Civil engineering Sanitary engineering

A DISCUSSION OF PUBLIC DRAINAGE METHODS IN KENT COUNTY, MICHIGAN

Thesis for Degree of C. E.

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1931

THESIS

PREFACE

In this thesis we will discuss the problems of the Drain Commissioners Office in Kent County, Michigan; accumulate the necessary data for their solution, and recommend changes and additions to the present methods of procedure incident to the handling of the drainage work in this county with the object in mind of assisting the present and future drain commissioner in the conduct of his office.

It is our aim to present the problems as successively as possible, keeping in mind the relation that should exist between office and field.

The matter of assessments as presented is believed to be entirely new and is in our opinion a judicious application of the statement in the law that "All apportionments of benefits under the provisions of this act shall be upon the principle of benefits derived "(Sec.2,Chap. VI; Act #316, Public Acts 1923)

In the chapter on design we have attempted a practical application of the underlying principles of hydraulics to the design of open drains.

The authors gratefully acknowledge their indebtedness to Mr.R.B.Patterson, Kent County Drain Commissioner, for his advice and co-operation, also to Mr.T.O.Williams, who for forty years has been surveyor of Kent County, for his many valuable suggestions.

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CHAPTER I

A HISTORY of DRAINAGE

There is something repulsive about swampland and marshes, man instinctively avoids them. They are the habitat of the most loathsome forms of animal life, they give forth in warm weather a foul stench, and to one attempting to traverse them they are a source of constant peril. From the earliest days man has peopled them with the worst and most mischievous demons of his imagination. Their connection with disease was known centuries before the bacillus was even imagined to exist. Yet for generations man himself increased the area of these wastes with the roads and footpaths which he built above the level of the surrounding land that he might pass and re-pass dry shod. Finally he discovered that if the trenches from which the filling dirt had been taken were properly sloped, the water instead of standing in them would flow away, at the same time drying up some of the adjacent land. Thus the cause of the trouble became a factor in the solution of the greater problem.

Every country, both in the Old and the New World has had its drainage problems. Historians tell us that the starting of Egyptian civilization and the organization of the Egyptian government was for the purpose of reclaiming swamp lands so that crops could be produced to feed the generation of that day. There have been many drainage problems that were of enough importance to attract the attention of the historians and poets of that day, among them being the drainage of Lake Copias by

the Greeks; and the drainage of the Fens in England which was started during the time of Charles the First and finished during the reign of Oliver Cromwell. The civilizing effects of this great project is well set forth by one of the Fen poets:

" With a change of elements suddenly
There shall a change of men and manners be:
Hearts thick and tough as hides shall feel remorse
And souls of sedge shall under-stand discourse:
New hands shall learn to work, forget to steal;
New legs shall go to church, new knees shall kneel."

One of the greatest drainage problems that the world has ever known was started by the Aztecs for the drainage of the Mexican Valley and was under way when Cortez conquered Mexico.

For centuries France, Germany and Italy have grappled with drainage problems of large dimensions; but perhaps no country in the world has had drainage problems of such magnitude as ~~those of~~ Holland, a country of seven million acres, four-fifths of which are below the level of the sea, and yet, let it be said to the credit of her engineers that nowhere upon the face of this globe is there a more prosperous agricultural community.

In our own country we have had our drainage problems in the Upper Mississippi Valley, in Florida and in Louisiana and all through the western and central states, and they are by no means completed at the present time.

The general history of drainage repeats itself in the history of Michigan drainage Legislation, as is shown by the following

excerpt from a paper prepared by Mr. T.H. Harrod and delivered before the 1930 County Drain Commissioners Convention:

As early as 1819 a law was passed in Michigan Territory permitting the drainage of roads; it was included in a law entitled "An act to regulate highways" and was adopted December 30, 1819. The portion of the act relating to highway drainage, Section 9, is as follows: 'And be it further enacted, that it shall and may be lawful for supervisors of highway or other persons, by their orders, to cut timber, to dig in the highways, and to enter on lands adjacent to the highways and to cut, make, cleanse and keep open such gutters, drains and ditches therein as shall be sufficient to convey and draw off the water from said highways with the least disadvantage to the owner of the land; the owner and every other person, except such supervisor, is hereby prohibited from filling up, stopping or obstructing such gutter, drain or ditch under the penalty of eight dollars to be recovered by action of debt with costs, by said supervisor before any Justice of the Peace of the proper county'.

This is the pioneer law for the drainage of highways in Michigan. The drain law as we know it was not started until 1827. In 1833 the drain law was restated with some changes made in the wording. Thus before Michigan was a State, before the Upper Peninsula was given to the State as a settlement for the boundary dispute between Michigan and Ohio, we find our State settled to a policy of both land and highway drainage.

The first drain law enacted after Michigan became a State was Act 80 of the laws of 1839. Nothing in this act referred to the drainage of highways. A petition was filed by the party wanting the drain with the Justice of the Peace. The Justice called out a jury of twelve freeholders who determined the necessity for the drain, approved or changed the proposed plans for the drain, assessed the damages if there were damages to offset benefits, and filed their report with the Township Clerk. The petitioner after paying the expense of the jury and the damages awarded by them, was entitled with his servants, his oxen etc. to enter upon the lands and construct the drain.

In 1857 by Act No. 169 the drain law was revised and provided the appointment of three commissioners by the Board of Supervisors to superintend the drainage of marshes and other low lands. This law no doubt was to permit the construction of drains traversing more than one township, for in the next session of the legislature we find Act 257 which authorized commissioners of highways to establish watercourses and locate ditches in certain cases. The commissioner of highways seems to also have been the township drain commissioner.

Act 216 of 1861 repealed the acts of 1857 and 1859. The Board of Supervisors were given authority to appoint three commissioners to act on the petition for a drain, which petition

had to be signed by five freeholders. From this time on, each legislature added to the drain law until in 1881 by Act 269 the drain laws for both County and Township were combined. There were still the drain commissioners appointed by the Board of Supervisors and the Township Drain Commissioners.

In 1897 by Act 254 the office of Township Drain Commissioner was abolished and the office of County Drain Commissioner was made, the Drain Commissioner being appointed by the Board of Supervisors. It appears that all local acts affecting drainage in counties were repealed at this time.

During the period from 1827 to 1897 our drain law was being built up to conform with the necessities of drainage and our Supreme Court was passing on these laws and confirming them. What appears to be red tape and repetition in our forms of procedure have generally been required by the Supreme Court to safeguard the rights of the individual and the public.

Since 1897 each legislature has felt it necessary to make some alteration or addition to the drain law until by 1923 it was so badly confused that it was almost impossible for even an attorney to follow it. In that year the 1897, 1901, 1909, 1911, 1915, and 1921 acts were all repealed and a new act passed codifying the drain law and thereby clearing the situation generally. Additions have been made in each session of the legislature since then, however, mainly designed to assist the County and State Highway Departments in obtaining highway drainage. A copy of the law as of 1929 is included as Exhibit A. in this thesis.

The records that are available of the work done under the township system are very incomplete in many of the townships. It would appear, however, that the first work was done in the early '70s and that it steadily increased until the county system was organized in 1897.

The drains were almost without exception short and shallow, what we would class today as laterals, and were of course all dug by hand or with teams. One interesting discovery made in going thru these old records is that frequently a cleanout of a still older drain is requested.

Since coming under the county system 204 drains have been designated and constructed as county drains in Kent County as is shown by Exhibit B, the total length being 227 miles, the net drainage districts covering approximately 152, 760 acres and the total cost being about $817,000. These figures are of January 1, 1931. The tendency has been towards longer projects, more economically designed, and more carefully constructed. Within the last few years there have been a number of storm sewer systems built to take care of the highways in the residential areas adjacent of the City of Grand Rapids.

CHAPTER II

ANALYSIS OF ADMINISTRATIVE PRACTICE

The County Drain Commissioner is elected bi-annualy by the people of the county at the regular election of county officials, his salary for the last 12 years has been fixed by the Board of Supervisors at $1500 a year and travelling expenses and he is allowed $500 a year for clerical work which includes recording all proceedings. The office formerly required only a small portion of the incumbent's time and therefore the remuneration was not unreasonable, but for the present and indicated future he is grossly underpaid. Kent County is fortunate in having a man of Mr. Patterson's experience and calibre filling the position, for another man who would assume the responsibilities and duties of the office and discharge them with equal ability would be hard to find.

In our preliminary investigations for this thesis we found no other source of information than the legal record books and a map drawn to a scale of two miles to the inch on which the drains were approximately located and which was last posted up to date in 1917. There were no record cards showing the history of the individual drains, no one knew without going thru all of the record books how many times a drain has been cleaned out and at what cost, it was practically impossible to tell what county drain, if any, passed thru a given description unless the name of the drain was recalled, and there was no method whereby adjoining drainage areas could be assessed without

danger of overlapping or omitting descriptions along the divide line. Many of the questions arising under these headings could be answered by Mr. Patterson because of his long experience and intimate knowledge of conditions, but what of his successor?

Our first step in preparing to write on this subject was to prepare a book of maps, one for each township, on a scale of 1500 feet to the inch on which we showed all drains now laid out and the district assessed for the construction of each, differentiating with colors between the respective drains. In some townships the result resembled the efforts of an amateur artist of the ultra-moderne school. The map of Grand Rapids township is included as Exhibit C. The maps in the book are blue line prints mounted on cloth with photographic enlargements of the United States Geological Survey maps, where available, mounted on the opposite page. Our first plan was to show the contour lines on the blue line prints but a trial convinced us that the confusion of lines was too great, so the present form was resorted to and has proven quite satisfactory. The book is bound in buckram and suitably entitled.

As we searched the records for the necessary information for the preparation of these maps we also filled in a set of record cards a sample of which is shown on page 8. By referring to the book of maps and the record cards we are now able to obtain nearly any information ordinarily desired in a very short time.

Name | Number

Location

County Joint

Est. | Liber | Field Notes | Plans

Built | Length | Av. Depth | Bottom or tile size

Area of Dist. | Map | Other drains in Dist.

