DRAINAGE SYSTEM

DESIGN.

A Thesis Submitted to

The Faculty of

MICHIGAN STATE COLLEGE

of

AGRICULTURE AND APPLIED SCIENCE.

By

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Bachelor of Science

in

Civil Engineering.

June 1925.

THESIS

BIBLIOGRAPHY.

"Engineering for Land Drainage" by Elliott.

"American Civil Engineers Pocket Book" by Merriman.

"Handbook of Construction Equipment" by Dana.

"Drainage in Michigan" by Miller and Simmons.

"Handbook of Cost Data" by Gillette.

"Michigan Agricultural College Experiment Station Bulletin" - - "Utilization of Muck Lands."

APPRECIATION.

The writers wish to take this opportunity to express their thanks to the members of the Civil Engineering Department, especially to Professors C. L. Allen and F. A. Gould, and to the members of the Farm Crops Department and Soils Department of Michigan State College, and also to Mr. Victor Mikan, of Durand, Michigan, for their aid rendered in the preparation of this work.

May 25, 1935.

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INTRODUCTION

In various places of the southern part of Michigan there are quite large areas of low or marshy land, surrounded in most cases by good farming land and near good markets. The soil in these marshy places is usually rich in plant food, the soil deep and free from rocks - - much better, in itself, than the soil surrounding it.

But due to the level of the ground being so low, the soil is cold and wet, sometimes flooded, and so can ot be used for any useful farming purposes. It is usually used for pasture, or perhaps a little hay of a very inferior quality is cut from it. Such land is valued at only about twelve dollars per acre, while land right beside it, not nearly so rich in plant food, rocky or hilly is vallued at one hundred dollars per acre or more.

If only such areas could be drained, they would immediately assume a value equal to or in excess of the land surrounding them , and the productivity of the farms concerned would be greatly increased by this opening up of new farming areas.

Some such places, of course, could not be drained without installing pumping stations, and lifting the water over levees or embankments. In most cases the cost of such a drainage system would be far in excess of the benefits to be gained by it.

But some other areas require much simpler and cheaper drainage. They have a river or small stream flowing through them, but usually it winds and meanders around so much that its velocity is much less than it should be. This low velocity and the fact that the land is so level and that the runoff is very slow, accounts for a good deal of the excess water in the soil. Added to these two factors is, of course, the additional one of the soil level being only slightly above the water level in the stream.

In most of these latter named cases, about all that is required to make this soil good and productive is to straighten out the drainage channel so the velocity of the water will be increased, and then insure a quicker runoff by the installation of a system of tile drainage.

This is the condition encountered in the area under consideration in this work, the south one-half of the southeast one-fourth of Section 19 of Township 2 South Range 1 West in Jackson County, Michigan. Here we have a small stream, meandering through a valley about 4000 feet wide all of which is marshy. Surrounded by good farming land, any of which will sell for one hundred dollars per acre, this marshy land is valued at twelve dollars per acre. Its only use is as rather poor pasture, and as a source of marsh hay, worth about one-fourth or one-fifth what cultivated hay such as should be grown there is worth.

The authors in undertaking this work wish to find if it will be possible to drain this area, and change this poor and unproductive land into some such valuable property as it seems that it should be, and discover if the cost of the improvement would be more than would be justified by the benefits gained.

STATEMENT OF PROBLEM.

It shall be the purpose of this work then, to do the following things:

1. Investigate the feasibility and probable benefits to be derived from changing the river channel through this area.

2. Investigate the practicability of a tile drainage system, and if deemed advisable to design such a system.

3. To determine the probable cost of such an improvement.

SECTION NO. I.

CHANNEL CHANGE.

As shown by the accompanying map, the river flows at this point in a wide arc so that its length is almost twice what would be necessary if a direct channel were made from the south to the north side of the area. Shortening this distance by a new channel would give a greater velocity and so carry the water away faster. An investigation of the possibility of this is now proposed.

