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RECLAMATION OF TIDE LANDS.

By

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RECLAMATION OF TIDE LANDS.

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During the past three or four years there has been a rapid and continuous increase of interest in the reclamation of the tide marsh lands along the Atlantic coast, and enough has been done to encourage the belief that it will be possible under proper methods to reclaim a great portion of this now almost worthless land and make it valuable for agricultural purposes. All the lands along the coast which are covered or practically covered with salt water at high tide are classed as salt marsh. They extend from the eastern point of Maine to the peninsula of Florida, being broken in places and with irregular boundaries, and vary in width from a few hundred feet to several miles.

CHARACTER OF SOIL.

The soil of these marshes is composed of sediment or silt, mingled with the remains of animal and vegetable life. There is a variety of opinions as to the fertility of this soil, but the chemical analyses of numerous samples, together with the crops produced where tracts have been reclaimed, show that they are extremely productive, and with proper treatment, including the leaching out of the excess of salt, can be made a valuable addition to our agricultural possessions. The soil varies in depth from a few inches to 10 or 15 feet, and usually rests on a bed of sand or clay. In some places, however, the vegetable matter so predominates that the soil is so light that when saturated with water it has a tendency to float. Such lands are called "floating marshes." They are difficult to reclaim, and are not so valuable as others for agriculture, but even these when drained become more firm and make good pasture and meadow. The value of these marshes depends largely upon their elevation above sea level. Large tracts below sea level have been reclaimed by means of costly dikes and expensive machinery for pumping the water, as in the Netherlands, but land always submerged is not strictly tide marsh, and will not be considered in this discussion.

The fluctuation of the tide along the coast varies from 2 to 11 feet, the average being about 4 feet. Where the fluctuation is above this average, drainage without resort to pumping is usually feasible. Dikes serve to keep out the sea at high tide and automatic gates permit the escape of the water through the dikes at low tide.

INDUCEMENTS FOR RECLAIMING.

While the country adjacent to these tide lands was sparsely settled and there was plenty of high land for cultivation, there was neither incentive nor necessity for reclaiming them, but during the last decade these conditions have radically changed. The eastern portion of the United States has become densely populated. Numerous towns and cities have grown up along the coast, creating a great demand for the products of the farm and garden. To make room for this rapidly increasing population and provide a suitable place possessing proper sanitary conditions for residences, and to satisfy the demands for fruit, vegetables, and dairy products, it is necessary to reclaim some of these marsh lands.

Within the last ten years the scientists of the country have proved conclusively that certain species of the mosquito are the most common, if not the only, means of disseminating the germs of malaria and introducing them into the human system. In places where the mosquito has been exterminated malarial diseases have greatly decreased or entirely disappeared. It is a well-established fact that the tide marshes are a serious menace to the health of the people in their vicinity and a great hindrance to the settlement and development of the country in that locality. They breed mosquitoes by the million, which destroy the comfort and enjoyment of the people and greatly annoy the domestic animals.

These waste places, rich in fertility and having an ample supply of moisture for plant growth, only need draining to enable heat and air to penetrate the ground to make them ideal locations for truck gardening on a large scale. Many of these are so situated as to offer economy in transportation which furnishes another important reason for their early reclamation. Either by rail or boat products can be landed cheaply and quickly in the market places of large cities or thriving towns at very little cost. This adds greatly to the commercial value of the land and allows for a much more liberal expenditure for its reclamation than could be borne if there had to be added to the cost of production the cost of a long-distance haul to market.

The desire to reclaim these marshes is evidenced by the many attempts that have been made to do so. That some skill and knowledge in this work are required is also shown by the numerous failures. (Pl. XII.) Works to keep out the sea on one side and prevent rains and storm water on the other from flooding or injuring crops, must be wisely planned and carefully executed. Nothing is so insidious in its attacks as water; and the dikes and drains which form a part of reclamation work on tide marshes have to contend with burrowing animals, with a foundation at first extremely unstable, and must

FIG. 1.—GREAT ST. GEORGE'S MEADOW, NEAR DELAWARE CITY, DEL., SHOWING EARTH EMBANKMENT AND RECLAIMED MARSH.

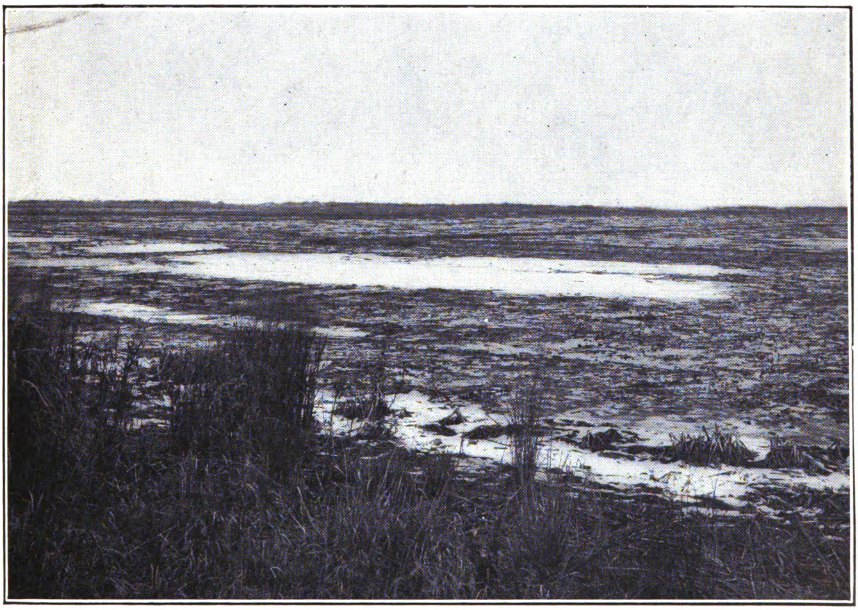


FIG. 2.—PORTION OF THE CLARK MEADOW, NEAR DELAWARE CITY, DEL., SHOWING RUINED EMBANKMENT IN THE DISTANCE.

anticipate the changes which will be brought about by the drying of the land on one side and withstanding the attacks of the sea on the other. If the plans are inadequate or the work poorly done, failure will surely follow.

These difficulties are understood now better than formerly and the owners of these lands or the communities interested in their reclamation are seeking to avail themselves of all the experience and information both in engineering and agriculture which can be gathered, and they are making many inquiries of the Department of Agriculture as to how particular projects should be carried out, how dikes and ditches should be planned and built, and the land be made ready for the planting of crops. Some of these inquiries are for information and advice about the organization of communities for the carrying out of large projects; others have to do with methods for removing the water and the subsequent treatment of small areas. As these lands, taken together, have an aggregate productive area equal to that of agricultural States like Illinois or Missouri, it follows that their successful reclamation and cultivation means an important addition to the national wealth. Many of the attempts to carry out these works have been delayed or have been prevented for the time by a lack of information and lack of confidence on the part of the landowners directly interested. These landowners are unwilling to sanction the improvement or contribute to its expense until they can be assured through some authoritative or disinterested source that the reclamation of tide marshes is feasible; that the land when drained will be productive; and that this drainage will not interfere with other industries such as the fisheries along the seacoast bordering the marsh lands. They wish to have some knowledge regarding the kind of dikes needed for protection from the sea and the kind of drains and pumps needed to put the land in proper condition for cultivation after the inflowing tides have been cut off. In order to answer these questions definitely and properly the Office of Experiment Stations commenced during the last year an extensive investigation to determine the areas of tide marsh land capable of being drained, the methods to be followed to insure success, and the relative measures of the cost and the benefits to come from this work. This paper is in the nature of a preliminary report on this investigation. Later on it is intended to prepare for publication a report giving more definitely the area susceptible of such reclamation, the measure of the benefits to agriculture which will come from their improvement, and more definite and detailed instruction regarding the methods which should be followed in carrying out this work.

SOME OF THE RESULTS OF DRAINAGE.