% Dist. | % Twp. | % Co. Rd. | % St. Hwy. | Method of pay't

Structures | Cost

Tile-Length | Cost | Open Length | Cost

Admin. exp. | Contracts | Engr. | Insp. | Total

Remarks:

CONSTRUCTION

Type*	Date	Length	Cost	F. N.	Plans	Liber

*A-Original Cons. C-Cleanout. D-Deepen, widen, etc. R-Repair (20%)

Date	Condition	Report No.	Inspector

We next turned our attention to the study of the drain law, (see Exhibit A). This act as found in the statute books is rather difficult to understand in that while it is very specific as to the details of the procedure on the majority of points it is not arranged according to the order of procedure. That we might have an outline for ready reference in keeping track of the various steps in connection with the construction of a drain, eliminate the danger of not observing proper time limits, and know which blank or form to use for each of the various proceedings, we prepared a brief or abstract of the drain law as shown on the following pages. The column headed " Form No." indicates the legal form given in the appendix to the bound volume of the drain law, edition of 1929, published by the Department of Agriculture. The "Blank No." is the designation of these printed forms used by the printing firm of Doubleday Bros. of Kalamazoo, whose legal blanks are used in this county.

PROCEDURE for CONSTRUCTING INTRA COUNTY DRAINS

Drain Law of 1929

	Drain Law Chapter & Section	Form No.	Blank No.
Application for laying out drainage dis. filed	III-1	13	D 312
1 - 15 days			
Copy served on probate judge and	III-2	13	
Petition for board of determination filed		14	D 140
1 - 15 days			
Appointment of board of determination	III-2	15	D 141
Notice of meeting (Pub. 2 wks & served on clks.)		16	D 142
Notice of board of determination		17	D 336
1 - 30 days			
Meeting of board of determination who make order of practicability		18	D 143
Order for survey	III-2		
Surveyor's report	III-3		
Drainage district designated	III-4	19	D 313
Notice of filing (Publish 1 week.)		20	D 314
Petition to construct or	IV-1	21	D 14
Petition to deepen, widen, straighten, extend or cleanout	VII-1	64	D 79
Copy served on probate judge and	IV-2	21	
Petition for board of determination filed		64	
		14	D 140
1 - 15 days			
Appointment of board of determination	IV-2	15	D 141
Notice of meeting (Pub. 2 wks, served on clks. and posted 5)		16	D 142
Notice to board of determination		17	D 336
1 - 30 days			
Meeting of board of deter. who make order of necessity	IV-2	18	D 143
1 - 5 days			
First order of determination	IV-2	22	D 14
1 - 60 days			
Right of way obtained by release	IV-3&4	10	D 6

PROCEDURE for CONSTRUCTING INTRA COUNTY DRAINS

Drain Law of 1929

	Drain Law Chapter & Section	Form No.	Blank No.
Petition to probate court for special comrs. for Rt. of Way not released	IV-5	23	D 18
Day of hearing appointed	IV-6	24	D 19
Citations issued (Personally served # 28, by reg. mail #27, or by publication #29 and #30)	IV-6 IV-7,8	26	D 20 D 23
Over 10 or 14 days			
Hearing on petition for special commissioners	IV-9		
Appointment of 3 special comrs. & date of hearing	IV-9	32	D 25
Notice to special commissioners	IV-10	33	D 36
5 - 15 days			
		34	D 37
Meeting of board of special commissioners	IV-11	35	D 38
1 - 30 days			
		39	D 42
Report of special commissioners	IV-12	36	D 39
Final order of determination	VI-1,3	43	D 50
Apportionment of benefits	VI-1,2	44	D 60
Notice of letting & board of review (Pub. 2 wks, post, serve on officials & residents if less than 100 desc. in district)	VI-4	45	D 51
Drain letting and board of review held	VI-4		
1 - 10 days		46	D 211
		47	D 204
Petition may be filed by prop. owners for Bd.Rev.	VI-5	48	D 212
Drain commissioner notified	VI-6	49	D 205
Bd. of Rev. appointed & time & place of meet.set	VI-6	50,51	D 206 D 207
Bd. of Rev. notified (5 days or more before meet)	VI-6	52	D 208
Notice of meeting (Personally served and posted 5 days previous)	VI-6	53	D 209
Meeting of board of review who may	VI-7	54	D 210
(1) Add land to district	VI-7	55,56	D 213
(2(Sustain appeal and change apportionment	VI-8	57	D 215 D216
(3) Dismiss appeal & assess costs to appelant	VI-8,10	58,59	D217
Contract with successful bidders made(Bonds 66& 67)	VII-3	65	D 55
Computation of cost made	X-1	72	D 116
Assessment roll made	X-2	73	D 71
Report to state drain comr.(Special form)			

PROCEDURE for CONSTRUCTING INTER COUNTY DRAINS

Drain Law of 1929

	Drain Law Chapter & Section	Form No.	Blank No.
Application for laying out drainage dis. filed	III-5	13	D 312
1 - 20 days			
Copies forward to state drain comr. & other county comrs. of drainage board	III-6	42	D 75
15 - 40 days			
Meeting called by comr. of agriculture	III-6		D 318
Notice of meeting (Published 2 wks, posted & served on clerks)	III-6		
1 - 20 days			
Meeting of drainage bd. who make order of prac. & order survey	III-7		
Surveyor's report	III-8		
Drainage district designated	III-9		
Notice of filing (Pub. 2 wks in each county)	III-9		
Percentage apportioned between counties	III-9		
Petition to construct or	VII-2	21	D 14
Petition to deepen, widen, straighten, extend, or cleanout	V-1	64	D 79
1 - 20 days			
Copies forwarded to Comr. of Agri. & other county comrs.	V-2		
15 - 40 days			
Meeting of Drainage Bd. called by comr. of agri.	V-2		
Notice of meeting (Pub. 2 wks, posted, & served on clerks)	V-2		
1 - 20 days			
Meeting of drainage bd. who make 1st order of deter., divide percentage & decide method of payment	V-2		
Balance of procedure is the same as for intra-county drains with board acting in place of comr. If special comrs. are required, 3 are appointed from each county.	V-3,4 5,6,7 12,13 V-8,9 10,11		

It will be seen by a study of the drain law that the commissioner has but few duties the details of which are not carefully set forth. The most important of these duties which are not carefully detailed and in which he is allowed to use his own judgment are (1) the apportionment of benefits and (2) the maintenance after construction.

According to section 2, chapter 6 of Act 316, Public Acts of 1923: " All apportionments of benefits under the provisions of this act shall be upon the principle of benefits derived." This seems to be definite enough, but the trouble comes in determining just what benefit is received by the different descriptions of land. At present the method is to confer with the supervisor and see how much he will take on the township as a whole, then with any other corporate bodies that may be affected, such as the State Highway Department, County Road Commission, or Railroad Co. and a similar agreement reached with them. The balance is assessed against the drainage district which includes all the watershed above the lower end of the drain.

While no definite rule is followed in dividing the percentage among the different descriptions, the results have been more successful than would be imagined, Mr. Patterson reporting only two appeals from his division of the tax in the sixteen years that he has been in office and on these occasions his judgment was sustained. However, it would seem from a review of some of the

more recent drains that the "run-off" area was paying too large a percentage of the cost and that the township at large and the special benefit district were being insufficiently taxed. In other words, it appears to us that the principle stated at the opening of the previous paragraph has been supplanted by one of expediency. We find that this is not peculiar to Kent County but is common to many of the other counties of the state and apparently is due to the lack of any established practice having been worked out and adopted. We submit the following method as being simple, determinate, and fair.

We would divide the assessment into four parts,

(1) special or direct benefits

(2) community welfare (township at large)

(3) public and private utilities (county or state highway departments, railroads, etc.)

(4) general or indirect benefits

The first step after obtaining the plans, estimate,and district map from the engineers would be a field trip to thoroughly acquaint the assessor with the land; especially that which will be directly benefited by the drain. While on the ground he should not only estimate the amount of land that will either be made tillable or increased in productivity, but also estimate the amount in dollars that this land will increase in value because of the drain. This figure he can arrive at in different ways; but probably the safest and surest yardstick is the comparative value of the land at present and the value of similar land in the locality that has been drained, deducting from

the difference the cost of clearing and conditioning the soil and the interest on the investment in the drain over a reasonable period of time in which to do this work.

With this information he can then go over and list the owners of the land which will be appreciated in value by the project, setting down opposite each one the number of acres and increase in value per acre as estimated. When these figures are multiplied and the products added he will have the actual amount that it is worth to these parties to have the drain built. This is in accordance with the statement which we find on page 653 of Volume 9 of Ruling Case Law where it says, "The foundation of the right to any assessments is the particular benefit of the land assessed."

The next problem is the township at large. When the direct benefit list above mentioned is prepared we would separate it according to townships and total each separately. This gives the amount that each township will actually increase in value because of the drain. That means increased revenue in taxes for which the township should pay. We arrive at the figure this way: Multiply the direct benefit total of the township in terms of thousands of dollars by the average tax rate in the township per $1000, and again by the average life of a drain before cleanout is necessary if no work is done on it; which in our county is about 10 years. This gives the amount of increased revenue which the township derives, but as they are paying in advance and money doubles in about 10 years at 7% compound interest we divide this

amount by two giving us the equation: Amount of benefits = $\frac{\text{Increase} \times \text{Tax Rate} \times \text{Life of Drain.}}{2}$ The township must also be assessed for any direct benefits to highways such as those which are subject to an annual repair charge because of washouts or serious rutting due to a saturated sub-soil. This annual cost is again multiplied by 10 and divided by 2 for the same reasons as above given.

Health is intangible and as near as we can see must be arrived at by arbitration with the respective supervisors. Bridges are another nice question; but applying the test of "benefits derived" the problem is simplified. If, as is often the case, the bridge is in good shape; but the footings are too high, the cost of lowering the footings should be borne by the district. If on the other hand, the bridge is in such poor condition that it will not pay to lower the footings, the major part of the job should be borne by the township; not all, but most of it, depending on the condition. Where widening is necessary and the present structure is adequate for the present stream, we believe the cost of the new structure should be borne entirely by the district. If the proposed structure is of a more permanent type than the present one, the relative life and maintenance cost of the two should be compared by the engineer and a portion of the cost borne by the township.

