, or corn should be grown for a year or two and then alsike clover and rye grass will do well where the water table is at such depth as to maintain a moisture supply. Canary grass or bent grass will make excellent pasture, and both have been successful on the peat lands near Coquille.

Meadows should be harrowed when sod bound, and after several years they should be replowed and used for grain and row crops, such as roots, for two or three years, then seeded down again.

Thoroughly drained and subdued peat land, where located within reach of markets, is used for potatoes, celery, onions, roots, and even for leafy
truck crops which thrive only on soils rich in nitrogen. The cranberry is also produced in certain localities on this type of land.

**Fertilizers for Marsh Soils.** Salt, if present, will generally leach out in a year or two after sea water is closed out. Peaty soils are apt to be raw when first drained, and may respond to manure. When subdued, such lands usually have an abundance of nitrogen and humus, but frequently respond to applications of potash. Fertilizer trials on muck soils in different sections of Oregon have not shown much benefit from potash, but superphosphate and manure have frequently caused increased yields. Phosphorus is more likely to increase yields on acid marsh soils. Potash is more likely to benefit deep peat that has not received inorganic material by inwash from adjacent uplands. Manure will generally be beneficial but may be more profitably used on uplands while rotation with clover is used to maintain the organic matter on bottom lands. Lime is beneficial on some of the heavier-textured marsh soils and has helped alsike clover on silty muck and shallow peat.

In sticky subsoils it may aid drains to collect water where sods or tussocks are placed over the tile for bedding.

Clover should be grown on the reclaimed tide-marsh land every few years in rotation with grain and manured row crops. A decidedly larger relative outflow has been observed in the wet season following a clover crop and water has stood less on such fields.

**Care of Tile Systems.** Inspection and cleaning of outlets, sluice boxes, channels, silt basins, and inlets should be practiced before the season of heavy precipitation and after heavy storms. Any obstructions in tile lines should be located and repaired promptly. Watch the land and extend tile lines if necessary until they serve the entire wet area.

The treatments above described are calculated to assist in loosening up and aerating the drained soils and to assist water in entering the drains provided. Legumes and manuring crops suggested will also maintain the humus and nitrogen supply. This treatment would pave the way for cash crops and make it possible to get the highest possible benefit out of the drains installed in order to render the enterprise thoroughly successful and profitable.

**State Aid.** In localities where there are a number of drainage problems to be met, the Agricultural College through its Extension Service makes a practice of sending a field man to make examinations and give a demonstration or advise the community publicly as to the means of securing drainage. Field work usually consists of subsoil and water table examinations and the taking of some preliminary levels to determine the available fall or best possible outlet and the location and design of drains required. Where there are several hours of surveying to be done, it will usually be necessary until they serve the entire wet area.

The results of such preliminary investigation will be the organization and development of feasible projects. To carry these projects through, a good attorney and drainage engineer should be employed, as it will pay to have the work done right.

The Extension Service of the College can also assist in the organization of feasible projects. The State could well afford to extend investigations of the effect of under-drains in the marshy, alkaline, and white lands as well as other wet lands of Oregon.
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