About the only agricultural product grown on these lands in their native condition is marsh hay. This hay sells at present in the vicinity of Boston at $8 a ton. On areas which have been drained the hay sells for $25 a ton, and the yield per acre is larger than on the undrained tracts. The simplest form of improvement possible, therefore, increases the productive value of these lands threefold, but the greater part of the lands which have been reclaimed are too valuable for the growing of hay, and have been brought immediately into intensive cultivation. (Pl. XIII.) Cranberries are probably the most important crop at present grown on tide marshes. The area of cranberry bogs is being constantly extended and the trade in this fruit has assumed large proportions. Cranberry growing during the past two or three years has been quite profitable, and this has resulted in a marked activity in the extension of the area devoted to the crop and to the value of the lands reclaimed. Good bogs along the North Atlantic coast now sell for $1,000 an acre and pay a large return on this investment. The need of these marshes for truck farming is more apparent now than formerly because of the great increase in the number and population of some seaside resorts. Along Cape Cod and much of the Massachusetts coast the uplands have not the fertility needed for successful gardening. Much better results can be had from these marshes when drained than from the higher lands. In many places the growing of fresh vegetables in the immediate vicinity of town, requires the reclamation of marshes, and they are proving well adapted to this use. Asparagus grows with unusual vigor in such soil, and in places near Boston excellent crops are being produced where the marshes are occasionally flooded with sea water. Celery does excellently in some localities, but has failed, for reasons not well understood, in others. Cauliflower, cabbage, onions, muskmelons and watermelons, cucumbers, lettuce, sweet corn, field corn, potatoes, oats, redtop, timothy, and alsike clover are all crops being successfully grown on reclaimed marsh lands along the North Atlantic coast; onions, celery, asparagus, cucumbers, and melons being the most profitable crops.

For many years the tide marshes of the South Atlantic coast were largely devoted to rice growing, and this is still the most important use of these areas, but changes in the flow of the rivers, which have taken place as the result of the removal of the forests and from other causes not so well understood, are bringing about a change in these lands, under which they are being more and more converted into truck farms. Asparagus, peas, potatoes, lettuce, beans, and cabbage are being raised in large quantities and shipped to the northern

FIG. 1.—CROP OF ONIONS ON RECLAIMED SALT MARSH, REVERE, MASS.

FIG. 2.—CROP OF HAY ON DIKED MEADOW, MARSHFIELD, MASS.

markets for sale early in the season. The products are of good quality, the business is proving profitable, and the area is being continually extended. There are, however, as yet many unsettled questions connected with this kind of agriculture. The best methods of growing crops, and the varieties of crops best suited to these conditions are not as yet determined, but this is being systematically investigated by the Bureau of Plant Industry of this Department. The requirements of drainage, the depth to which the water level must be lowered and kept, and the kind of devices or machines needed for this work are being studied by the Office of Experiment Stations as a part of its drainage investigation.

DRAINAGE IN EUROPEAN COUNTRIES.

The most notable example of the reclamation of salt marshes is furnished by the Netherlands. Here the work has been carried on for centuries, during which a large part of Holland has been wrested from the sea. Lands no more fertile than the marshes of this country now support a population of 450 to the square mile, while the density of population in New Jersey is but 250 and that of New York 153. These figures show the possibilities of salt marshes in the climate of the North Atlantic States. Equally encouraging evidence of the value of the marsh lands of the South Atlantic seaboard is furnished by the results of draining the low lands of Italy along the Adriatic Sea. This work was begun in a systematic way in 1882. Before that time the cost of constructing efficient drainage works was beyond the unaided financial resources of individuals or communities. Agricultural progress was practically at a standstill; the health of the population was menaced by malarial conditions and depopulation of some districts was threatened. Foreseeing this danger the Italian Government, after a thorough, detailed study, passed a comprehensive drainage law providing for the organization of districts and for financial aid from the General Government and from the provinces. As a result of this work many thousand acres of land have been reclaimed and is now growing high-priced crops. Land values have been largely increased, and some of the drained districts now have a population of between 400 and 500 to the square mile.

INFLUENCE OF DRAINING TIDE MARSHES ON PUBLIC HEALTH.

Along some parts of the coast of Long Island and New Jersey efforts have been made to drain the marsh lands as a means of ridding neighborhoods of mosquitoes, and have been partially successful; but without a general effort and the drainage of all the marshes in a certain locality the best results can not be secured. A most successful example of the effect of drainage on health conditions is to be seen in the drainage of the neck at Charleston, S. C. The city of Charleston is located on a tongue of land between the Ashley and Cooper rivers. This land was formerly infested with mosquitoes and was extremely malarious. During the last four years the land has been thoroughly drained. The report of the sanitary and drainage commission of Charleston County, S. C., for 1905, speaking of the results, says:

When we took charge of this territory, ponds and morasses were everywhere. The Anapholes mosquito, the disseminator of malarial poison, was present by the millions. The public road was almost impassable in places, and the public ditches choked up and more or less filled with a stagnant water, and the whole country had the appearance of the utmost neglect, and there were but very few business enterprises with the exception of the fertilizer factories. To-day there are no ponds, no morasses, the Anapholes has been banished, and an avenue 40 feet wide, with ditches on each side, has been built to Tenmile Hill. A new town has been laid out and 100 homes are being erected in this town. New dwellings and new stores are to be seen on all sides.

William Reybold, writing from Newcastle County, Del., says:

If, after reclaimed, marshes are kept well drained, there is less of malarial diseases than when not reclaimed, and the pest of mosquitoes is almost driven away.

A writer from Fairfax County, Va., says:

The marshes are very little utilized, but some have been diked successfully and produce good crops of hay. This matter is of such importance, and the health of the tide-water region, in conjunction with its agricultural advantages, would justify the Government in inaugurating some system of improvement.

John L. Grubbs, of Henrico County, Va., says:

There is a decided improvement in the health of the neighborhood where marshes are diked and drained.

BEST METHODS OF RECLAMATION.

There are three things in the reclamation of salt marsh that require special attention and treatment. These are:

(1) The method of protecting the land from overflow by tide waters.

(2) The plan of internal drainage.

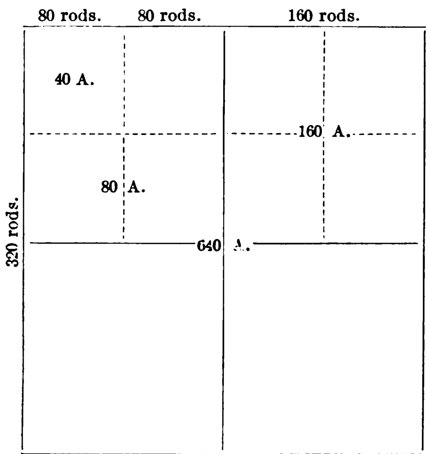
(3) The treatment of the soil to rid it of the excess of salt.

The usual, and probably the best means, of protecting a marsh from the overflow of the tide is an earthen embankment constructed of the material found along the line of the work. The location, size, and character of this embankment are of the utmost importance, as upon its efficiency and stability depend the success of the reclamation. Practically all the failures in reclaiming marshes in both this country and Europe have been due to the lack of proper precautions in the construction of embankments.

LOCATION OF DIKES.

In locating a dike there are many things to be considered:

First. The direction must be such that with the shortest line of dike the greatest possible area may be inclosed. An examination of this principle shows that the larger the area to be inclosed the less it will cost per acre to do the work. The following diagram illustrates this fact:



In case of a level tract to be inclosed on all sides:

40 acres would require 320 rods of embankment, or 8 rods per acre of area.

80 acres would require 480 rods of embankment, or 6 rods per acre of area.

160 acres would require 640 rods of embankment, or 4 rods per acre of area.

640 acres would require 1,280 rods of embankment, or 2 rods per acre of area.

Marsh lands are frequently so situated that they do not require embankments on all sides; yet this general rule holds good—the larger the area the less the cost per acre to inclose it. This shows the importance of cooperation in this work. Where the marsh is held in small tracts, as is the case in many of the New England and Middle Atlantic States, it can be embanked at a much less cost per acre if the owners organize into districts as they do in some parts of Nova Scotia and New Brunswick. There they have dike laws for reclaiming and protecting tide marshes. The principle of these laws is very much like those of the drainage laws in some of our States, and under their operation much work has been done that could not have been accomplished by individual effort. Under the dike laws whole townships of the best agricultural lands have been created from worthless bogs and morasses.

Second. The dikes should run parallel with the coast or stream, or else at right angles to it, and should have a wide berm or foreshore between the toe of the slope and the water's edge. The action of the waves is less destructive when they strike the bank at right angles than when they strike it obliquely, and they also do less damage where there is a wide berm in front of the dike. Experience shows that dikes which lie directly on the brink of the shore are much more liable to injury than those which lie farther in and have some land before them. In no case should the width of the berm be less than that of the base of the dike, and when the embankment is exposed to the action of the wind or waves it should be 100 feet or more in width. The distance from the shore must be determined in a great measure by the quality of the ground. It should be located far enough away from the stream or shore to be secure against undermining by caving.