Three good sized lakes only about a mile upstream act as a reservoir to practically eliminate a large flood flow, so the channel need not be designed for very extreme conditions.

One of the writers has lived for ten years within sight of the river, so his knowledge as to the maximum flow to be expected, based on his long observation, was used in the computations for the size of the new channel. Measurements of the depth of water and size of the old channel were made, at a time when the flow was about fifty per cent of the maximum. The computations for this are found on the accompanything computation sheet Number 1.

The proposed new channel does not follow the shortest possible line between its upper and lower ends. Instead it is deflected slightly in order to follow the property line, since the area under consideration belongs to two different farms. But this deviation is so slight, and the increased length so negligible, that this course was deemed advisable.

In the computations for earth work quantities in the channel change, a constant cross section was assumed, instead of the more often used method of cross sections at regular intervals and computation of quantities by end areas. At first this seems inaccurate, but in view of the very level nature of the ground, and the fact that a straight grade was assumed for the channel, this was deemed to be entirely sufficient.

To arrive at this cross section the mean depth was taken from the profile, by adding up all the cuts at the different stations, and dividing by the total number. Side slopes of 2:1 were assumed, and a bottom width of seven feet, which was found to be sufficient (Computation Sheet Number 1).

In conclusion, it seems that such a channel would be a very good drain, and would serve very well the purpose for which it is intended, and so such a channel change should be put in as the first step in draining this area.

Computation Sheet No. 1.

Determination of Flow and Necessary Size of New Channel

For these computations Kutter's formula was used, as follows:

$$v = \left[\frac{\frac{1.811}{n} + 41.6 + \frac{.00281}{s}}{1 + \left[41.6 + \frac{.00281}{s}\right] \frac{n}{\sqrt{r}}} \right] \sqrt{rs}$$

When v = velocity of flow

s = slope of channel

n = coefficient of roughness, varying with each type of channel

r = hydraulic radius = $\frac{\text{channel area}}{\text{wetted perimeter}}$

SECTION NO. II.

TILE DRAINAGE SYSTEM.

In the study of the possibility for a tile drainage system five things are necessary, as follows:

1. A contour map of the area.
2. A study of the practicability of a tile drainage system for the area.
3. A determination of the plan and grades of the various systems.
4. Determination of tile sizes in the various parts of the systems.
5. An estimate of the cost.

To obtain the data for the contour map a transit and stadia survey was made of the entire area. A magnetic bearing was used to establish a base line, as it was not deemed necessary to take the extra trouble to establish a true meridian for this problem, which was in no way connected with any other project.

For similar reasons a purely arbitrary datum plane was assumed and two bench marks placed in outstanding trees on the edges of the area. The location and elevations of these bench marks are given on the accompanying map. So far as the purpose of this investigation is concerned, this seemed entirely adequate, and at any time a reduction to mean sea level data is necessary it can be so reduced by reference to these bench marks established.

From this base line, then, and with this assumed elevation, a transit and stadia survey was made, and later plotted up and the contour map of the area drawn.

In this survey distances were measured to the nearest foot, and elevations were usually taken to the nearest tenth of a foot. Angles were measured very carefully, especially in moving the transit from one point to another.

In making the map, the contours were drawn with a contour interval of five tenths of a foot, because of the extremely level ground surface.

The next problem, then, was to study the practicability of a tile drainage system for the area. On the west side, no especial difficulties were encountered. There it was easily apparent that a very good drainage system could be installed , which would take care of the excess soil water and while the slope might be a little flat, this could be taken care of by increasing somewhat the size of the tile.

But on the east side, or the system designated as the "C" system, more difficulty was encountered. This is the area through which the streamnow flows, so it is, of course, the lowest ground of all. Investigation showed only a small difference in elevation between the ground surface and the bottom of the proposed channel change. In Merrimans "American Civil Engineers Pocket Book" depth for drainage tile of two and one-half feet is recommended, to avoid damage from freezing, and interference with cultivation of the land.