We now have the direct benefit district and the township disposed of. Next comes the public and private utilities, particularly the State Highway Department or County Road Commission

where they are the major beneficiaries - as in several cases in our county. Our method of handling these cases would be to assess these organizations the estimated cost of a drain of sufficient size to care for the runoff from the section of highway for which the drain is being built. This will always be considerably less than the estimate for the proposed drain as no account would be taken of the runoff from abutting property, and would represent only what it would cost the highway department to take care of the runoff from their right-of-way if it could be entirely segregated from the surrounding land. Manholes, of course, should be included if the outlet is a tile job. One point that must be considered is that often the drain will be designed for a greater depth than would be required for the highway only in order that abutting houses may connect basements and septic tanks. In this case a higher grade line must be used in figuring the cost of the theoretical highway drain than that shown on the plans for the proposed project.

The above factors are all determinable as has been outlined, we would total these and deduct this amount from the estimated cost of the drain, dividing the remainder by the area of the drainage district. This gives a uniform rate per acre for the entire district for trunkage, or future benefits.

Following the above procedure the assessor would now have all the necessary data to prepare his apportionment of benefits roll in terms of dollars and cents, the total equaling the est-

imated cost. It is only necessary to multiply this amount by the reciprocal of the estimate to obtain the percent of cost that the statutes provide he shall read on the day of sale. The first operation can be performed mentally in most cases and the second operation, conversion of amount into percent, is very simple with a computing machine or logarithms.

Where the drainage district lies in more than one county it is only necessary to separate the items according to location and total. The prevailing practice is to divide percentage between counties first and then assess, but this appeals to us as "getting the cart before the horse". The drainage district was created long before any governing body laid out county lines which are purely lines of convenience for political purposes and the bargaining ability of the respective commissioners should not be reflected in the tax rate of the property owners in the drainage district. The interested commissioners should either go over the ground together and make all the assessments together or leave it to their engineer to work out and report in detail.

As an example of this method of assessing we cite the Geers Drain, a small inter-county project on the line between Kent and Newaygo counties. In this case the drain commissioners and ourselves went over the ground together to arrive at the special benefits and upon returning made up the following preliminary computation. The drain has not yet been declared necessary so

the computation of benefits (the "per cent sheet" so called) and assessment roll has not yet been made out, but that is purely a clerical problem.

COMPUTATION of ASSESSMENT

Geers Drain

Direct Benefits	Rate Per Acre	Acres	Benefit	Tyrone Kent Co.	Grant Newaygo Co.	Total
J. Geers	$20	25	$500			
H. Geers	20	16	320			
Longcare	20	25	500			
Landheer	20	25	500			
Slacker	20	18	360		$2180	
F. Geers	10	3	30			
Berry	10	3	30			
Van Galen	10	8	80			
A. Geers	20	30	600			
Van Single	20	25	500			
Landheer SR.	8	15	120			
Gorby	18	25	450			
H. Van Single	18	15	270			
F. Vander Hey	10	20	200			
S. Van Single	10	20	200			
A. De Graff	3	60	180			
Veusink	3	20	60			
Puit	3	40	120			
Mouthaan	5	20	100			
Cordes	2	50	100	$3040		$5220

Note: Attention is called to the fact that the above list includes only those property owners whose lands are subject to a direct benefit tax and is not a complete list of all parties subject to an assessment.

	Tyrone Kent Co.	Grant Newaygo Co.	Total
Brought Forward	$3040	$2180	$5220
Runoff Benefits			
1410 acres in Tyrone Twp. @ $.50	$ 705		
260 acres in Grant Twp. @ $.50		$ 130	$ 835
Townships at Large			
Highway runoff			
5¾ miles	$ 23		
1½ miles		$ 10	$ 33
Culverts			
#1 and ½ of #2	$ 700		
#3 and ½ of #2		$ 684	$1384
Direct Highway Benefit			
W½ N. line, Sec. 3-10-12 (⅛mi)			
S¼ E. line, Sec. 3-10-12 (¼mi)			
S. line, Sec. 3-10-12 (1mi)			
1⅝ miles @ $500	$ 875		
E½ S. line, Sec. 33-11-12 (⅛mi)			
S¼ E. line, Sec. 33-11-12 (¼mi)			
⅜ mile @ $500		$375	$1250
Convenience			
$\frac{L \times I \times R}{2000}$ using L=10 & R=30	$ 456	$326	$ 782
Totals	$5799	$3705	$9504
Estimate $10,466.50	61%	39%	
C. of Ben. 9,504.00			
$ 962.00 = Inc. necessary = 10.13% of $9504.			

CHAPTER III

PHYSICAL FEATURES

The commanding officer of a body of troops who is laying out a plan of battle must know not only what forces he has at his disposal, but he must also have accurate knowledge of the size and location of the enemy, the quantity and quality of their defenses, and the nature of the terrain. With this information he can plan, with a fair degree of accuracy, his line of attack or defense. Similarly, the drainage engineer must know not only how to compute run-offs and cross-sections, but he must be informed regarding climatic conditions, soil conditions, and the topography of the area in which he is working. Since we are discussing the work of the County Drain Commissioner a general outline of these subjects as applied to the entire area under his jurisdiction would appear pertinent.

Kent County is twenty four miles wide east and west and thirty six miles long north and south which gives an area of approximately 553,000 acres of which 541,000 are land, the balance being taken up with inland lakes.

The population, according to the 1930 census, is 240, 515 of which about 85% is urban and only 15% rural. The City of Grand Rapids alone counted 183,041 and the suburbs adjacent thereto together with the outlying villages total about 21,000 more, leaving only about 36,500 rural residents.

The climate is temperate, the temperature varying from a maximum of 103 degrees F in the summer of 1916 to a minimum of -24 degrees F in the winter of 1899 and averaging 48.1 degrees F over a period of thirty-six years. Precipitation is moderate,

averaging 33.73 inches annually during the last fifty years with a maximum of 52.14 inches in 1883 and a minimum of 20.92 inches this last year, 1930.

The ultimate purpose of drainage of cultivated lands is to bring about a condition of soil moisture best adapted to plant growth. To accomplish this result the types of soil to be dealt with should be known and given consideration. It is necessary to consider the physical properties of soils especially insofar as these properties affect the moisture content and the movement of water through them. Soils may be classified in regard to their drainage properties as porous, or water bearing, and non-porous. These terms are only relative since there are no soils through which water will not pass, to a limited extent. However, we have in this county areas of clay so finely divided that the rate at which water moves through it is very low, such material consequently may be considered as non-porous when viewed from the practical standpoint of sub-surface drainage.

The porous materials, from a drainage standpoint, to be found in this county are the various sands, gravel, and muck lands. Sand and gravel when not mixed with finely divided soils carry water freely, and may be regarded as our best examples of porous soils.

Broken clay or clay mixed with gravel is often porous enough to permit the passage of water through it . In our gypsum areas

the upper portion is usually fissured sufficiently to permit a slow flow of water through it.

For a detailed description of the various soils to be found in Kent County, see pages 10 to 37 inclusive of the Soil Survey of Kent County, Michigan, by the U. S. Department of Agriculture, a copy of which is included as Exhibit D.

The terrain of Kent County as shown by Exhibit E is marked by a very hilly mass in the western central area, arms of which extend off to the south, east, and north, leaving nearly level areas in the southeast (Bowne township), southwest (Byron, Wyoming and Paris townships), and the northeast (Nelson and Spencer townships). The low point in the county is of course in section 18, Wyoming, where Grand River crosses its west line, the elevation being about 580' above sea level. There are three high points, located respectively in section 19, Gaines township, section 4 Solon township, and section 21 Nelson township, which are all approximately 1020 feet above sea level, making the maximum total difference within the county about 440 feet.

Geologically the land is a mass of eskers and lateral moraines that have been cut thru by the Grand, Flat, Thornapple, and Rogue Rivers and innumerable small streams. The southern parts of Gaines and Plainfield townships are distinctively marked by "pot holes" of considerable depth but small diameter probably caused by the melting of blocks of solid ice which remained after the glaciers receded. The drainage district of the Flat River is characterized by the large number of lakes of all

sizes. There are also a number of other lakes scattered thruout the county but not in nearly as great numbers as in the section above mentioned. Most of these lakes are what are known as "spring fed", that is they fluctuate with the ground water level although a few of the larger ones, Wabasis, Lincoln, and Murray, are fed by running streams.

Erosion has played an important part in the formation of the contours in this county as is shown by a study of the United States Geological Survey maps of those parts that have been surveyed to date. Unfortunately the work has been completed over only about 2/3 of the county, the unmapped areas being on the north, northeast and extreme west. The map used for Exhibit E was prepared for the Michigan Geological Survey in 1902, the horizontal measurements being made with a cyclometer and the vertical measurements with a barometer. Naturally a map prepared in such a way would not have the character that the more accurate federal government maps have so it is necessary to study the latter to observe the work of erosion.

The drainage problem in this county is quite different than in the counties on the eastern side of the state and in some of the more level counties to the south and west. It consists to a large extent of increasing the capacity of the present water courses either by straightening and widening the channel or by straightening out the hydraulic grade line. The deposition of eroded material by present or former streams has in many cases

formed dams impounding the water in ponds or marshes and in other cases the outlet of basins that were probably lakes at some former time have not yet cut sufficiently deep to complete the drainage of the area, leaving a swamp or marsh. A third cause of over-wet land is the loss of slope in streams due to the meandering of the present channel in the former bed. All three of these types of obstructions are found in the Pratt Lake Drain in Lowell and Bowne townships, the first case being found near the outlet into Tyler Creek, the second case at the upper end, and the third case in the central section. Incidentally Pratt Lake practically disappeared during the summer of 1930 altho the upper end of the drain is nearly a quarter mile west of the lake. The facts that the drainage district above this point amounts to less than two square miles and that the lake is very shallow probably are more pertinent in view of the especially dry season than the fact that there is a drain nearby, although a gradual lowering of the ground water level may have taken place as the drain has been in operation eleven years.

CHAPTER IV

ANALYSIS of DESIGN

As is well known, there are two major types of drains, - open and closed. The latter, known as storm sewers, are a part of the sewerage system of every city and their design has been the subject of countless volumes. Up to date in Kent County it has never been necessary to build storm sewers in excess of 54" in diameter so special sections have not been involved. In the projects that have been constructed, the "Rational Method" of computing capacity as described by Metcalf and Eddy in their Volume on "Design of Sewers" has been followed.

