experience with it and have never had a failure with it except one year. That year the frost caught me awfully bad and that is the only failure I had.

Now, gentlemen, if the Drainage Association does its duty, each of us must become a missionary—a swamp angel. If we do this, we will help the farmers and we will help the whole community, as well.

SLOPES IN OPEN DITCHES

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The subject assigned to me is "Maintenance of Slopes in Ditches." I think that most of us will agree that if ditches could be constructed as most specifications provide that they shall be constructed, and if the cross-section of the ditches would remain unchanged after the work is completed, many of our troubles would be reduced to a minimum. This, however, is not the case. It is true, however, that the greater portion of our trouble is due to caving banks, and if this trouble could be overcome the cost of maintenance would be comparatively low.

As a rule the caving of banks is due to three causes:

Caves or breaks due to the inability of a layer of drift to hold the weight of the overhead bank. These breaks usually occur where a layer of sand or gravel or unstable clay lies some distance below the surface of the ground and as this layer crumbles a crack develops in the bank some distance from the edge of the ditch, and as the crack gradually widens the bank moves slowly into the channel. Where caves occur due to this cause, the only practical remedy is to flatten the slopes until sufficient weight has been removed to establish a state of equilibrium in the ditch banks. It is also necessary that the spoil bank be deposited far enough from the edge of the ditch to relieve the ditch banks from the excessive weight of the excavated material.

A second cause of caving banks is due to gravity slides, which result from the movement of the overhead bank upon a slippery layer of clay or other material due almost entirely to an excavated slope steeper than the angle of repose for the particular
soil excavated. This condition will be further aggravated if the spoil bank is deposited too near the edge of the ditch.

The third cause of caving banks is due to erosion, which is a gradual breaking down of the banks due to rain and wave action and the action of frost. The freezing and thawing of the bank especially contributes to the breaking down of the slopes. This condition can be remedied to a great extent by sowing grass seed on the slopes.

The necessity of sloping banks in ditch construction is almost self-evident. Solid rock is about the only material which will stand up permanently if excavated with vertical sides, all other materials will wash and slide until they come to a certain slope where they will remain stationary, this slope or angle of repose varies with different soils.

The selection of a proper slope for drainage ditches must be determined by soil conditions, such slope or ditch section as will not deteriorate or cave is the proper slope to adopt. The caving of ditches to some extent is inevitable, yet can be reduced considerably by the construction of wide and sloping banks. Where ditches are constructed with floating dredges the U-shaped ditch is invariably the result.

Dredge owners and operators will argue that the banks will break at the weak points and melt down to its line of repose and form a proper slope. This argument seems plausible, yet it is not true that the ditch will adjust itself to such a slope. It is true, however, that large sections of ditch will break down and form a slope that will remain intact for years.

As a rule the slope adjustment on a U-shaped ditch will be followed by a vertical crack from three to six feet from the bank line and extend down to the medium stage of water in the ditch or to a stratum of sand or gravel or other unstable soil. The base of this rectangular section slides and falls into the channel; if it does not immediately slide into the center of the channel, it will remain on the slope, and eventually slide down to a 1:1 or 1½:1 slope depending on the soil. In any event the section of broken bank eventually reaches the center of the channel with the result that the final ditch is a wide shallow one with a capacity of anywhere from 20 to 50 per cent less than was orig-
inally planned. I have seen the same results in ditches constructed with a 1:1 slope.

We know that the water level in the ditches varies from time to time, as does the water table in the ground. In dry periods there is considerable shrinkage of the soil above the water table and with the water table changing frequently there is certain to be a shifting of the soil due to shrinkage. It is therefore absolutely certain that this shifting for a distance of three to six feet from the ditch bank, will be in the direction of the ditch, which is the line of least resistance, the result is that the shifting soil usually lands in the ditch and very materially reduces its capacity.

The sloping bank will reduce the amount of caving to a minimum. Just what this slope should be depends on the nature of the soil. My experience has been that a peat soil will stand up well with a \( \frac{3}{4} : 1 \) slope; clay 1:1; and loamy soils should be provided with not less than a \( 1\frac{1}{2} : 1 \) slope or better still 2:1 slope.

A great deal of attention has been given to the design of open ditches, but comparatively little to their maintenance. In sections of the country where drainage has been only partially developed the general impression is that a ditch once constructed will require no maintenance, unfortunately this is not true, and open ditches like roads and bridges, will require more or less attention from time to time in order to keep them up to their highest state of efficiency. While the amount of repair work will vary with conditions, considerable can be eliminated by careful designing. The method of construction has a bearing on the maintenance, yet in spite of the most careful designing and construction all ditches will require more or less repair work from time to time. Economy requires that this work be done at regular intervals during the dry months of summer and fall and not be allowed to fill in gradually until they will no longer carry off the water, or until the outlets are no longer sufficient. As a result of such conditions there usually follows a general agitation and condemnation of all parties who had anything to do with the construction of the ditch, followed by perhaps several years of quarreling among otherwise friendly neighbors, until finally steps are taken to have the ditch cleaned
out or reconstructed. My experience has been that the recon-
struction or clean out work generally costs as much as the
original construction. Railway companies have bridge men and
track men to patrol their right of way; road builders all over
the country have had or are at the present time arranging for
a patrol system to keep their railways or highways in a con-
dition for traffic, realizing that maintenance work must be pro-
vided at regular intervals in order to protect their structures.
How many drainage districts do we find that have followed this
policy?