Such a depth, however, was found to be impossible, if any slope was to be maintained in the tile line. But it was found that if the bottom of the tile line were placed two feet deep, this would make available a slope which was considered adequate, and would permit the laterals to be laid at a sufficient depth, since the ground slopes up on each side of the proposed location of this "C" main.

This proposed placing of the main tile at such a shallow depth, however, introduced the danger of breaking it by cultivation of the land, or by wheels driving over it. But it was thought that this danger might be avoided by leaving uncultivated a strip of land about five or ten feet wide, directly over this main tile. Such a strip would soon become heavily sodded and would make an excellent protection for the tile underneath.

It is admitted that such a thing would be bothersome in an otherwise unobstructed field, and would usually be poor practice. But since the drainage of the entire system depends upon a main placed at that location, and this seems the only safe way to have a main so placed, it was deemed advisable and practicable to do this.

So it seems that a tile drainage system for this area is practicable, and could be made to reduce the water level sufficiently to make the land a good farming area.

The next item, the determination of the plan and grades for the different systems, was comparatively simple. The plan was to run one large main, with laterals leading off from one or both sides, depending on the contour of the ground. Various authorities consulted as to the necessary distance differed rather widely, but it was thought that in view of the sandy, fairly porous nature of the soil a distance between drains of one hundred fifty feet, as recommended in Elliott's "Engineering for Land Drainage", would be about right. This, then, was the distance used in drawing up the plan of the drains.

An effort was made wherever possible to have the drains follow the natural slope of the ground. The main benefit from this was to decrease the necessary amount of excavation for the tile lines, and get as much fall as possible.

The grades for each system were different, but the same grade was adopted for all parts of each individual system. This was deemed better, in view of the very level ground, than to break grade in the mains, or to use a number of different grades in the laterals, and increased the necessary excavation only very slightly if at all.

This grade was arrived at by placing the upper end of the mains at what was thought to be the correct depth, and then, knowing the length of the main, lay a straight grade for its entire length, utilizing all the fall available.

The mains were made fairly short in the "A" and "B" systems, in order to keep the size of the tile low. But in the case of the "C" system this could not be done, for every bit of fall available had to be utilized to obtain enough of a grade to keep the tile free from sediment. As a result we have a quite long tile, with quite large sizes.

The next item necessary was the determination of the sizes of tile necessary. Poncelets formula was used in the computations for these tile sizes, and the work is shown on the accompanying computations sheets.

In every case larger tile was used than would appear necessary from these computations. The reasons for these larger sizes were as follows. The grade in every case is quite flat, and the soil is a fine, often silty sand or muck. This will have some tendency to enter the tile and clog it. This would render useless a small tile line, but a larger one could stand some sediment without becoming fully stopped up. So for these reasons larger tile were used than would at first appear to be necessary. This will, of course, make the first cost of the project more than if smaller tile were used, but it will be a much more permanent improvement.

It will be noted that on the plan the tile sizes are increased to 16" on the "C" system, without any new tile shown entering the main. This was done with the idea in mind that later the area north of that in this problem might be drained, and this main is made large enough to care for this possible future development.

The last item of this section, the cost, will be taken care of in the next section.

In conclusion, it seems that this land can well be drained by a system of tile drainage as here outlined. The systems "A" and "B" are good and sufficient systems, their only drawbacks being that somewhat oversize tile have been deemed necessary. The system "C" is not so good, owing to the fact that the main must be laid so shallow, and large and expensive tile are necessary at the lower end. But these obstacles were unavoidable, and are not considered serious enough to render the project impracticable.

Computation Sheet No. 2.

Quantity of Flow in Old Channel

s = .00078

n = .030

r = 1.43

v = 1.05 feet/second

Q = area x velocity = (20 x 1.05) = 21 cu.ft/ sec

This was estimated to be 50 per cent maximum flow.