As nothing original has been contributed to any phase of storm sewer design in the past, and as in our opinion it is unlikely that large capacity storm sewers will be required in this county in the future, we shall confine ourselves to a discussion of open drains.

The design of open channels has been in the past largely a matter of guesswork. For years the petitioners designated the size of drain to be built as well as the place of beginning, route, and terminus. Anyone who could run a level and make a profile could lay out a drain - and it is remarkable how many of these old drains are still functioning. The law in this respect has been changed in recent years and the size left more to the engineer, but in general the "rule of thumb" has not yet been superseded by the "rule of reason". However, as mentioned previously, we are getting into larger projects and undoubtably will continue to do so as the increased construction of the feeders or laterals hastens the concentration of the runoff into the trunk lines.

For example, there is an application being signed at present for the laying out and designating of Buck Creek as a drainage district throughout its entire length. We also have prepared plans within the last two years for the Black Creek Drain in Spencer Township in Kent County and Maple Valley Township in Montcalm County but the petition to construct has not been presented, probably due to the extreme drought of last year. It would seem that in view of this tendency, more careful thought should be given to the matter of design.

The hydraulics of drainage cannot be computed with as much accuracy as can be expected in some other branches of engineering owing to the uncertain data available and the variable conditions that must be met. For this reason formulae of less refinement than are thought essential to some other hydraulic work may be used in making drainage computations, but great care must be used in the applying of these formulae which necessitates a thorough understanding of their derivation and the value be given to the component factors.

The major factors previously mentioned as being involved in the design of a drain - climatic conditions, topographical features and soil conditions - may be divided as follows:

1. Rainfall
2. Temperature
3. Hypsography
4. Size of the district
5. Shape of the district
6. Character of soil
7. Culture of soil

We shall discuss them in the above order.

The problem of determining the quantity of storm water to be carried by a drain begins with the measurement of the rainfall upon the watershed. The duration of the peak storms and their intensity are also important from the standpoint of total runoff and of the time of concentration which is the time necessary for the entire watershed to contribute the maximum amount of water at any particular point. This runoff will generally exceed the natural runoff because of the more favorable conditions provided by the drain for collecting and discharging the excess water of the district.

Temperature, as a factor in drainage, must be considered from the standpoint of evaporation and the affect of frost. Quantitative data on evaporation are not available and consequently must be determined by observation. Freezing and lower temperatures cause a corresponding dimunition of runoff of precipitation. This accumulates snow and ice which may, because of a sudden rise in temperature, run off in such a short period of time as to cause a peak load on the drain. Data on both rainfall and temperature in this vicinity are available at the United States Weather Bureau in Grand Rapids which has records dating back to 1870.

A knowledge of the hypsography of the area to be drained is essential in order to determine whether necessary slopes and outlet are available. This may be determined approximately, for preliminary studies, from a United States Geological Survey map

when such is available but more definite data is necessary before the final plans can be prepared and these can be obtained only by inspection and instrument work in the field. The U. S. Geological Survey maps are sufficiently accurate however to determine the general slopes of the watershed which must be known before the time of concentration can be computed.

The size of the district obviously is essential to any computation that seeks to arrive at the quantity of water to be handled.

The shape of the district influences the time of concentration at any given point as the distance of the extreme outlying tributary areas from the main channel affects the time required by the runoff from them to cause maximum conditions at the point in question. Evidently, the time of concentration for a long narrow area will be considerably less than that for a wide flat area.

The character of the soil is responsible for its degree or permeability. Of the precipitation upon a drainage basin a part is lost in evaporation, some is absorbed by the soil and either retained as capillary water or percolates slowly through the subsoil to a lower level where it may possibly reappear as springs, a portion is absorbed by vegetation and the remainder flows over the surface until collected in natural or artificial channels.

It is this remainder, the volume of which is largely dependent upon the character of the soil, which constitutes the chief problem of drainage.

The culture of the soil is responsible for the amount of water absorbed by vegetation and by porous soil and which therefore does not find its way into the drain at all or at least until the peak load has passed out.

From the above we see that the total gross precipitation on the watershed is determined by the volume of the rainfall and the size of the area, that the portion of this total which reaches the drain during or immediately after a storm depends on the temperature, slope of the terrain, and the character and culture of the soil, and that the time required to cause the maximum concentration at any given point on the drain is influenced by the duration of the rainfall, the slope of the ground, and the shape of the district.

While the problem of determining the quantity of storm water to be carried by drains is still difficult some progress has been made in the methods of attacking it, due largely to the accurate records of rainfall that have been kept, and the experimental work done by the different agricultural colleges and government agencies. In our future work we propose to use the "Rational Method" of computation for open channels, as well as for closed drains,because it allows the engineer to exercise his judgement more readily and design drains

peculiarly adapted to local conditions. This method involves the use of the expression Q = CIA where Q is the total runoff from a given area in cubic feet per second, C is an empirical coefficient representing the ratio of runoff to rainfall, I is the intensity of rainfall in inches per hour, and A is the area of the watershed in acres.

A set of curves (pages 34-A to 34-G) have been prepared by the Kent County Road Commission using the experiments of Mr. C.E.Ramser of the United States Bureau of Public Roads which gives values of Q for various areas, soils and slopes. The values of the coefficient C recommended by Mr. Ramser for the soils and slopes used are shown in the following table:

	Slopes	Soil	
		Sand	Clay
Very Flat	0-0.2%	.10	.20
Flat	0.2-1.0%	.15	.30
Moderate	1-2%	.20	.40
Rolling	2-4%	.225	.45
Steep	4-8%	.25	.50

Only two types of soil, sand and clay, are given in these curves but these are the extremes encountered in Kent County and intermediate types can be judged in respect to these two and the runoff interpolated for between the two extremes given.

The above range of slopes covers everything that we have in Kent County. While some portions of an area may be steeper

than an eight per cent slope, it is doubtful if the main thread of a drainage basin will be found which exceeds this slope. In classifying an area for slope it is intended that the basins of less than a square mile in extent should be governed by the slope of the main thread. In the larger areas, the slope of the contributing areas should govern. As many basins are made up of areas, some of which are flat and some steep, it will be necessary to strike an average for the whole area which will give a reasonable result.

The values of I, which represents the intensity of rainfall in cubic feet per second per acre (or nearly enough, the rate of rainfall in inches per hour), were calculated for the various areas by assuming suitable periods of duration for such areas and referring to an intensity curve (page 34-A) prepared from the rainfall records of the United States Weather Bureau in Grand Rapids during the last 25 years. The maximum storms for this period were plotted and a curve selected which most nearly represented the expected 10 year storm. This curve may be expressed by the following equations:

(1) I equals 175 divided by 24 plus the time duration in minutes. This applies to storms of less than 120 minutes.

(2) I equals 226 divided by 66 plus the time duration in minutes. This applies to storms of more than 120 minutes.

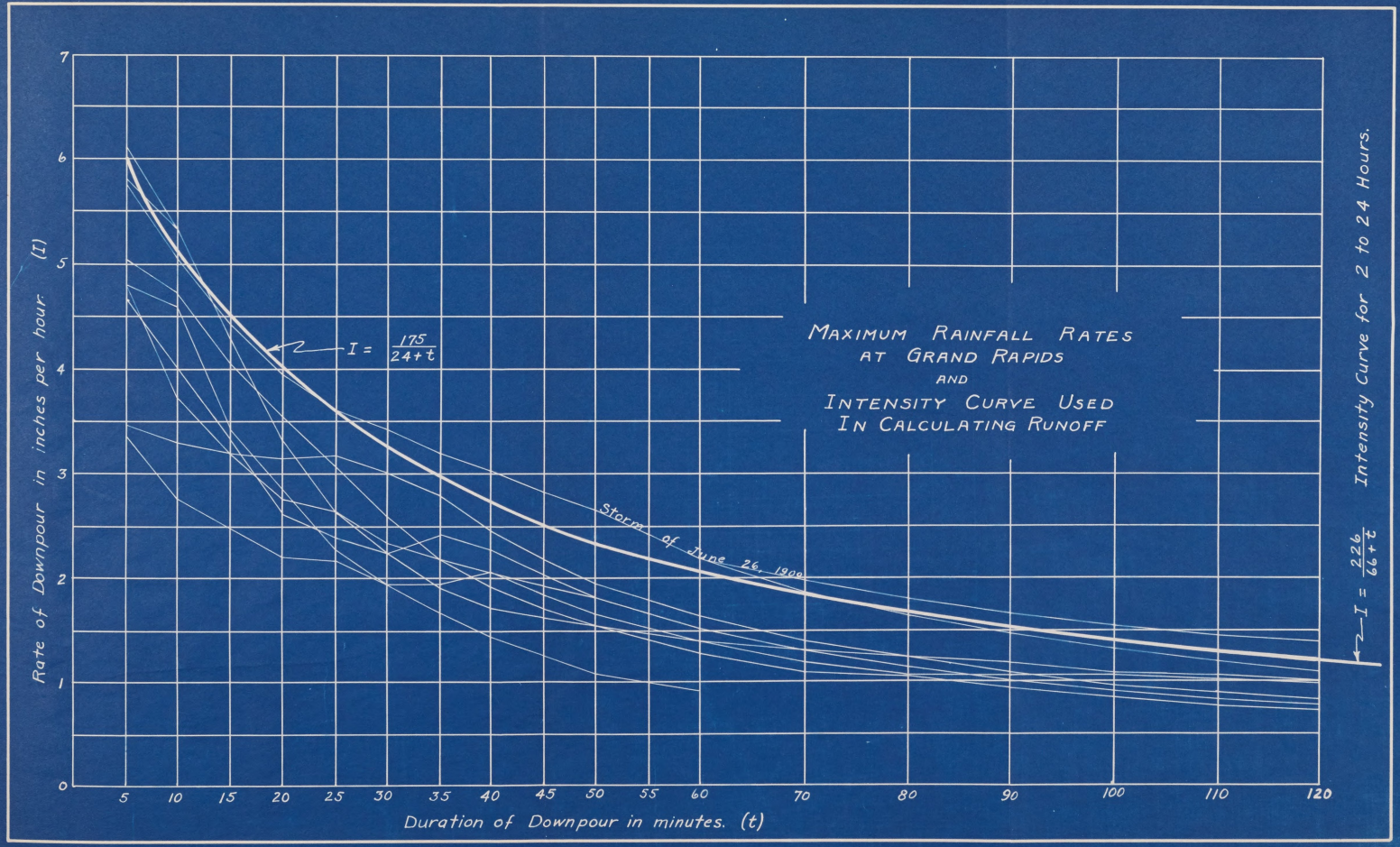
While the runoff curves are very convenient as a guide and in many cases can be used directly they do not take into consideration the shape of the district which will affect the time of concentration, consequently the values of Q obtained therefrom will have to be increased for long narrow watersheds.