Such a system is surely needed and unless this is done at regu-
lar intervals it will be necessary to re-dredge the neglected
ditches at great expense. At the summer meeting at Racine I
mentioned this necessity for establishing a patrol system for
open ditches and I believe such a system could be maintained
at an annual expense to the district of approximately $10 to $15
per mile. We are spending approximately $30.00 per mile per
annum for the maintenance of permanently improved concrete
highways. Is it therefore unreasonable to spend less than one-
half of this amount per mile for the maintenance of our ditches?

The time in which our ditches are subject to the greatest fill-
ing action is during the first year after construction when the
waste banks, and slopes are in a loose unsettled condition, and
easily affected by the action of frost and water. If during this
period the patrol system was rigidly and effectively maintained
the plan would result in a great saving to the district and less
grief for the commissioners and others connected with the work.
I have sometimes thought that our drainage laws should con-
tain a provision making it necessary for the commissioners to
file a written report to the court at least four times a year during
the working season stating the condition of the drainage ditches.
Each report would necessarily be based on a thorough inspec-
tion of the ditches. This plan if followed would make it possi-
ble for the commissioners to note all sections of the work which
would require attention and the court would be provided with
a record of the true condition of the drains within the district
and having these records could demand that the commissioners
give them proper attention. Some such an arrangement would
also furnish a valid reason for frequent trips of inspection by
the commissioners, and thereby eliminate criticism from the landowners that the commissioners are incurring unnecessary expense to the district by making unnecessary trips of inspection. It is a common practice for engineers in designing drainage ditches in Wisconsin to specify a 1:1 slope regardless of soil conditions. I believe that a 1:1 slope should be the minimum regardless of soil conditions and a 2:1 the maximum.

In order to avoid excessive top widths with these flatter slopes the bottom may be kept comparatively narrow. This will aid in making the ditch more nearly self-cleansing and would also reduce the cost of construction.

The comparison of yardage in a ditch with a ten-foot bottom and eight foot deep is as follows:

1½ : 1 slope 20 per cent greater than 1 : 1.
2 : 1 slope 20 per cent greater than 1½ : 1.

In a ditch with a twenty-foot bottom the comparison is as follows:

1½ : 1 slope 14 per cent greater than 1 : 1.
2 : 1 slope 14 per cent greater than 1½ : 1.

In railroad and highway construction the slopes in cuts are never less than 1 : 1 and 1½ : 1 is now more commonly specified. The slopes of railway and highway cuts are exposed to less erosive forces than the sides of open ditches.

However, in specifying such flat slopes for open ditches and adhering strictly to the specifications it would practically eliminate the construction of ditches with the floating dipper dredges for the reason that dipper dredges cannot cut a smooth or true side slope. Yet we cannot eliminate the dipper dredges for the reason that some of our marshes are so soft that no machine other than a floating dredge can be successfully operated. It has been my experience in drainage districts where floating dredges were used that the work was usually completed within the time limit specified in the contract. On the contrary the majority of the dry land machines while by a careful manipulation of the dipper they will cut almost any desired slope, yet they require more time to complete a job than does the larger floating dredges.

It is therefore necessary to provide specifications for practi-
ally all types of excavators as well as varying soil conditions and in order to maintain a proper slope on ditches constructed with a dipper dredge the specifications should provide for a deeper and wider ditch so that when the banks cave in and the sides erode the ditch will still have sufficient depth after the sides will have broken down to their proper slope. On ditches constructed with a dry land machine the specifications should provide that the slopes vary from $1:1$ to $2:1$ depending on soil conditions as it is far more economical to excavate the side slopes to the necessary inclination in the first instance than to later reconstruct the entire ditch. If this is done and a systematic patrol system adopted until such time as the ditch slopes have become firm, less trouble and expense would be experienced in maintaining the side slopes and as stated before after the sides of the ditches have become smooth they should be sown with grass seed which will protect them from erosion. Let me say in closing that the best way to eliminate the maintenance of slopes in open ditches is to eliminate, wherever possible, the open ditches and use tile.

Note: On both the Racine and Watertown field trips examples were seen where spoil banks of dredge ditches were levelled and the slopes of the ditch seeded for less than 50 cents a rod.—Editor.

A SANE PLAN FOR MARSH DEVELOPMENT

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Well drained and well managed marsh lands are among the most profitable in Wisconsin. Poorly drained and poorly managed, they are about the most unprofitable. What our marsh lands need is safe and sane development. In Wisconsin we have examples of success and examples of failure.

A typical successful project may be cited in southeastern Wisconsin. The main ditch and large tile laterals were installed by the district about 1910. No one man owned more than 80 acres of marsh land. Some of this was peat to a depth of six feet, but all of it was a part of the farms on the surrounding upland, which was thickly settled, highly developed and selling for about $200 an acre. In its natural condition the wet land