Quantity of Flow in New Channel

Assumed bottom width of 7 feet, side slopes 2 to 1, and depth of water 2,5 feet.

s = .00144

n = .030

r = 1.375

v = 2.18 ft/sec.

Q = 22 x 2.18 = 48 cu. ft/sec.

Since this quantity is more than the estimated maximum flow, this channel is considered wholly adequate.

Computation Sheet No. 3.

Tile Sizes.

Ponoelets formula for velocity in closed channels:

$$v = m\sqrt{\frac{dh}{l + 54d}}$$

when
- v = velocity
- m = constant for each tile size
- l = length of tile
- h = head in feet
- d = tile diameter in feet

- -

To find area drained by each size of tile. Runoff coefficient equals 1/4 inch/ 24 hour.

<u>Drain Ca</u> ---------- 16 inch tile.

$$v = 47\sqrt{\frac{1.33 \times 2.6}{1000 + (54 \times 1.33)}} = 2.66 \text{ ft/sec.}$$

Discharge = Area (sq. ft.) x velocity (ft./sec.)

$$D = 1.39 \times 2.66 = 3.71 \text{ cu. ft/sec.}$$

$$\text{Possible area drained} = \frac{\text{discharge}}{\text{runoff coefficient}}$$

$$A = \frac{3.71}{.0105} = 353 \text{ acres.}$$

Therefore a 16 inch tile is ample for the drain Ca.

Computation Sheet No. 4.

Drain Cb ------------ 12 inch tile.

$$v = 45\sqrt{\frac{2}{946 + 54}} = .666 \text{ ft/sec.}$$

$$D = .785 \times 636 = .5 \text{ cu. ft/sec.}$$

$$A = \frac{.5}{.0105} = 47.5 \text{ acres}$$

Therefore a 12 inch tile is ample for Cb.

- -

Drain Cd --------------- 10 inch tile.

$$v = 44\sqrt{\frac{.833 \times 2.32}{645}} = .765 \text{ ft/sec.}$$

$$D = .5375 \times .765 = .411 \text{ cu. ft/sec.}$$

$$A = \frac{.411}{.0105} = 39 \text{ acres.}$$

Therefore a 10 inch tile is ample for Cd.

- -

Drains Aa, Ba, and Ce --------- 8 inch tile.

$$v = 40\sqrt{\frac{.67 \times 3.4}{(150) + (54 \times .67)}} = 4.47 \text{ ft/sec.}$$

$$D = .349 \times 4.47 = 1.56 \text{ cu. ft/sec.}$$

$$A = \frac{1.56}{.1050} = 147.5 \text{ acres.}$$

Therefore an 8 inch tile is ample for drains Aa, Ba, and Ce.

Computation Sheet No. 5.

All Laterals ------- 6 inch tile.

$$v = 36 \sqrt{\frac{.5 \times 2.7}{600 + 27}} = 1.67 \text{ ft/sec.}$$

$$D = .197 \times 1.67 = .328 \text{ cu. ft/sec.}$$

$$A = \frac{.328}{.0105} = 31.15 \text{ acres.}$$

Therefore a 6 inch tile is ample for all laterals.

Note: All sizes are taken large because of the sandy soil through which they are laid.

SECTION NO. III.

COSTS.

The costs of this improvement are quite well shown in the following estimate sheets. Some explanation, however, as to how these costs were arrived at will be necessary.

The authors spend some time seeking information on the subject from various sources, without much success. Nowhere, apparently, could be found very good and recent information as to cost of excavation, laying and backfilling for the tile system.

So a request was made to a friendly contractor, Mr. Victor Mikan, living at Durand, Michigan, who owns a ditching machine and does a good deal of this kind of work. The authors desire to take this opportunity to thank him for his kind assistance.

His estimate of costs for machine trenching, laying tile, and backfilling, and for trucking from the railroad to the farm have been used. Competitive bidding on the job might result in a lower price, but the authors have made no attempt at that.