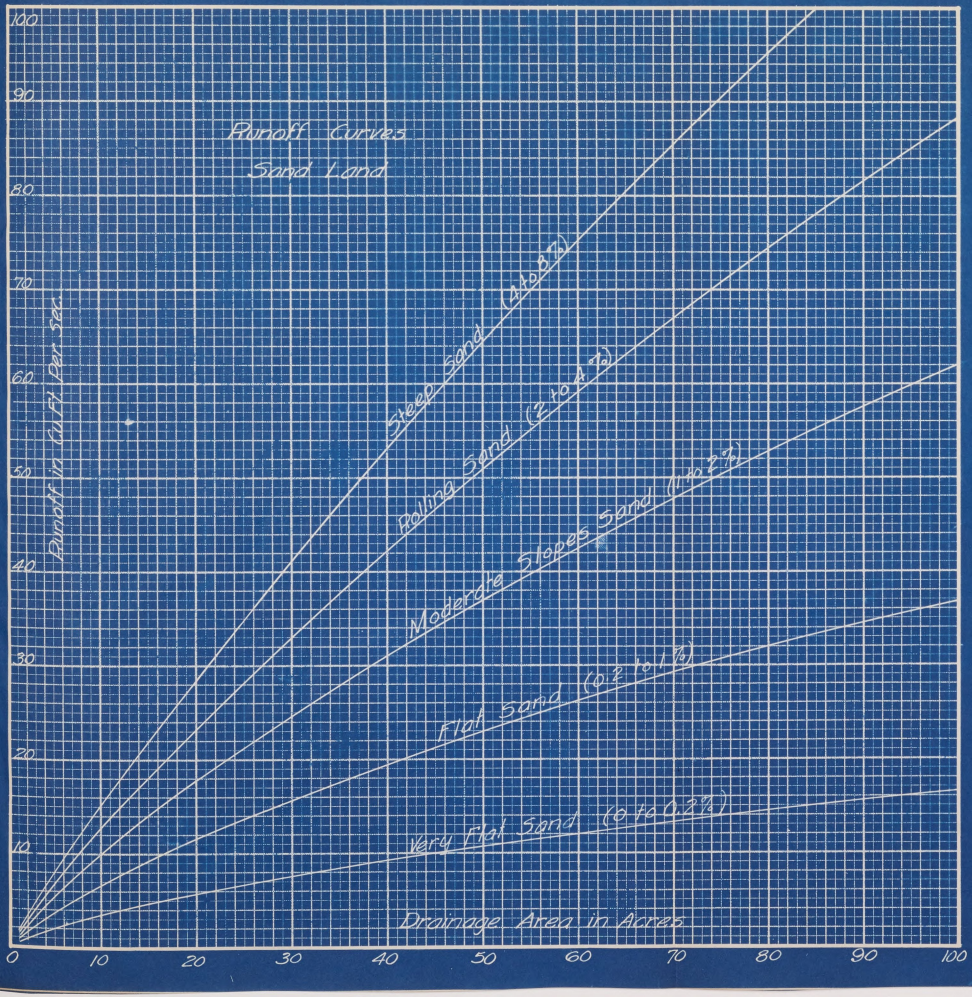
With "Q" the runoff, in cubic feet per second calculated and the slope of the drain determined from the profile a cross section of the channel is chosen and checked for capacity. This cross-section must be large enough to give the capacity required and also of such shape that it can be maintained in working condition. This means that the side slopes must be flat enough to have stability and prevent sloughing that will obstruct the drain. There is no general rule by which the most advantageous section can be chosen, it must be based upon the conditions of each particular case. In firm soils that will withstand erosion of the banks a narrow and deep channel is generally the most economical to construct and maintain as such a section gives a greater velocity for a given grade and volume of flow from a wide shallow one. The narrow channel also gives less opportunity for the growth of plants which tend to obstruct the drain,and for the indiscriminate crossing by cattle. However, in unstable soil where the banks are likely to cave in and partially fill the drain a narrow deep channel is impractical. Where a drain is dug in soft soil, semi-fluid in nature, the bottom may be pushed upward by the weight of the adjacent banks. This condition can be minimized and sometimes entirely prevented by

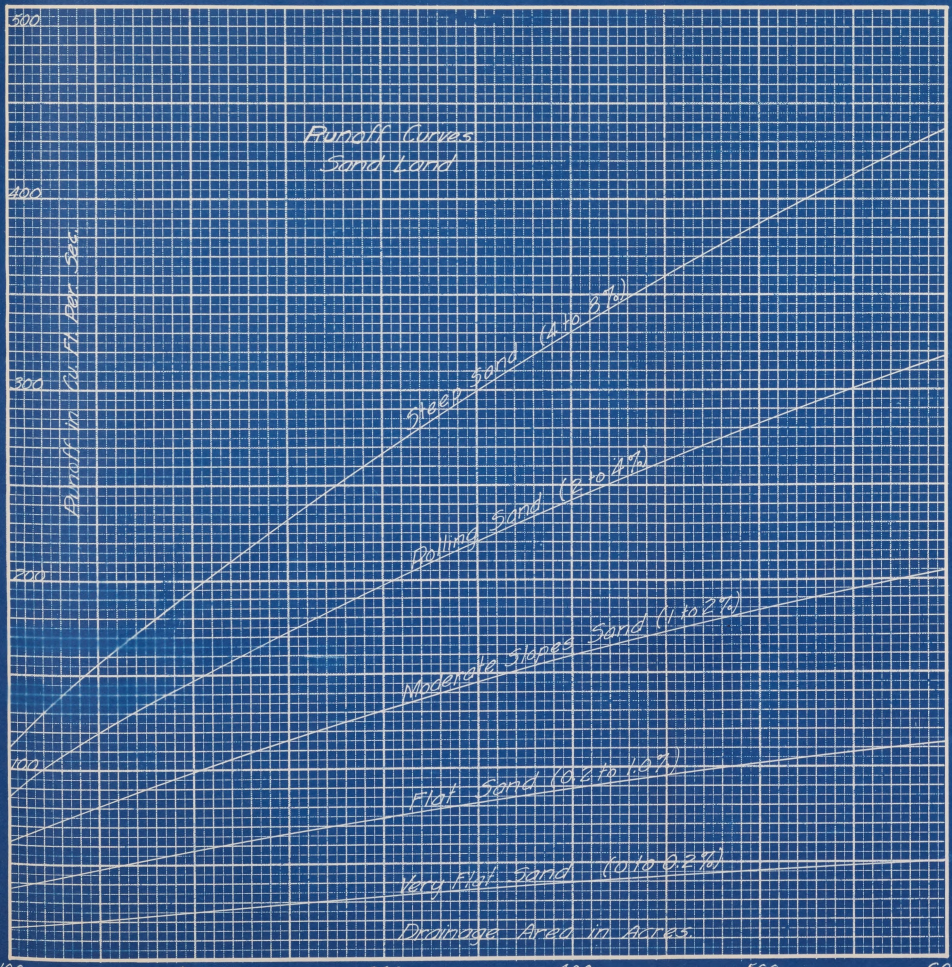
using a wide channel with flat side slopes so as to reduce the weight of the banks. The cross section of a drain should be as nearly uniform throughout the entire length of the project as is practical, however, making variations only in order to obtain stable banks. Most of the drains in Kent County have been dug with 1 to 1 slopes or steeper. This slope is excessively steep as only clay and some loams have an angle of repose as great as forty-five degrees under the most favorable circumstances. We recommend a more general use of a $1\frac{1}{2}$ to 1 slope, and in sand and muck would strongly advise a 2 to 1 ratio.

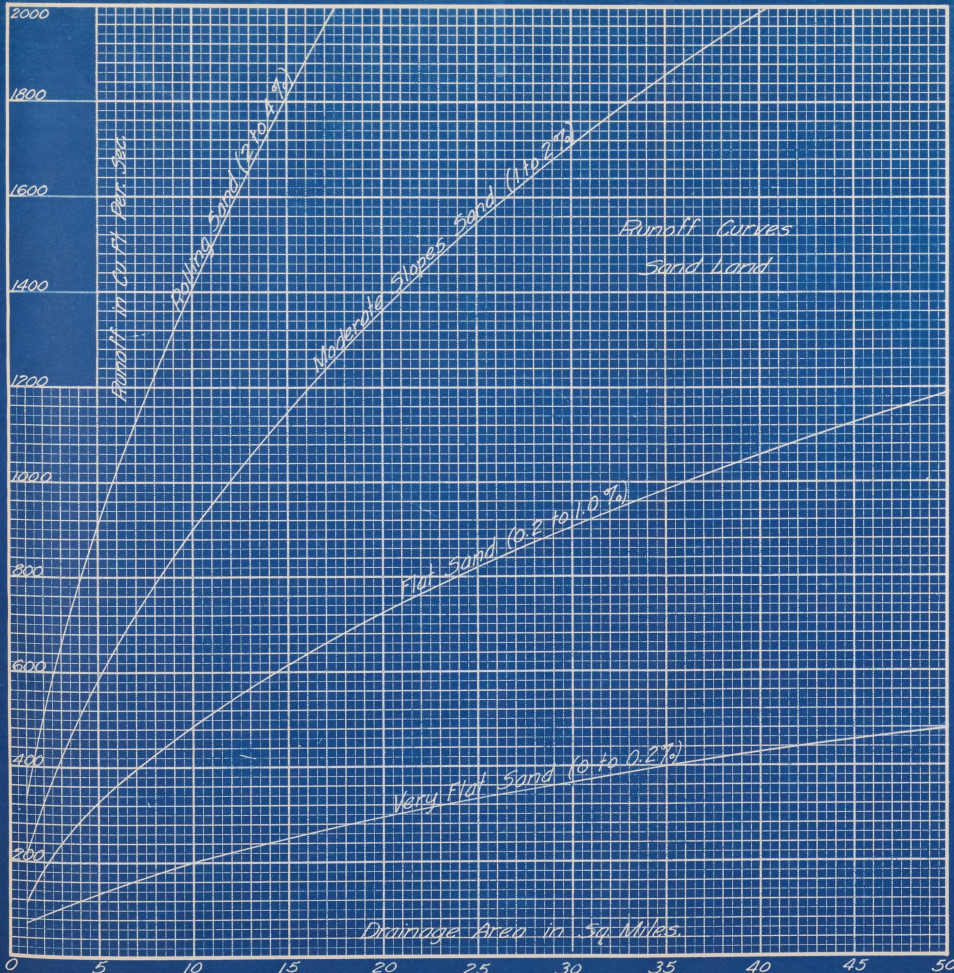
The velocity for testing the chosen cross section is derived from Chezy's formula $V = C\ (RS)^{\frac{1}{2}}$ using Kutter's formula to determine "C". Substituting this value into Q AV and solving for Q we are able to ascertain whether or not our cross section assumed is of the proper size.