HEIGHT OF EMBANKMENT.

After locating the dike the height is the next important element to be considered. No one can tell with certainty to what point a storm tide at any point will rise, but when observations extend over a long term of years the greatest height reached may be safely taken as the maximum that is likely to occur in the future. The height of the embankment should be at least 18 inches above this mark. This may seem excessive, but nothing less is absolutely safe. When the waves reach near to the top of the embankment and a strong wind prevails, much damage is likely to occur, and in case they overtop the embankment the entire work may be greatly impaired or even destroyed.

CROSS SECTION OF EMBANKMENT.

The form of dike best suited to turn water and its proper dimensions are matters of the greatest importance. In nearly every case of failure the cause has been found to be that the embankment was not high enough and was overtopped by the waves, or the cross section was too light to withstand the pressure. For the cross section of the dike it is not enough to obtain ample strength to resist the force of the water on the dike but this strength must be obtained at the lowest possible cost.

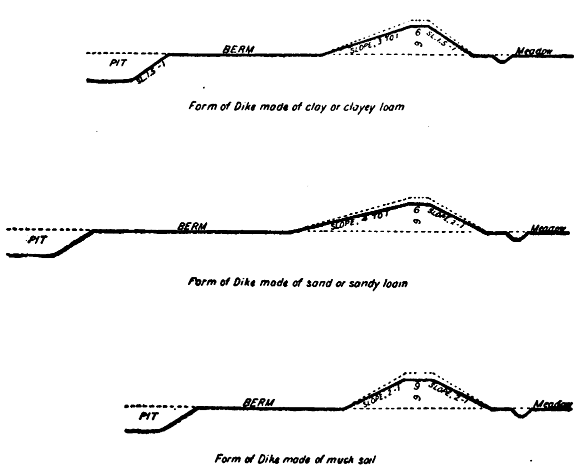


FIG. 2.—Forms of dike made from different materials.

The form and area of the cross section of the embankment depend largely upon the character of the material out of which the embankment is made and the length of time the water will remain against it. Where the material contains a large percentage of clay, a smaller cross section may be safely used than where the material contains a large amount of sand and vegetable matter (fig. 2). Experience has shown that the top width should be two times the square root of the height, with bank slopes on the water side of not less than 3 horizontal to 1 perpendicular and on the land side as steep as the material will stand without sloughing, which is usually 1 or 1½ horizontal to 1 perpendicular. This has proved to be the most economical cross section that can be constructed to safely withstand the water that may come against it. When the material is more or less sand or sandy loam, to insure safety it is necessary to increase the slope on the coast side from 3 to 1 to 4 to 1, and where exposed to the influence of the wind it ought to be 5 horizontal to 1 perpendicular in order to break the force of the waves and prevent washing. Where the material is of a peaty nature with a mass of fibrous roots, a better practice seems to be to increase the top width to that of the height and make the slopes on either side 2 to 1. This form seems to withstand the seepage better than a narrow top and a slight slope when the material is of a fibrous nature.

The Mississippi River from Cairo to New Orleans is restrained by levees built of sandy loam. Large areas of Nova Scotia and New Brunswick have been protected for centuries by dikes built of marshy soil, and the dikes that protect Holland from the sea are in most part made of sand. There is no occasion for failure on the Atlantic coast if the embankments are properly located and carefully constructed, but great care must be given to the details of the work to insure success.

SPECIFICATIONS FOR BUILDING EMBANKMENTS.

The ground should be cleared of all coarse vegetable matter and a strip in the center one-half as wide as the base should be broken up with a plow or spade (fig. 3). Where the ground is very wet or covered with water, a successful method is to excavate a ditch 5 feet wide and about 18 inches deep along each side of the base of the embankment 6 feet inside the toe and parallel therewith, placing the earth excavated on the outside of the ditches so as to form the toes of the slopes, the trenches being refilled with new material as the bank is made. This preparation will disclose any underground timbers and channels and prepare for a proper union between the base and the new material. All stumps and logs should be removed from the base and should there be any old trenches they should be

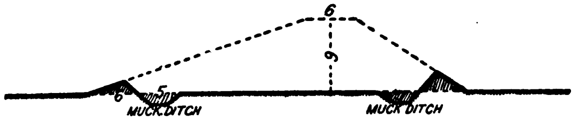


FIG. 3.—Method of preparing base in marsh lands.

cleaned of all silt and vegetable matter and filled with fresh earth. Neglect of any of these small precautions may lead to a break in the levee causing great damage. The bulk of the material for building the embankment should be taken from outside, leaving a berm as wide as the base of the levee, from which no material is taken, and the borrow pit should be broad and shallow next to the berm and increasing in depth as it recedes from the embankment.

It is permissible, and often advisable, to take sufficient earth from the land side of the levee to form a drainage ditch. This cuts off the seepage and protects the land inclosed, and also strengthens the levee by keeping it well drained. Where the line of levee crosses low places it is a good plan to build up the berm to the general level. This strengthens the embankment by reducing its height on the water side.

In constructing a levee proper allowance should be made for shrinkage. Material such as is usually found shrinks when dry from one-fifth to one-eighth owing to the method in which it is placed in the embankment. To be on the safe side, it is well, therefore, to increase the height of the levee one-fifth, leaving the width of the base and width of top the same as specified for the finished work. This will allow the necessary settling to take place and still leave the levee as high as the established grade.

METHOD OF DOING THE WORK.

In building embankments the earth is usually handled in one of three ways: (1) By spade and wheelbarrow; (2) team and scraper, or team and dump cart; and (3) some form of dredge.

Where the embankment is small the earth can be dug with a spade and thrown into place at a cost of 8 to 12 cents per cubic yard, according to the price of labor and the stickiness of the soil. Where the embankment is larger and it is necessary to leave a wide berm the earth can be dug and transported in wheelbarrows at a cost ranging from 12 to 20 cents, according to the price of labor and the distance the material has to be conveyed. This method is expensive and should be used only in places where the quantity to be handled is too small to justify the outlay for some modern plant.

Where the ground is firm enough to permit the use of teams and wheel scrapers the earth can be handled quite rapidly at about one-half the cost of wheelbarrow work, but where the ground is soft and boggy, as is the case in most places along the Atlantic coast, it is impracticable to use teams and scrapers. Where the yardage is large enough to justify the outlay, the cheapest and most satisfactory way of building an embankment is by means of a dredge of some type.

The improvement in excavating machinery during the past ten years has developed some very good dredges for this class of work.

By selecting a machine adapted to the conditions, excellent work can be done at a very low price.

FLOATING DREDGE.

Where the ground is very soft a floating dipper or clam-shell dredge boat, as shown in the accompanying drawings, can be used to good advantage. The machinery (engine and boiler) is mounted on a barge that floats in the excavation and the material dug with the dipper is placed in the embankment by means of a swinging boom. A clam-

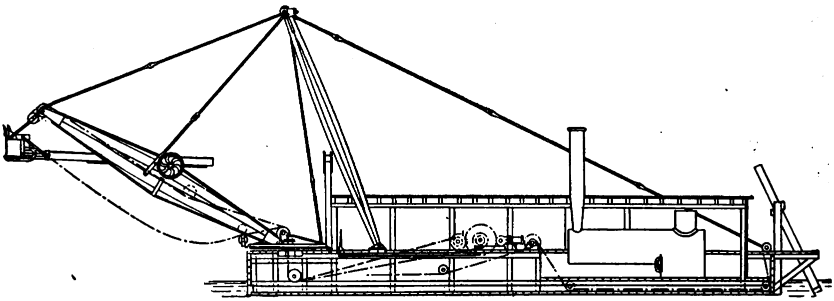


FIG. 4.—Outline of dipper dredge suitable for ditching and for building small dikes.

shell is better than a dipper dredge (fig. 4) for this kind of work, as it is possible to use a much longer boom, thereby leaving a wide berm between the pit and the toe of the embankment. Machines of this type have been successfully operated with a boom 120 feet long carrying a bucket holding 2 cubic yards, but the dredge best suited