The costs for tile delivered at the nearest railroad point were taken from a price list of the American Vitrified Products Company (Michigan Branch) with offices at Jackson, Michigan. This tile is, of course, higher in price than ordinary drain tile, but as brought out in another part of this report, the added expense was thought justifiable.

In computing the cost of excavating the channel change, the authors are indebted to Mr. F. A. Gould of the Civil Engineering Department, and to information obtained from the "Handbook of Cost Data" by Gillette, in determining upon a suitable unit price for excavation. The unit price may seem rather low, but in view of the fact that no rocks or very difficult excavation is to be anticipated, and that it will not be necessary to haul the excavated earth for any very great distance, it was thought by the authors to be ample.

The estimate sheets covering each item of cost, are found immediately following this section.

CONCLUSION.

As a result of the inquiry and investigation embodied in this report, it seems that this land may very well be drained, and that if it is drained its value will be increased more than enough to make it economically worth while.

The cost of the improvement averages about Fifty Dollars per acre, which is a fairly high but not at all prohibitive cost. For after drainage this land would probably be the best land on the farm. As brought out in the Michigan Agricultural College Experiment Station Bulletin "The Utilization of Muck Lands", this land is good for a variety of crops, and will raise more than the land surrounding.

It will raise corn, preferably ensilage corn, requiring a heavy, rank growth as well as higher land. It will grow hay, yielding very often two and one-half to three tons per acre, as brought out in the aforementioned bulletion. A yield of two tons per acre on land adjoining is quite uncommon.

On lands of a similar nature, on the same farm, buckwheat was grown two years ago, which yielded a net income of about twelve dollars per acre, after all expenses were paid. There is no reason why this land will not do the same, as this was not an especially favorable year.

Again, as brought out in the bulletin mentioned, it will raise truck and such crops as onions, beets, etc., very successfully. To quote from this bulletin, "The area (on the Michigan State Prison Farm, on muck land) was approximately six and one-quarter acres. It was fertilized with about 150 spreader-loads of coarse horse manure and 2,375 pounds (380 pounds per acre) of a complete fertilizer. The following yields were obtained: 2300 crates of onions, 310 crates of beets, approximately 3500 crates of carrots, and 3,500 crates of parsnips."

Certainly land that will yield crops like that is worth the expenditure of fifty dollars per acre for drainage.

But actually the cost of this work alone is less than that, for no small part of the total is taken up by the lower part of the "C" system main. This part of the system may with a good deal of reason be said to serve the area north of the tract under consideration, since it was made larger in size to care for the probability of wanting to connect onto it for draining this area. So a good part of the cost of this main may be considered as a part of the cost of draining this other area, and would undoubtedly be paid for as such by agreement with the owner of the area benefited.

The drainage system as here outlined would be absolutely permanent. This is assured by the use of vitrified tile, and of the large sizes used. If the owner of the land desired to cut the factor of safety somewhat - - which, in the opinion of the authors, could be done and still have some margin of safety - - the cost could be appreciably cut by using ordinary drain tile, or by using 4" laterals. The sizes used are very conservative; more, even, than is usually recommended. So if it was desired to be a little more liberal in design, a quite appreciable saving in cost could be effected in that way.

Estimate Sheet No. 1.

Excavation for New Channel and Cost.

From computations as shown on Computation Sheet No. 1, a bottom of 7 feet with a 2:1 side slope and a depth of 2.5 feet will be adequate.

Average depth of the channel is 2.7 feet from profile.

The cross-section area using a depth of 2.7 feet is 33.48 square feet.

Length of channel is 2175 feet.

$$\frac{33.48 \times 2175}{27} = 2697 \text{ cubic yards.}$$

2697 cu. yds. @ $.20 = $539.40

Estimate Sheet No. 2.

Lengths and Sizes of Tile Required

Drainage Systems A. B. & C.