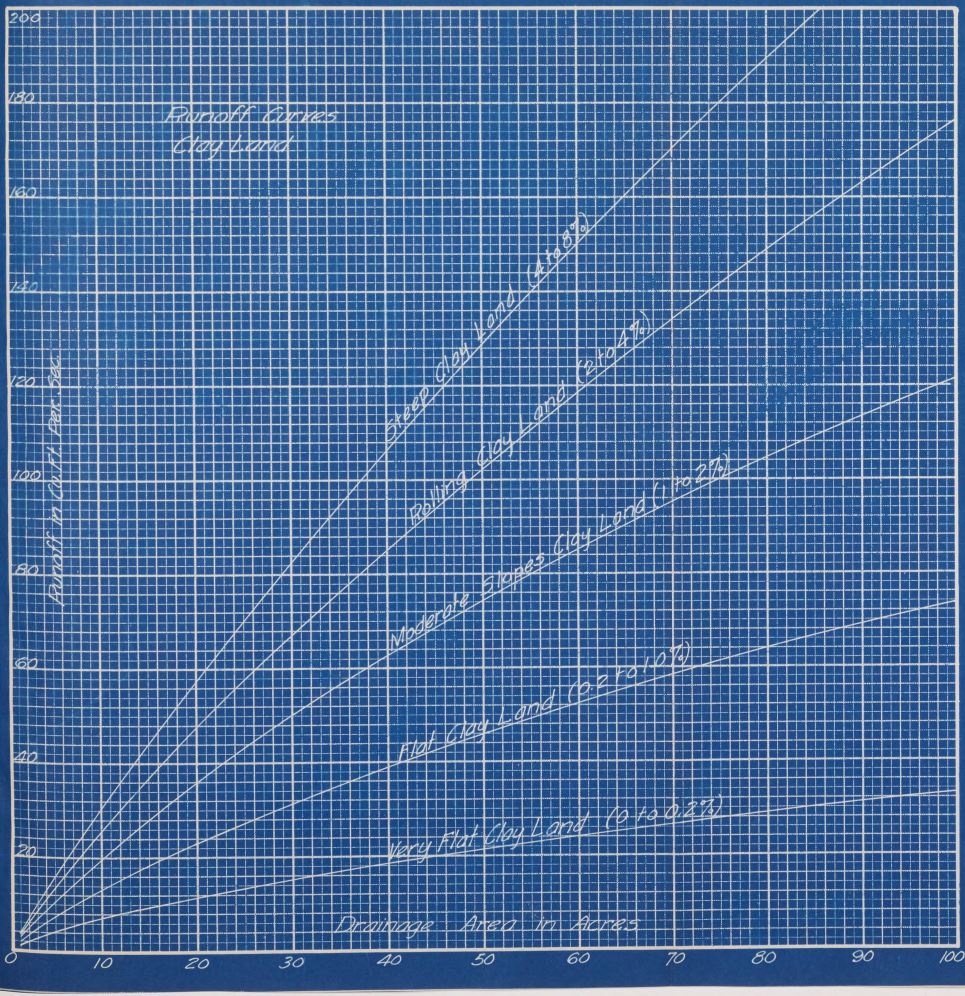
The design notes of a typical drain are included as an appendix.

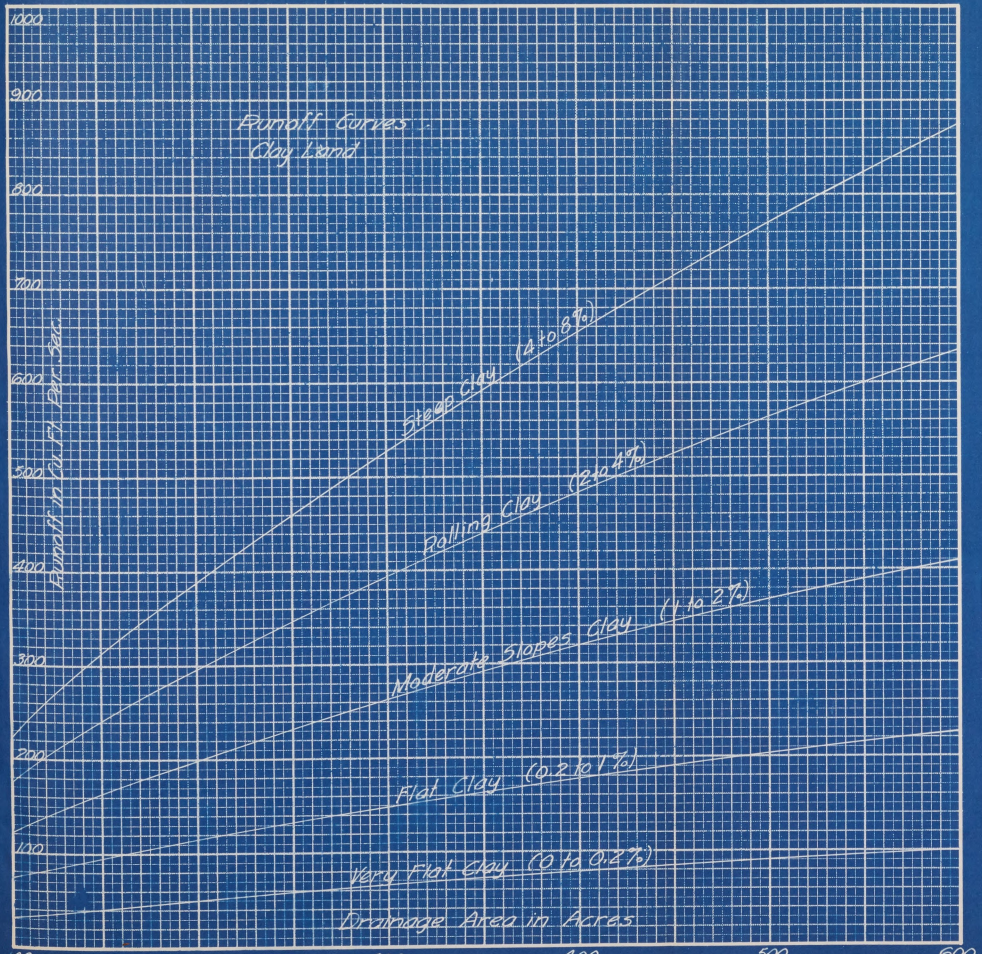

Rate of Downpour in inches per hour (I)
Duration of Downpour in minutes. (t)
0
1
2
3
4
5
6
7
5
10
15
20
25
30
35
40
45
50
55
60
70
80
90
100
110
120
I = 175/24+t
Storm of June 26, 1900
I = 226/66+t
Intensity Curve for 2 to 24 Hours.
MAXIMUM RAINFALL RATES
AT GRAND RAPIDS
AND
INTENSITY CURVE USED
IN CALCULATING RUNOFF

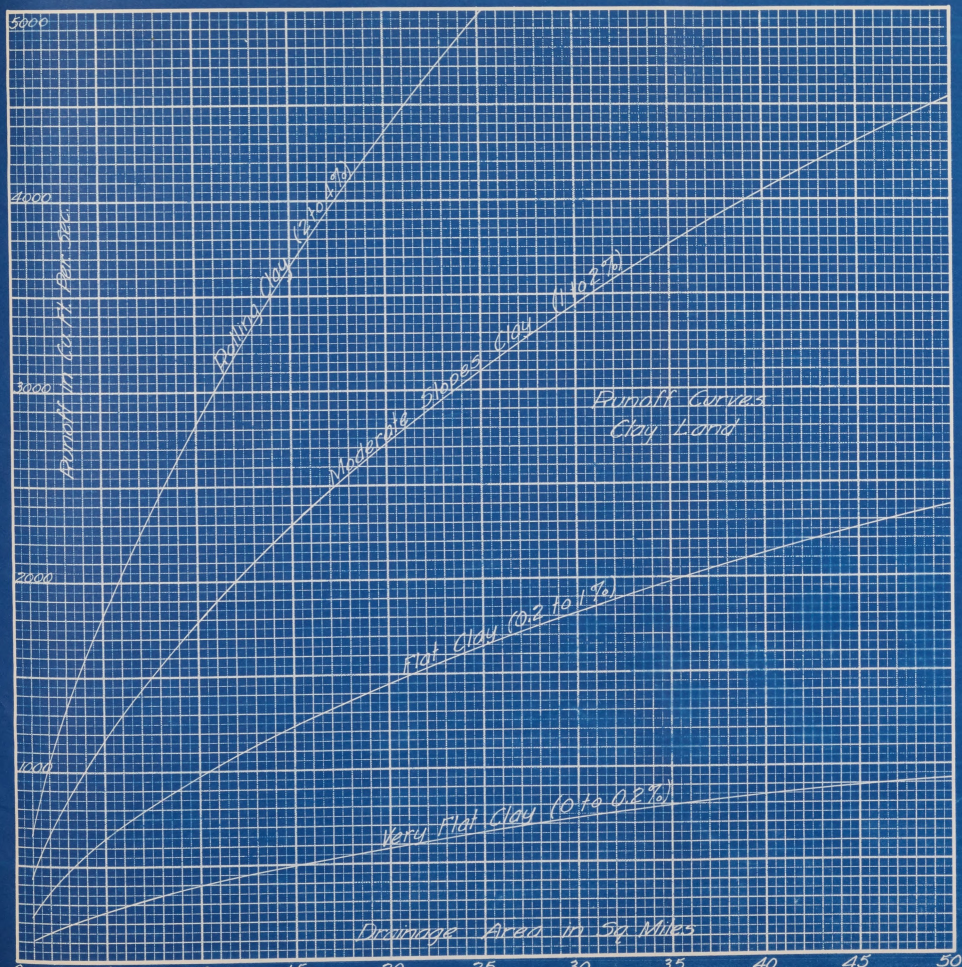

Runoff Curves
Sand Land
Runoff in Cu. Ft. Per sec.
Steep Sand (Above 8%)
Rolling Sand (2 to 8%)
Moderate Slopes Sand (1 to 2%)
Flat Sand (0.2 to 1%)
Very Flat Sand (0 to 0.2%)
Drainage Area in Acres
0
10
20
30
40
50
60
70
80
90
100