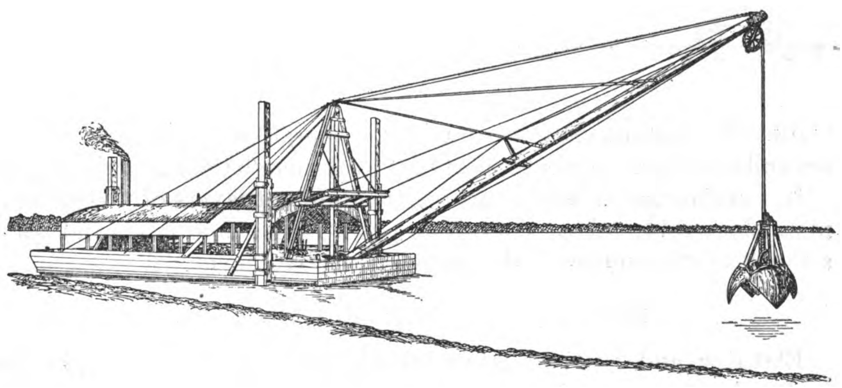


FIG. 5.—Long boom dredge with orange-peel bucket, suitable for building large embankments.

to the conditions along the coast is one having a boom 80 to 90 feet long and a bucket holding 1 to 1½ cubic yards (fig. 5). The advantage of this method of construction is that the levee is built in layers of wet material and is very compact and firm and permits little or no seepage during times of high water.

TRACTION DREDGE.

Where the ground is firm enough for a man to walk, a more satisfactory way is to use a traction dredge with a swinging boom and a clamshell bucket (fig. 6). In this case the machinery is mounted on a platform that moves on rollers or is self-propelling on a temporary track. It digs in front and backs away from the work (fig. 6). With a machine of this kind very large embankments may be built, leaving a wide berm and a shallow pit. Traction dredges of this type with a boom 100 feet long and carrying a 2½-yard bucket, are successfully used for levee building along the Mississippi River. Where there are no stumps or logs an embankment can be built with any type of dredge as above stated, at a cost ranging from 3½ to 6 cents per cubic yard. Although this method of constructing embankments is very cheap it is only practicable where there is a large quantity of material to be handled, as it is very expensive installing a dredge suitable to do the

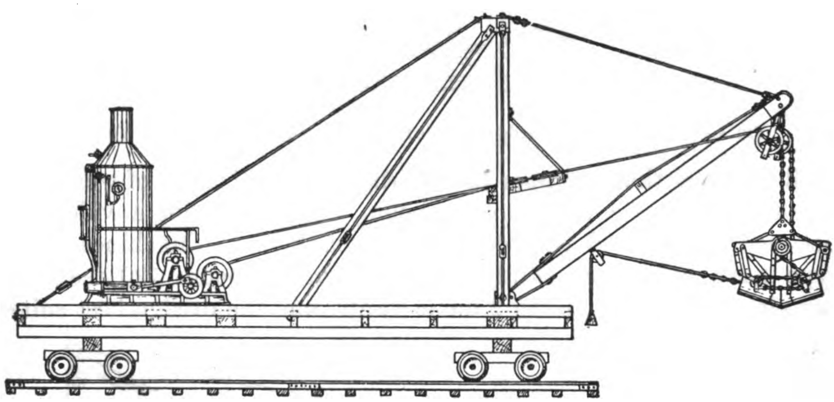


FIG. 6.—Type of traction dredge suitable for building dikes.

work. This is one great reason why cooperation is necessary to successfully reclaim the greater part of the salt marsh under consideration.

In building levees with a dredge the different layers of material are more thoroughly mixed than when put up with hand labor and make a much more compact and impervious embankment.

ELEVATOR AND SUCTION DREDGES.

Elevator and suction dredges discharge so much water with the material they excavate that they are not well adapted to building levees. They have, however, been used quite successfully in some places by building parallel walls of turf and sod to hold the material until the water drains out. The great difficulty in building a levee with a dredge is to get one with a boom or carrier long enough to place the material in the embankment without digging a deep pit too near the toe of the levee. Where the ground is firm enough to use a traction machine this difficulty is overcome as the machine can be run on the berm between the toe of the levee and the pit, as shown in the annexed cut (fig. 7). When a sufficient amount of material has been placed in the embankment to secure the proper width and cross section it should be dressed to a smooth surface and planted in some species of grass that will form a tough sod. South of Virginia the Bermuda grass is the best for this purpose, while along the north coast red top or herd's grass seems to be best suited.

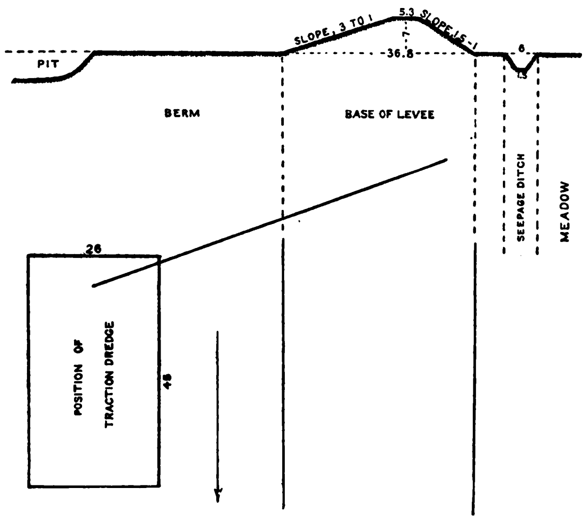


FIG. 7.—Relative position of borrow pit, dredge, and levee.

WAVE PROTECTION.

Where a levee is exposed to high winds it should be protected from wave wash when first put up until the sod is formed and the material thoroughly settled. This can be done as follows: Plant a row of 6 by 6 posts along the berm about 3 feet from the toe of the levee and bolt a stringpiece 4 by 8 to the front of these posts at about the elevation of high tide. If the posts are more than 6 feet out of ground, another piece should be bolted on about 1 foot above the ground. Drive a double row of sheet piling 2 by 6 or 2 by 8 on the front side of this stringer, inclining about 1 foot horizontal to 6 feet vertical toward the levee. The pieces should be driven so as to break joints with each other and penetrate the ground 3 feet. The planking should be further secured by placing a waling piece 2 by 6 or 2 by 8 on the front side opposite the stringer and securing it by screw bolts passing through the waling strip, sheet piling, and stringpiece at intervals of 6 feet. At each post the barrier should be braced by a strut of 3 by 8 secured at one end to the top of the posts by means of screw bolts or spikes and extending back almost horizontal to the surface of the levee, where it should be securely spiked to a stake 2 by 6 driven firmly into the ground. A barrier thus constructed breaks the action of the waves and at the same time does not injure the levee, but leaves it so that it can be mowed and kept clear of noxious weeds. Protections placed directly against the slope form a refuge for muskrats and other pests that destroy the levee. If made of creosoted lumber, it will not be attacked by toredo and will last a great many years. The surface of the embankment should be kept in grass and be carefully mowed at least twice each year. This will destroy the refuge for burrowing animals, improve the sod, and become a source of revenue.

TIDE GATES.

When embanking a piece of marsh, provision must be made for discharging the water that accumulates within the embankment. Where the land is sufficiently above low tide, this can be most easily accomplished by means of a sluice or tide gate. This provision for the escape of the water is an essential feature of the reclamation, and, like the embankment, must be properly designed and well built. The ultimate success to be achieved in reclaiming salt marsh and rendering it fit for meadow or cultivation depends almost wholly on the character and efficiency of the tide gates devised and erected to keep out the salt water. They must be of a permanent character, substantially built, and so constructed as to open and close promptly with a minimum amount of pressure. Care should be taken in placing the abutments that carry the gate to see that they have a firm foundation and that the flow line of the chamber is slightly above mean low tide. What is known as the tankard gate, suspended by a double hinge so as to readily close against the face on all sides, is recommended. The seat is lined with rubber so as to form a tight joint with the abutment, and if carefully constructed will not allow any water to pass when closed. As the gate is necessarily heavy, an adjustable counterweight is attached so that it may be nicely balanced in order to open with a small head against the upper side. The position in which it is hung will cause it to close by gravity as soon as the pressure on the inside is exhausted or overcome by an equal pressure on the other side. In designing the gates to accommodate a large volume of water, it is deemed better practice to make a series of smaller ones having the required opening, as they can be much lighter and are less liable to warp and spring, causing leaks when closed. The relative merits of steel and wooden gates have been considered, but owing to the difficulty in building and holding structural work in a true plane and the deleterious effects of salt water on steel and iron, it is thought that gates of creosoted timber are better suited for the purpose. The treatment of any porous wood, preferably white or yellow pine, free from heart, with 14 pounds of creosote oil per cubic foot, will insure the material against decay, prevent it from swelling and shrinking, and protect it against the ravages of the toredo. Such gates are no more expensive than steel and are far more desirable. The gates here recommended are so planned that they can be readily detached from the framework without injury to it, if at any time repairs should be necessary.