6 inch Tile

No.	Length in Feet	Average Depth in Feet	No.	Length in Feet	Average Depth in Feet	No.	Length in Feet	Average Depth in Feet
Ab ...	400	3.00	Bf...	700	3.00	Cm ...	900	3.25
Ac ...	770	2.50	Bg...	760	3.00	Cn ..	910	3.25
Ad ...	740	2.75	Cc...	1800	3.00	Co ..	490	2.50
Ae	740	2.75	Cf	420	3.00	Cp	590	2.75
Af	570	2.75	Cg	570	3.00	Cq	440	2.75
Ag	165	2.75	Ch	710	2.75	Cr	400	3.00
Bb	510	2.75	Ci	360	3.00	Cs	360	3.00
Bc	590	2.25	Cj	590	3.00	Ct	310	2.50
Bd	310	2.50	Ck	730	3.50	Cu	310	2.50
Be	640	2.75	Cl	780	3.25	Cv	90	2.00
						Total	17,505	----
						Average	-----	2.82

Cost of tile delivered at nearest freight depot $1,342.00

8 inch Tile

No.	Length in feet	Average depth in feet
Aa	160	3.00
Ba	160	2.75
Ce	470	2.75
Total	790	Average 2.94

Cost of tile delivered at nearest freight depot $98.00

Estimate Sheet No. 3

Lengths and Sizes of Tile Required

Drainage Systems A. B. & C. (con't).

10 inch Tile

No.	Length in feet	Average Depth in feet
Cd	600	2.75

Cost of tile delivered at nearest freight depot $107.00

12 inch Tile

No.	Length in feet	Average Depth in feet
Cb	640	3.00

Cost of tile delivered at nearest freight depot $153.00

16 inch Tile

No.	Length in feet	Average Depth in feet
Ca	750	3.00

Cost of tile delivered at nearest freight depot $300.00

Estimate Sheet No. 4.

Number of Branches Needed

Size of Tile	Number of Branches	Unit Cost	Total Cost
16 in.	1	$ 1.75	$ 1.75
12 in.	6	1.11	6.65
10 in.	9	.82	7.40
8 in.	6	.58	3.50
6 in.	9	.35	3.20
			$22.50

Total cost of tile laid down at nearest freight depot $2,022.50
Cost of trucking to job -- 3 miles at $2.00 per
ton-mile, 134 tons @ $6.00 .... 804.00
Cost of tile on the job $2,826.50

Cost of excavation and laying tile:

6 inch tile, 1060 rods @ $.60 $636.00
8 inch tile, 48 rods @ .60 30.50
10 in., 12 in., and 16 in. combined, 120.5 rods @ .60 72.50
Total $739.00

Cost of back-filling, 1228.5 rods @ $.11 135.00

Total cost of excavation, laying and backfilling 874.00

Total cost of system $3,700.50

Sta. 0+00
System C
Co 750'-6"
Cb-690'-12"
Sta. 0+00
System A
Aa 140'-8"
Ac-770'-6"
Ad-740'-6"
Grade of A System .00109
Ae-740'-6"
Af-570'-6"
Ba-165'-8"
Sta. 0+00
System B
Bb-510'-6"
Grade of B System .00044
Bc-540'-6"
Bd-310'-6"
Bf-700'-6"
Bg-760'-6"
N-1°54'-E Proposed Channel Change
LINE FENCE
Cc 1800'-6" Grade .0025
Cf-420'-6"
Cg-570'-6"
Ch-710'-6"
Ci-360'-6"
Grade of C System .00259
Cj-590'-6"
Ck-730'-6"
Cl-780'-6"
Cm-900'-6"
Cn-910'-6"
Co-490'-6"
Cp-590'-6"
Cq-440'-6"
Cr-400'-6"
Cs-360'-6"
Ct-310'-6"
Cu-260'-6"
B.M.3 Spike in foot of lone oak tree Elev 100.26
B.M.2 Spike in foot of large lone poplar tree Elev 99.78
West Branch Kalamazoo River
Profile and Drainage MAP for THESIS
W.B. Reinicke F.W. Moore
scale 1" = 100' June 1925