Runoff Curves
Sand Land
Runoff in Cu. Ft. Per Sec.
500
400
300
200
100
Steep Sand (4 to 8%)
Rolling Sand (2 to 4%)
Moderate Slopes Sand (1 to 2%)
Flat Sand (0.6 to 1.0%)
Very Flat Sand (0 to 0.2%)
Drainage Area in Acres
100
200
300
400
500
600


Runoff Curves
Sand Land
Moderate Slopes Sand (1 to 2%)
Flat Sand (0.2 to 1.0 %)
Very Flat Sand (0 to 0.2 %)
Drainage Area in Sq. Miles.
Runoff in C.F.S. per Sec.
2000
1800
1600
1400
1200
1000
800
600
400
200
0
5
10
15
20
25
30
35
40
45
50


Runoff Curves
Clay Land
Runoff in Cu. ft. per. sec.
Steep Clay Land (4 to 8%)
Rolling Clay Land (2 to 4%)
Moderate Slopes Clay Land (1 to 2%)
Flat Clay Land (0.2 to 1.0%)
Very Flat Clay Land (0 to 0.2%)
Drainage Area in Acres
0
10
20
30
40
50
60
70
80
90
100
200
180
160
140
120
100
80
60
40
20


Runoff Curves.
Clay Land
Runoff in Cubic Feet per Sec.
1000
900
800
700
600
500
400
300
200
100
Steep Clay (4 to 8%)
Rolling Clay (2 to 4%)
Moderate Slopes Clay (1 to 2%)
Flat Clay (0.2 to 1%)
Very Flat Clay (0 to 0.2%)
Drainage Area in Acres
100
200
300
400
500
600


Runoff Curves
Clay Land
Rainfall in Cu. Ft. per Sec.
5000
4000
3000
2000
1000
Drainage Area in Sq. Miles
0
5
10
15
20
25
30
35
40
45
50
Broken Clay (2 to 10%)
Moderate Sloped Clay (1 to 2%)
Flat Clay (0.2 to 1%)
Very Flat Clay (0 to 0.2%)

CHAPTER V

DISCUSSION of CONSTRUCTION

Great progress has been made in the last few years in the method of excavating open drains. It is easy to remember when small ditches constructed by hand or with teams were the rule in Kent County and it is a fact that a large part of the reclaimed land in the entire State of Michigan has been drained by this type of structure. But it has been found that as the communities developed and the demand for fertile low lands increased that deeper and larger drains were required in order to prevent overflow and to more completely drain these areas. This demand for deeper and larger projects has led to the use of machinery in place of teams even on the smaller jobs and it is now the exception rather than the rule when the abutting property owners take any part in constructing the drain. This has resulted beneficially in many respects and the majority of the contractors are anxious to do work that will be a credit to them for the sake of future jobs. However, in this locality the business is still in a transitional stage and the high standards that highway work has attained to in the last twenty years has not been paralelled in drainage.

The first introduction which the contractor has to the job is when he inspects the engineer's plans and specifications. While formerly these consisted almost entirely of a line profile and verbal instructions the plans which are now used in Kent County are quite complete and show the alingment of the drain in its relation to ~~natural~~ features such as roads, fences,

trees and streams and property owners. The profile, which is on the same sheet, shows the surface elevations taken at intervals of 100 feet and in broken ground at intermediate points. It is important that the profile show accurately surface elevations along the line noting depressions or natural waterways which terminate at or cross the line. The grade line of the drain is shown together with the necessary cuts, width of bottom, and slope of the banks. The specifications which we use are simple, covering only the ordinary questions that arise relative to the work to be done and mentioning any special features that may be involved. As an example of these plans and specifications we refer to the "Engineer's Report on Geers Drain "which is included as an appendix.

In addition to preparing plans and specifications, the engineer should establish the line in the field and mark the cut to grade on the stakes. He should also make the necessary inspections to insure the excavation of the drain to the required cross-section and grade and to insure the disposal of the excavated material in the specified manner. On inter-county drains the Department of Agriculture requires a certificate of approval by the engineer upon the completion of the work and before payment of the final estimate, and Mr. Patterson has adopted the same policy for drains in Kent County.

In our opinion, proper maintainence of a drain is so important that it should be given consideration in the original plans

for construction. It is necessary for this purpose that provision be made for moving machinery along the drain in the future. This may be taken care of either by leaving a berm of sufficient width or by leveling off the spoil banks. This latter method has the advantage of removing an unsightly object, relieving the pressure on the side slopes and bottom of the channel, and of making the land available for use by the abutting land owner. The first is purely an æsthetic consideration, the second is obviously important on certain types of soil, and the third is entirely an economic problem. Assuming a width of berm of 15 feet and a spoil bank 20 feet wide at the base, an acre of land is eliminated from the workable area for every eighty rods of frontage on the ditch and where the value of the land is equal to or in excess of the cost of leveling off, this work is justified even on the firmest of soils.

Difficulty is often experienced in digging drains to the required depth when the material taken out is in a saturated condition. Some soils when wet have so little cohesion among particles that the side slopes will not stand to any considerable height, yet these same soils when dry may be relatively stable and open drains may be maintained in them with little or no difficulty. Drains can be excavated in the soils above described only to a shallow depth below the ground water level because hydrostatic pressure forces material into the channel as fast as it can be removed. Excavation under these conditions

can be accomplished only by doing the work in successive stages. The channel is first dug as deep below the water table as is possible without causing sloughing from the sides and then allowed to stand until the ground water level in the soil adjacent is lowered and the banks stabilized. Another cut is then made and the process of gradually drawing down the water table is continued until the desired depth is reached. A second cutting is generally all that is required for drains of ordinary depth.

CHAPTER VI

DISCUSSION of MAINTAINENCE

Maintainence work has been mentioned as one of the two duties of the drain commissioner wherein he is allowed to use his own judgement. We have also stated that there are approximately 227 miles of drains in this county in which have been invested about $817,000 that is of record. Many of these drains were constructed years ago and have not been cleaned out by the drain commissioner since. Some are filled up and some have been kept clean by the abutting property owners. In the first case the investment is entirely lost and in the second case more expense has been incurred but in an amount that cannot be estimated.

The drain law of 1929 requires that an annual patrol be made of all drains constructed under the 1923 act. However, it does not specify how this patrol should be paid for and as most commissioners do not receive sufficient salary to justify their doing the work themselves and as it would be very difficult to hire a man to do the work at a reasonable price who would accept drain orders for the work, it has in many counties not been attempted. Also it would appear to us that the use of the word patrol presupposes something more than a mere inspection of the drain but rather anticipates that the party making the patrol should be equipped with suitable tools to enable him to remove minor obstructions before they cause the accumulation of silt and floating debris that will cause a permanent stoppage or dam.

In the summer of 1930 an inspection was made of most of the drains built in this county since 1923, although some were not

covered as the work was not started in time to complete it before the fall rainy season. A typical report is that given below on the Saddle Bag Drain and its branches. Reference to Exhibit B shows that these drains are located in the extreme northerly end of the Plaster Creek drainage district. The first construction was done by the townsnip drain commissioner and since coming under the county system they have been cleaned out repeatedly,-1896, 1901, 1906, 1914, 1923, - at a total cost of approximately $10,000. The purpose of this system of drains is the reclamation of the Saddlebag swamp which is a fertile stretch of land located so close to Grand Rapids that it is very valuable for truck gardens although at present owing to the poor condition of the drain much of it is in pasture. The total length of the system is 21648 feet, the bottom width according to the records is two feet and the average width is three feet and the fall at no place in excess of 0.1 foot per hundred feet. This drain if any in the county should be carefully watched, yet for seven years has been abandoned with the following result:

September 29, 1930 A.N. Phillips, Inspector.

Main Drain

Section 36 Grand Rapids township. All fair except north 300 feet where bottom is narrow and willows are starting.

Section 25

SW¼ SW¼. Ditch is crooked following natural gulley, bottom good except north 200 feet where willows are starting.

NW¼ SW¼. Ditch is deep and crooked, bottom good. Banks are getting brushy. Inlet to mudhole and 200 feet above mudhole full of brush with poor bottom. From 200 feet above mudhole to Bailey Lake ditch is fair except last 200 feet which is full of brush. Road culverts O.K.

Carmody Branch

Commencing at upper end tile has weeds and straw in it from muskrats, outlet has about 3" of dirt in it. Michigan Street culverts OK. 6" dam 10' south of culvert due to road ditch. Ditch

is open from Michigan Street south, is crooked but has good bottom to 1/8th line. From here to Bailey Lake there is practically no ditch, tramped in by cows and filled up with fallen trees. Could not find R.R. culvert in weeds, looked carefully.

Main Drain

Section 25

NW¼. Fairly straight, about 6-8' bottom and about 2' deep in bogland, good condition to about 700 feet west of section line, where there is a dam 3' high caused by concrete headwalls falling into ditch.