Plans and complete drawings for a cheap wooden abutment, with one or more gates, as required, and also plans and drawings for a concrete abutment with creosoted wooden gates are given on page 396. This is the most desirable gate that can be constructed, and where sand or shells can be readily procured its cost will be but little more than a wooden abutment serving the same purpose.

The following general directions for constructing either of these gates will serve as a guide for any locality:

EXCAVATION.

The foundation for the abutment should be prepared by excavating the muck and soft material to a firm clay or sand bottom. In order to do this successfully it will be necessary in nearly all cases to drive some form of tongue-and-groove sheet piling, so as to form a tight cofferdam around the proposed pit. A pumping plant of sufficient capacity to keep the pit dry at all times must be provided. The abutment may be of timber, as shown on the first set of plans, or it may be of stone, brick, or concrete, as shown on the second set. In case timber is used, the foundation should be brought up to the proper grade by filling in with good clay or a grouting of broken stone and cement mortar. Great precaution must be taken to make the foundation such that water can not find its way under the timbers, in which case the earth would be washed out and the value of the structure destroyed. In case a firm foundation can not be secured otherwise, round piling, on which to rest the abutment, should be driven in the pit. In the wooden structure the bottom sills can be secured to the piling by means of drift bolts. This will support the structure so as to prevent settling and the water can be shut off by the sheet piling above and below the abutment. Where broken stone or suitable sand can be readily procured, concrete will be found the most desirable material, and we recommend its use. The desired shape for the masonry may be secured by making forms of lumber which can be removed after the mortar has set. The proper proportion of cement and sand to form concrete depends in a measure on the strength of the cement and the quality of the sand used. With any good natural cement and clean, sharp sand a proportion of 1 to 5 or even 1 to 7 would make very substantial work. Methods of mixing and tempering mortar for concrete are so well known that it is hardly necessary to explain them here. The things to be insisted upon in any concrete work are fresh cement, clean, sharp sand, plenty of water, thorough mixing, and immediate use. If these are observed with due care, good results may be expected. It is quite important to have the face of the abutment both true and smooth in order that the gates may set properly. This can be secured by having the forms in perfect alignment and plastering the face with a fine mortar. The abutment should be level on top when completed, so it may be floored over and used as a bridge for crossing the channel.

HEAD BEAM.

In case of the wooden abutment, the head beam to which the gates are hung is formed by bolting a piece of timber to the cap of the bent, but on the stone or concrete abutment a head beam of 10-inch steel channel weighing 20 pounds per linear foot, from which the gates are hung, should be secured to the face of the abutment, as shown on the drawing. Cast-iron fillers of a suitable pattern may be used at the points of attachment to hold the channel out from the face of the wall the thickness of the gates.

SWINGING GATES.

The essential features of a good tide gate are durability, tight closing, and easy movement. They are made, as shown on the drawing, of two thicknesses of material, the pieces of each layer being at right angles to those of the other. Between the two is placed a sheet of 8-ounce cotton duck, painted on each side with a heavy coat of white lead and oil. The boards in each layer should be drawn up tight with a clamp and securely bolted at each intersection with two machine bolts with wrought washer under both head and nut. To resist the action of the salt water, the bolts and washers should be galvanized. If the workmanship is not of a high class so as to form tight joints, the vertical seams, being the outside of the gate, may be calked with three threads of cotton to prevent leaking. In case creosoted lumber can not be obtained, other lumber may be used, but it should be thoroughly soaked by immersing it in water several days before using. A suitable seat is formed by fitting to the inner side near the edge a piece of 6-ply rubber belting 2½ inches wide. This can be secured to the wood with brass screws 1¼ inches long, with heads sunk well below the surface of the rubber. The gates should be hung to the head piece by a double joint or link hinge, as shown on the drawing. Such a hinge allows the gate to adjust itself to the face of the abutment in closing, so as to form a tight joint on all sides, permitting the water to rise above the top of the gate without leaking. A suitable hinge probably can not be purchased in stock, but can be made in any machine shop from the detail drawing furnished herewith. The holes should be true and accurately bored and the bolts turned and neatly fitted, so as to insure free movement. To withstand the action of the salt water, it is desirable to make the hinges of hard brass, or if iron is used it should be kept well painted and the bolts should be made of hard brass. For the purpose of balancing the gate so it will open and close with a minimum pressure, a projecting arm with an adjustable weight is attached to the inside, as shown on the drawing. When the gate is hung, this weight can be shifted in or out until the position is found where the gate opens with least pressure and then fixed by means of the set screw in this position. A gate constructed as above specified possesses all the essential requisites of a good tight gate. The creosoted material gives it the qualities of durability; the link hinge and rubber cushion allow it to firmly seat itself on all sides and form a tight joint; while a counterweight renders it sensitive to the least pressure. A cheap structure might be erected, but there would be constant danger of its giving way at a critical time, and it would have to be replaced at frequent intervals, so that a permanent structure, even at an increased cost, is more economical.

A bill of material required to construct either the wooden or stone abutment with the necessary gates is given on page 397.

PUMPING PLANT.

Where the fluctuation between high and low tide is not sufficient to afford natural drainage, some kind of pumping plant must be provided to discharge the water. The pump should be placed within the inclosure at the lowest point adjacent to the embankment and should be used to lift only such water as will not flow out during low tide. This water can be discharged through a sluice and need not be lifted over the embankment. A centrifugal pump operated by a steam or gasoline engine is probably the best for this class of work. The size of pump and engine depends upon the area to be drained. From experience in numerous places it seems that where such land is in cultivation the pump should be able to discharge 1,000 gallons per acre per hour to properly protect the crops in times of heavy rains. But where the land is used for pasture or meadow the removal of one-half of this amount is sufficient. The pump and engine should be placed on a solid foundation and carefully housed against damage from the weather. The additional expense incurred in providing substantial foundations for the pump and engine and making an ample sump for the suction pipe will be more than repaid in economy of operation and efficiency of plant. Many crops have been destroyed and much damage occasioned because of the inadequacy of the pumping plant or its failure, owing to faulty construction, at a critical time.

The cost of installing and operating a pumping plant depends largely upon the extent of the tract to be drained. As a rule, the larger the volume of water to be handled the less the cost per acre or per gallon for doing it. Even where the water is ordinarily discharged through a tide gate, it is wise to have an emergency pump to take care of the seepage and rainfall, during periods of high tide when the gate does not open.

INTERNAL DRAINAGE.

After the embankment is completed a system of internal drainage must be constructed to collect the water and lead it to the tide gate or pumping plant. On most tracts there are old channels that can be used to advantage in planning a system of internal drainage that will lessen the cost of excavation. Since the natural drainage is intermittent, effective only at low tide, it must be supplemented by a large storage capacity. Hence the ditches should be made wider than would otherwise be necessary. The removal of one-half inch of rainfall in twenty-four hours from a comparatively level tract of land, when the rainfall does not exceed 60 inches per annum, has proved to be adequate for the successful culture of field crops. If the tide gates are made of ample capacity to discharge all the water from the storage basin at each low tide (twice in twenty-four hours), ditches having a capacity for storing 0.25 inch of rainfall from the entire watershed without raising the water in the ditches more than 1 foot will be sufficient to properly drain the land for either meadow or cultivation. Since most of the salt marshes are practically level, the ditches will have but little grade and will depend upon the hydraulic head to induce a current. As the water nearest the gate will be discharged in the shortest time, it is expedient that the greater part of the storage capacity be as near the outlet as practicable. When the gate opens, this portion will be discharged at once, and should it close before the ditches are entirely empty the water in the more remote laterals will flow into the basin just formed, thus holding the water down to the lowest level to be obtained without pumping.

In planning a system of ditches it should be the aim to locate them in such a way as to leave the land in the best possible shape for cultivation. Where there is high land that drains into the marsh, an intercepting ditch should be cut along the foot of the slope to lead the water into the storage basin without overflowing the low land. The depth of the ditches required and their distance apart depend largely upon the character of the soil. The main ditch should be as deep as the sill of the tide gate, while the laterals should range from 2½ feet deep at the upper end to 3 or 3½ feet at the lower end, according to the depth of the outlet channel. In most places ditches in marsh soil will stand with almost perpendicular banks, owing to the fibrous roots in the material, so to increase the storage capacity they should have wide bottoms, with bank slopes one-half horizontal to 1 perpendicular, unless places should be found where the material requires a greater slope. It is not practicable to give specific directions for laying out a system of internal drainage, as each marsh must be viewed and treated according to its shape and peculiar location.

METHOD OF DOING THE WORK.

Where the work is of sufficient magnitude and the ditches are large enough, the use of a dredge of some type is the most economical way of excavating them; but where the ditches are small, hand labor will be found the most feasible. There are on the market some machines for cutting small ditches, but they can not be successfully operated on a soft marsh.

SUBDRAINAGE.

If it were practicable, tile drainage would be by far the best method to use in the reclamation of salt marsh; but the soil conditions are generally such that tile can not be used. The depth of the outlet in most places is not sufficient to permit them to be laid on the solid ground, and if laid in the muck above the sand and clay they would settle out of alignment and fill with silt. It is highly probable that after a term of years the marsh will settle and become sufficiently firm to permit the use of tile in some of the ditches.

TREATMENT OF SOIL.

After the dikes or embankments have been completed so as to exclude the tide and the drains constructed so as to collect the rainfall and seepage, and some reliable method provided for discharging the water from within the inclosure, the soil must be prepared for cultivation. The marine marshes are not all fertile. Some are bare mud flats without vegetation, while others are covered with a heavy growth of grass and reeds. Such differences are due mainly to the age of the marsh and do not indicate its fertility. The tides deposit such materials as they get, and if the materials are fertile so are the marshes. As a rule those marshes that receive the wash from the hillsides build up faster and are more fertile than those formed by the slow action of the tides alone. If these mud flats were embanked and the tide gates left open, so that the tide would enter, it would greatly accelerate the deposit, and eel grass would soon spring up and spread so as to cover the entire area. This growing grass would retard the coming in and receding of the tide, hastening the deposition of the sediment, and the marsh would soon be built to the elevation of the high tide.

Laboratory examinations show these marshes to be exceedingly rich in the elements of fertility, but possessing from 1 to 5 per cent of soluble matter, mostly salt left by the sea, which must be removed before the land is fit for agriculture. The usual way is to allow the rain to wash out the salt. This is a slow process, but is the one generally followed. The length of time required to complete this treatment depends upon the frequency and amount of rainfall and the system of internal drainage. The salt must be dissolved in water and that water drained away. This process can be accelerated by judicious irrigation if fresh water is at hand; but flooding, unless the water can be promptly removed, would be of but little use. Where irrigation is practiced, small amounts of water applied at frequent intervals will be found most efficient. While this process of sweetening is going on the salt grass should be frequently cut and removed, as its growth takes up a large amount of saline matter. As fast as the salt is removed, if the land is desired for meadow or pasturage, it should be seeded with tame grass, either herd's grass, red top, or timothy. It improves the meadow to have it closely pastured with sheep or cattle, as it compacts the soil and hastens the destruction of the coarse grass and weeds; but stock has a tendency to fill the ditches, making frequent cleanings necessary, as they must be kept open so as to allow the free flow of water.

If it is desired to put the land in cultivation certain crops that withstand a large amount of salt, as onions, sorghum, and beets, may be cultivated and yield a good revenue. Where a forage crop for cattle is required, sorghum, sowed broadcast and cut just at the time the seed ripens, will be found very profitable.

Salt marsh soils are often well supplied with lime in the form of shells, but when these are not present and the soil is acid, or becomes so through the decomposition of the grass roots, lime must be added to correct this acidity. In all cases it would be wise to send samples of the soil to the Bureau of Soils, United States Department of Agriculture, and have an analysis made to determine the proper treatment.

The best method of subduing a rank marsh soil is not fully determined. In Europe and some parts of America it has been the custom to burn the sod to a depth of 10 or 12 inches. This practice is a great waste of organic matter and is not to be recommended. Clearing the land of all vegetation and giving it a chance to become thoroughly aerated is the first step to be taken. At present the judgment of the farmer must be his guide as to the best method of bringing these marshes into good tilth. In some localities where the practice has been tried it is claimed that the turning under of a heavy green crop in June or July will hasten the rotting of the sod. Others claim that late fall plowing is best and that all vegetation should be removed before turning the land over. In other places it is claimed that better results may be secured by scarring the land with a disk harrow and not turning it over. All, however, are agreed that shallow plowing is more efficient in reducing the sod to a workable state.

CAUSES OF FAILURE.

From a personal inspection in a number of places and the testimony of trustworthy people along the coast where the reclamation of salt marsh has been carried on, the following are noted as the chief causes of failure:

(1) The inefficiency of the dikes because of poor construction from a lack of knowledge as to how to do the work or a false economy practiced in the construction of the same.

(2) The failure of the tide gates to keep out salt water and their lack of capacity to vent the accumulation of fresh water at low tide.

(3) The lack of proper care of the dikes after they are constructed.

In nearly 100 cases of failure investigated the reason assigned was that the "dike went out." Upon a further examination in most cases it was easy to see why the dike went out. It was located too near the shore and was cut away by the action of the water; was too low and was overtopped by the waves; did not have sufficient cross section to withstand the pressure; was built on a poorly prepared base, or was destroyed by muskrats. While the embankment stood, the reclamation was a success and disaster only followed its giving way. (See Pl. XII.) It has been thoroughly demonstrated in many places that an earth embankment will stand if properly constructed, and there is little excuse for failure. Nowhere is the old maxim "whatever is worth doing is worth doing well" more forcibly illustrated than in the building of a dike. Many persons have undertaken this work without knowledge as to how it should be done and have persisted in carrying on a practice that was radically wrong, while others have had but little confidence in the ultimate success of their undertaking and have not been willing to put in sufficient funds to properly do the work. It has been their aim, if after a time the work proved profitable, to enlarge and strengthen the embankment, but this method can not be successfully carried out, because the earth while it is yet fresh, to withstand the action of the water, must be put up in the proper manner and of sufficient quantity. If the embankment is too low and is once overtopped by the waves it will practically be destroyed. If the cross section is too small or has steep slopes it will not withstand the action of the waves and will give way when most needed.

Another reason for insufficient embankments having been constructed is the lack of proper appliances for doing the work. It is only within recent years that dredges have been constructed suitable for this work and where it was put up by hand labor it was difficult, because of the water, to secure the necessary material near the work, and the cost of handling earth in that way made large and substantial embankments prohibitive in many places, but with the introduction of modern machinery this difficulty is removed and large embankments can now be built at a less price per cubic yard than smaller ones.

Another source of trouble has been the sluices. These have rarely ever been large enough to serve their purpose, and have been put in in such a way that many of them have failed at a critical time, flooding the meadows and thus destroying the work of many years. With the cheapness of concrete construction, permanent structures can now be made at a reasonable cost, and such structures of unquestioned capacity should be constructed in all embankments made. If care is taken to secure a proper foundation such tide gates will be permanent and efficient.

In many places complaints are made of the ravages of muskrats. It is stated that they burrow in the embankment and cause it to give way during periods of high tide. This trouble can be greatly lessened, if not entirely avoided, by keeping the embankment free from a rank growth of vegetation. It should be mowed at least twice a year and the material cut at once removed. This will destroy the harbor for these animals, and the damage they do can be more readily detected and repaired.

Where an embankment is constructed by a number of landowners there seems to be a division of responsibility, and no one looks after it and it does not receive the care necessary for its protection and security.

If instructions given in this report are closely followed as to the location, construction, and care of the embankments there should be fewer failures in the future.

WHY SO LITTLE PROGRESS HAS BEEN MADE.

It has been fully demonstrated by the work done in Nova Scotia and along the Atlantic coast that many of our marine marshes can be reclaimed and made profitable for agriculture. Such being the fact, it is natural to inquire why so little progress has been made in this work. There are many reasons why more work of this kind has not been done, among which are:

(1) To do such work economically it must be carried on upon a large scale. This requires a considerable outlay of money or labor, or both, and the individual ownership of large areas of marsh land or cooperation among several small owners. This outlay must all be made and two or more years elapse before the marsh will yield any returns. American farmers and capitalists prefer, as a rule, to work for results that come more quickly or to invest in securities that are convertible into cash on short notice. This lack of means has held back many persons who are fully aware of the fertility of the land

and convinced of the great profit that would result from its reclamation, but the lack of sufficient funds, together with the knowledge of certain failures that have been made, has perhaps more than any other consideration held back the reclamation of large areas of recognized fertile lands.

(2) In the New England and North Atlantic States nearly all the marsh is owned in small tracts in connection with the highlands, and it is extremely difficult to get the proprietors interested to unite in carrying out any comprehensive plan of improvement. No one holds enough land or has sufficient interest to take the time and spend the money necessary to work up an organization for joint effort. This want of united action among the many owners of small tracts has been a great drawback to the improvement of the marshes along our coast.

(3) Another serious hindrance has been the lack of proper tools with which to do the work. Because of the swampy conditions where the work is to be done and the amount of water encountered, it is both difficult and expensive to construct a large embankment by hand labor. In many localities where the marsh is favorably located and could be reclaimed by a small amount of labor, the lack of information as to how banks should be built and experience in doing the work have held back many owners from reclaiming small tracts of very valuable land. Education along this line of work, the improvement and development of machinery suitable for carrying it on, and the accumulation of capital available for projects of this kind will no doubt remove many of these hindrances and bring about improvement in this work.

RECOMMENDATIONS.

In order to encourage the development of these marine marshes, the Federal Government should be induced to cause a survey to be made to determine their area, character, and fitness for reclamation and the probable cost of doing the work. Such an examination would have a tendency to establish their commercial value and would be of inestimable benefit to both the owners and the Government.

Simple but equitable drainage laws should be enacted by each State having within its borders any considerable amount of salt marsh. Without such a law the progress of reclamation would be slow. It is not right that a few men, owning but a small portion of the marsh, should prevent its improvement and development by refusing to sell or aid in the cost of the work and yet reap the benefits when made by others. Such will, however, always be the case in the absence of just and equitable drainage laws. The drainage of the farms in Ohio, Indiana, Illinois, and Iowa would never have reached such a degree of perfection as they have had it not been for the efficient drainage laws enacted by the several States. In both Nova Scotia and New Brunswick, where diking is so extensively employed, they have complete statutes providing for their construction and maintenance, and no material progress need be expected in this country until we have such laws enacted.

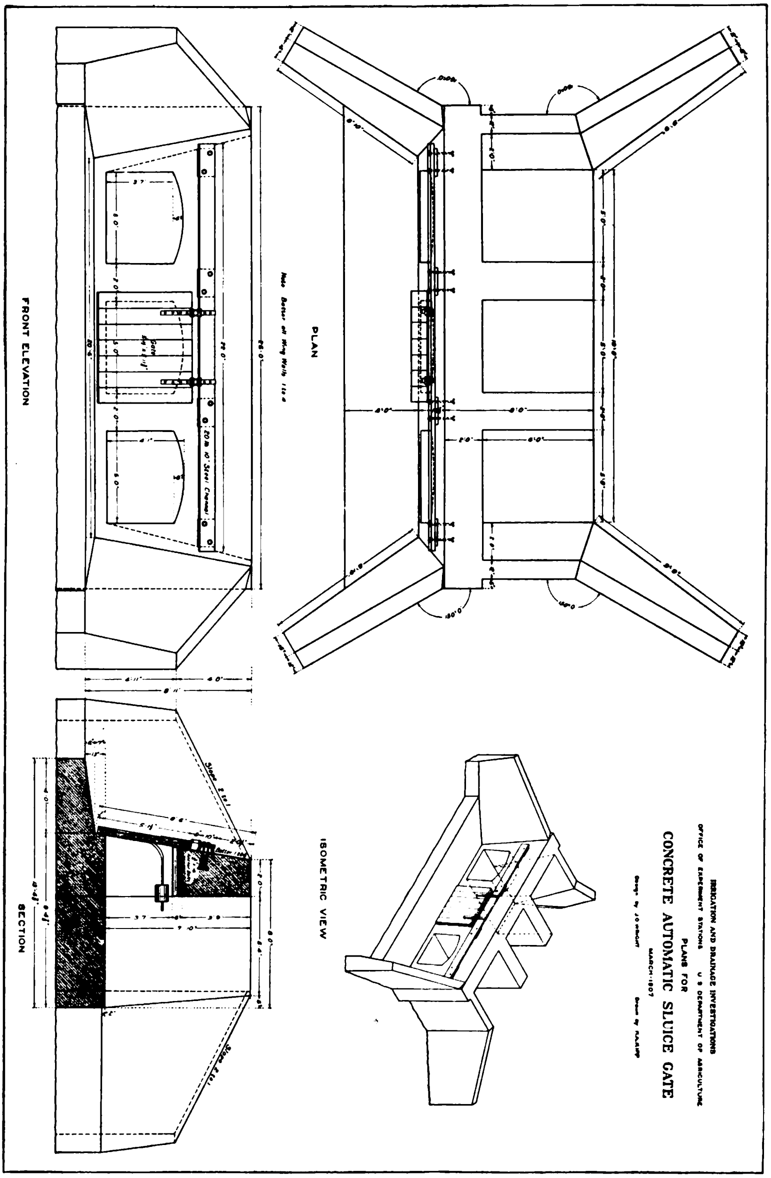
Since our eastern coast has become so thickly populated, any State has, under its police regulations, the power to declare this mosquito-breeding marsh a nuisance and a menace to the public health and compel their abatement, thereby bestowing upon the owners a blessing that they have so long and so persistently refused to accept.

Any State law that would provide for the formation of a district comprising a marsh or series of marshes that could be reclaimed under one plan of improvement and trust the management of its affairs to a board of interested landowners, would be a step in the right direction. Such a law should clearly define the riparian rights of the owners and show the status of such improvement in its relation to the navigation of streams on which such lands are located. It should also make provision for doing the reclamation work as a whole and provide for the issuance of bonds, to be a lien on the lands benefited, to raise money for paying for the work as it is done. These bonds should run for a long term of years at a low rate of interest and be paid in annual installments by a tax on the land reclaimed in the ratio that such lands are benefited by the improvement. Such a law would not work a hardship on the landowners and would enable anyone having unimproved marsh to reclaim the same and pay the cost out of crops to be produced after the work is completed. To further encourage this work the several States should remit the State and county tax on lands thus reclaimed until the cost of improvement has been paid, as the benefit to the State from the increased population and products raised on the marshes will be of more value than the land in its present condition.

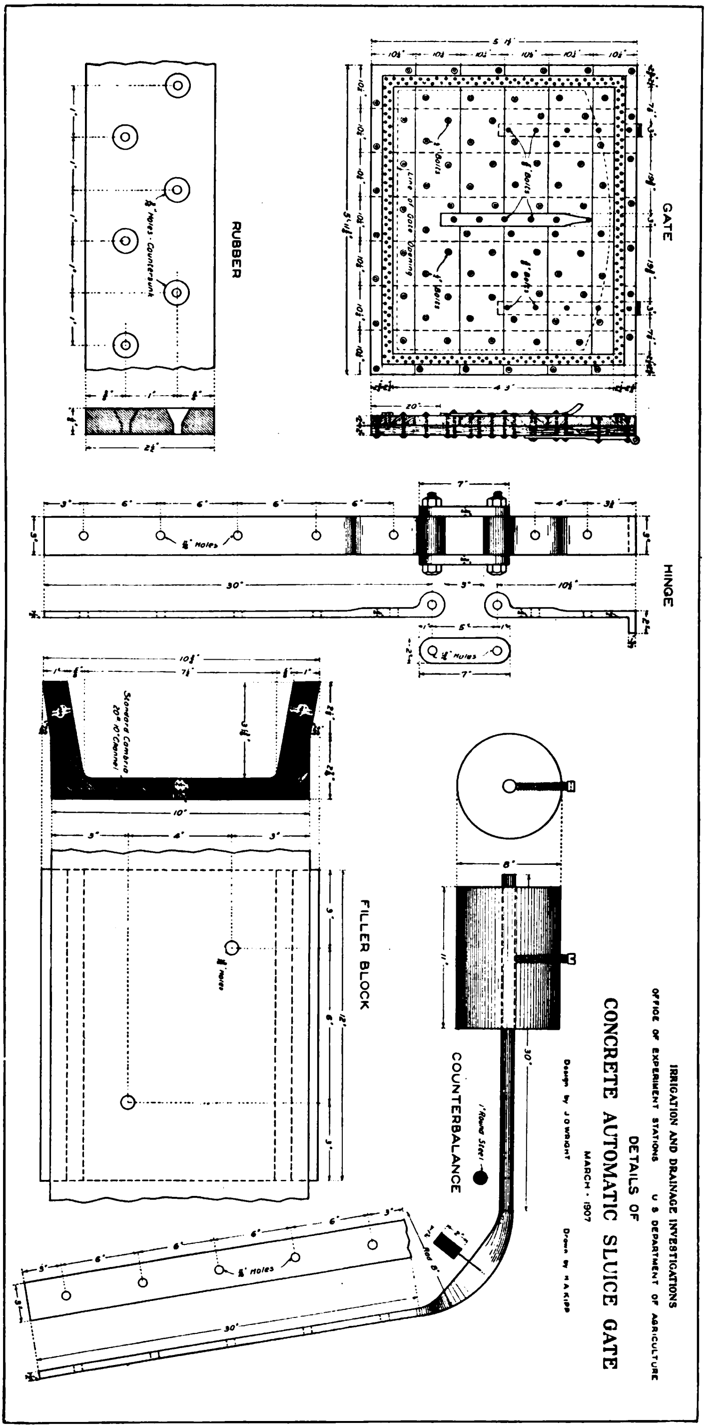
APPENDIX.

Bill of material for a three-chamber concrete sluice gate as shown in Plates XIV and XV.

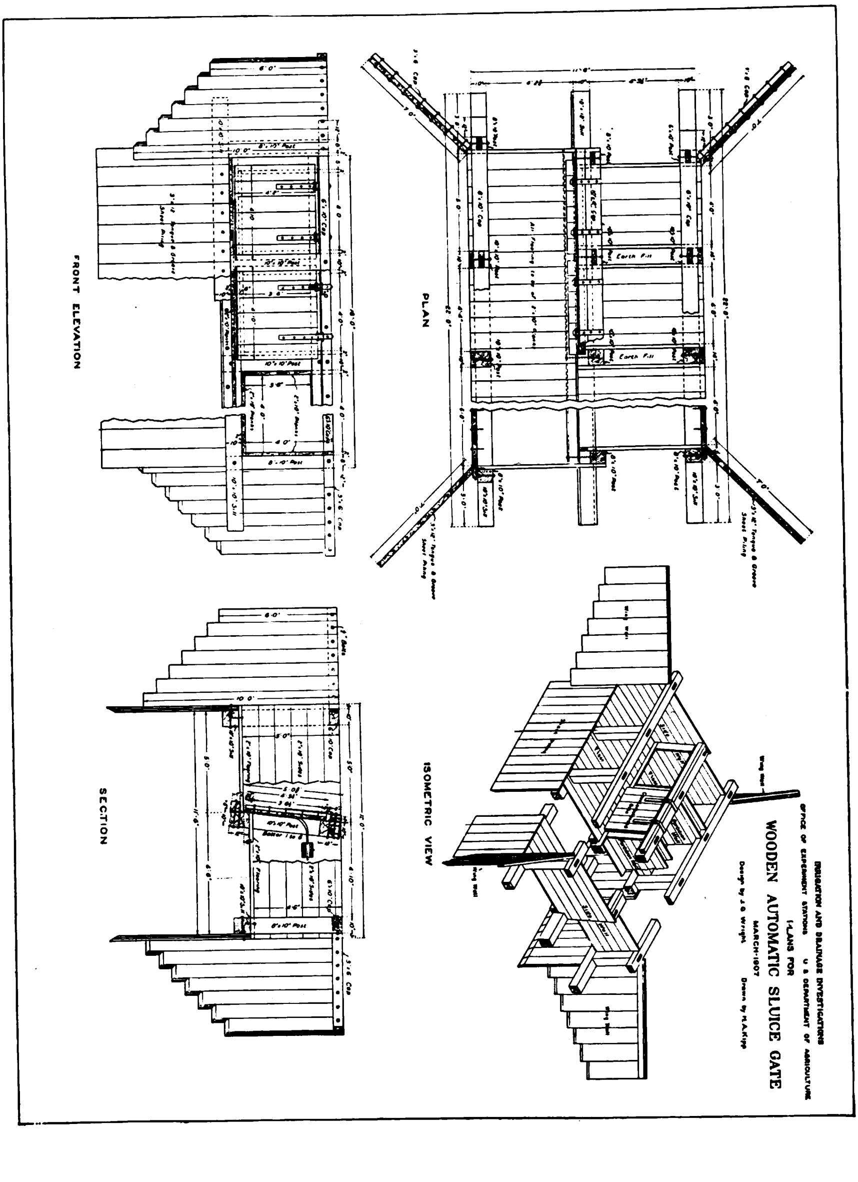
86 cubic yards concrete.
20 pieces creosoted lumber, 3 by 12, 12 feet long, 720 feet B. M.
60 feet 6-ply rubber belting, 2½ inches wide.
750 wood screws 1¼ inches long.
255 machine bolts, ½ by 5 inches.
600 wrought washers for ⅝ bolts.
45 machine bolts, ⅝ by 5½ inches.
8 T-head anchor bolts ¾ by 16 inches
3 counterbalances, as shown on drawing.
6 link hinges, as shown on drawing.
10 square yards cotton duck.
White lead and oakum as required



PLANS FOR CONCRETE AUTOMATIC SLUICE GATE.



DETAILS OF CONCRETE AUTOMATIC SLUICE GATE.



PLANS FOR WOODEN AUTOMATIC SLUICE GATE.

For each additional gate:
17 cubic yards concrete.
7 pieces creosoted lumber, 3 by 12, 12 feet long, 250 B. M.
20 feet 6-ply rubber belting, 2½ inches wide.
250 wood screws, 1¼ inches long.
85 machine bolts, ½ by 5 inches.
200 wrought washers for ⅝ bolts.
15 machine bolts, ⅝ by 5½ inches.
2 T-head anchor bolts, ¾ by 16 inches.
3½ square yards cotton duck.
1 counterbalance.
2 link hinges.

Bill of material for a three-chamber wooden sluice gate as shown in Plate XVI.

Lumber for frame work:
1 cap, 10 by 12, 20 feet long.
1 sill, 10 by 12, 20 feet long.
2 sills, 10 by 10, 22 feet long.
2 caps, 6 by 10, 20 feet long.
6 posts, 10 by 10, 6 feet long.
6 posts, 8 by 10, 6 feet long.
1 gate beam, 4 by 6, 16 feet long.
1 floor beam, 6 by 6, 16 feet long.
33 pieces sheet piling, 3 by 12, 14 feet long.
25 pieces of flooring, 2 by 10, 12 feet long.
17 pieces siding, 2 by 10, 14 feet long.
2 caps for sheet piling, 3 by 6, 14 feet long.
Total, 3,930 feet, B. M.

Hardware:
28 machine bolts, ½ by 7½ inches for wings.
56 wrought washers for ½-inch bolts.
9 machine bolts, ⅝ by 17 for floor beams.
9 machine bolts, ⅝ by 15 for gate beams.
12 machine bolts, ⅝ by 11 for bent joints.
12 machine bolts, ⅝ by 10 for bent joints.
84 wrought washers for ⅝ bolts.
1 keg boat spikes, ⅜ by 6.

Material for three swinging gates:
6 pieces, 3 by 12, 14 feet long} 576 feet B. M
9 pieces, 3 by 12, 12 feet long}
54 feet 6-ply rubber belting, 2½ inches wide.
8 yards heavy cotton duck.
180 machine bolts, ½ by 5 inches.
360 wrought washers for ½-inch bolts.
45 machine bolts, ⅝ by 5½ inches.
90 wrought washers for ⅝-inch bolts.
600 wood screws, 1¼ inches long.
3 complete counterbalances, as shown on drawing.
6 link hinges, as shown on drawing.
White lead and oakum as required.

O