Section 26. Through E½ E½ ditch is deep and about 3' wide, good condition. Condition is fairly good to G.T.R.R. no brush. Iron culvert under R.R. is broken back about 5' on lower end.

Section 22. Between drain is straight and has good bottom, but brush is beginning on banks near R.R. From Michigan Street to Powell Lake ditch is O.K. except for last 50' which is very narrow and poor - probably under water in a normal year. From lake to 200' west of section line ditch is O. K.

Section 23. From 200' west of section line to 100 feet north of angle point ditch is 6' deep but caved in causing dams 18" high in some places. Ditch is high from here to 500 feet south of Sixth Street where water is standing. Channel under bridge is O.K. From here to end ditch is O.K. though not deep, brush on banks but not in bottom.

Myler and Medema

From Powell Lake west for 200' the ditch has been tramped in by cattle. From here to N&S¼ line section 23 ditch is in good condition. Along quarter line ditch is crooked and deep and has narrow bottom, at angle points dirt has washed in and made dams. Many weeds in bottom and trees and brush along banks. From ¼ line to Havens Branch drain is in fair condition. From Havens Branch to Leonard Street cattle have broken down the banks. North of Leonard Street drain is O.K. All culverts are O.K. Channels are full of annual weeds.

Havens Branch

From Myler and Medema Drain to Leonard Street drain is in poor condition, very shallow. North of Leonard Street the ditch is deeper but full of willows.

It must be remembered in evaluating this report that 1930 was a very dry season, the rainfall being only about 60% of normal.

Parenthetically, we would mention an interesting fact in connection with this drain. When levels were being run for the 1923 cleanout we continued to the northeast across the north-

west quarter of section twenty-four and found that about 600' of deep cutting maximum about 30 feet for a distance of about 150 feet would reverse the flow of this entire area and cause it to empty directly into Grand River instead of following its present route to the southeast and back to the northwest. At this time we attempted to interest the petitioners in such a project but having no information available as to previous costs or frequency or cleanouts were unable to convince them of the economy of such action.

Another drain reported on is the Clark and Bunker Drain located in Bowne township. This drain was established in 1902 the length being 14200 feet and the cost $1989. In 1927 it was cleaned out and extended 6139 feet at a cost of $10295 making a total investment of $12284. This is a fairly good sized job for Kent County, the bottom width being four and five feet and the depth averaging about six feet. Three years after it was dug the inspector made the following report:

September 22, 1930 A.N. Phillips, Inspector

Commencing at the south line of section 20, Bowne twp. the first 800 or 1000 feet runs thru low ground and ditch is only about 18" deep in some places. In the T. Gougherty property there is an elm tree across the ditch. The rest of sec. 20 is fairly good. There is a pile of sand at the south end of the culvert at station 17 plus 20 caused by road ditch to west. Ditch is good all thru sec. 17. At the north side of the angling road thru sec. 16 there is a crossing which partly dams the stream. Sec. 16 is nearly all muck land but the ditch except for a few muck chunks is in good condition. The first ¼ mile of sec. 9 is thru higher ground so ditch is deeper and bottom is quite narrow in places due to bank slides, cattle

crossings, and stones. North of the highway the land soon breaks into low muck and water is nearly stagnant due, I believe, to height of culvert at highway. Ditch is plenty big clear to lake. There is about an 18" culvert 500' south of the north lake which is clear but seems small for about a 10' ditch.As the highway culvert in section 9 is high I do not believe that the bad spots below it will impede the flow. It would cost a great deal to lower this culvert as it is in a fill and has heavy wing walls. All other bridges and culverts are O.K.

It seems unnecessary to comment in detail on these reports, they speak only too clearly for themselves of the urgent necessity for a wise and firm maintainence policy. One point which we would call attention to in both reports, however, is the fact that both highway and railroad culverts are seldom placed at sufficient depth. Especially when floors are built in them, the lowering makes an added expense to the drain that could easily be avoided at the time that the culvert is being constructed. In general we would recommend that the drain commissioner should be authorized by the board of supervisors to employ a man by the week or month, preferably one who has a truck, to go over all drains twice a year, once in the spring and once in the fall and clean out all minor obstructions in open drains and all catch basins in closed drains, reporting any major obstructions such as dams, cattle paths, or broken pipe to the commissioner who should then order the necessary work done under the clause which gives him the right to spread 20% of the original cost each year for repairs. Payment for this work should be made in orders on the revolving fund which can be cashed immediately, a balance being affected from time to time by ledger transfers.

CHAPTER VII

CONCLUSION

It is nearly as difficult to know where to stop such an analysis as we have been conducting as it is to know where to start. Many inconsistencies and errors, both of omission and commission, occur in the drain law itself; but this is something that is statewide in its effect and we have chosen to discuss only those things that can be changed locally under the present law. Some of these changes have taken place since we have started our work on this thesis a year ago. The records of the drain commissioner's office have now been brought up to date with a set of information cards, a book of township maps, and a filing system for the original papers of the various drains. The new method of assessing which we have proposed has been put into effect. Better cooperation has been arranged with the treasurer's office and the financial records brought up to date.

In summation, the office of County Drain Commissioner has now begun to take the place among the county offices which its work justifies and with the dawning appreciation of its importance and method of functioning by the Board of Supervisors, progress should continue until it becomes one of the major offices, rather than one of the most minor, as has been the case until recently.

APPENDIX

R E P O R T

O N

GEERS DRAIN

COUNTIES

OF

KENT AND NEWAYGO

STATE OF MICHIGAN

BY

WILLIAMS & WORKS

January 27, 1930

TABLE OF CONTENTS

DRAINAGE BOARD

Ernest L. Hunter, Chairman

Chief, Division of Drains

Dept. of Agriculture

R. B. Patterson - Kent County

O. A. Rhodes - Newaygo County

MINUTES OF SURVEY AND SPECIFICATIONS

Minutes of survey and specifications to "locate, establish and construct" the Geers Drain located in Tyrone Township, Kent County and Grant Township, Newaygo County, State of Michigan.

Done by order of Ernest L. Hunter, Deputy Commissioner of Agriculture; Robert B. Patterson, County Drain Commissioner for the County of Kent; and Orley A. Rhodes, Drain Commissioner for the County of Newaygo, the Drainage Board for said drain.

MINUTES OF SURVEY

The following is a description of the hub-line which is 15 feet to the right of the center line of the drain.

Commencing at a point 305.32 feet north and 2225.28 feet east of the southwest corner of Section 2, Town 10 North, Range 12 West, thence north 79 degrees and 36 minutes west 1838 feet, thence north 59 degrees and 20 minutes west 460 feet to the west line of Section 2, Town 10 North, Range 12 West at a point 872 feet north of the southwest corner thereof, thence on the same course 117 feet, thence north 43 degrees and 37 minutes west 530 feet to the south one-eighth line of Section 3, Town 10 North, Range 12 West at a point 475 feet west of the east line of Section 3, Town 10 North, Range 12 West, thence on the same course 380 feet, thence north 65 degrees and 35 minutes west 618 feet to the east one-eighth line at a point 517 feet north of the southwest one-quarter of the northeast one-quarter of the southeast one-quarter of Section 3, Town 10 North, Range 12 West, thence on the same course 70 feet, thence north 9 degrees and 58 minutes west 785 feet to the east and west one-quarter line of Section 3, Town 10 North, Range 12 West at a point 218 feet west of the northeast corner of the northwest one-quarter of the southeast one-quarter of Section 3, Town 10 North, Range 12 West, thence north 20 degrees and 14 minutes west 1395 feet to the north one-eighth line at a point 581 feet east of the north and south one-quarter line of Section 3, Town 10 North, Range 12 West, thence on the same course 533 feet, thence north 60 degrees and 01 minute west 442 feet to the north and south one-quarter line of Section 3, Town 10 North, Range 12 West at a point 842 feet south of the north line of Section 3, Town 10 North, Range 12 West, thence on the same course 732 feet, thence north 16 degrees and 39

minutes west 517.5 feet to the north line of Section 3, Town 10 North, Range 12 West (which is the County line between Kent and Newaygo Counties) at a point 789 feet west of the north one-quarter corner of Section 3, Town 10 North, Range 12 West. This point also being 1149 feet west of the southeast corner of Section 34, Town 11 North, Range 12 West, thence north 45 degrees and 50 minutes west 245.5 feet to the east one-eighth line of Section 34, Town 11 North, Range 12 West at a point 167 feet north of the south line of said section, thence on the same course 1372 feet, thence north 88 degrees and 29 minutes west 311.5 feet to the north and south one-quarter line at a point 1096 feet north of the south line of Section 34, Town 11 North, Range 12 West, thence on the same course 1028.5 feet, thence south 70 degrees and 51 minutes west 349 feet to the west one-eighth of Section 34, Town 11 North, Range 12 West at a point 972 feet north of the south line of Section 34, Town 11 North, Range 12 West, thence on the same course 1382 feet, to the west line of Section 34, Town 11 North, Range 12 West at a point 481.2 feet north of the southwest corner of said section, thence on the same course 601 feet, thence north 88 degrees and 29 minutes west 1893 feet to the end which point is 206 feet east and 282 feet north of the south one-quarter corner of Section 33, Town 11 North, Range 12 West.

The length of drain on each description of land is as follows: Tyrone Township, Kent County.

Description	Section	Owner	Length
S. 100A., SW¼	2-10-12	Edward Cordes	2298 feet.
SE¼, SE¼	3-10-12	S. VanSingle	647 "
NE¼, SE¼	3-10-12	Fred VanderHey	998 "
NW¼, SE¼	3-10-12	H. Van Single	855 "

Tyrone Township, Kent County

Description	Section	Owner	Length
SW¼, NE¼	3-10-12	Pearl Gorby	1395 feet.
NW¼, NE¼	3-10-12	H. VanSingle	975 "
NE¼, NW¼	3-10-12	Albert Geers	1249.5 "

Grant Township, Newaygo County.

Description	Section	Owner	Length
SE¼, SE¼	34-11-12	J. Slachter	245.5 "
SW¼, SE¼	34-11-12	A. Landheer	1683.5 "
SE¼, SW¼	34-11-12	L. Longcore	1377.5 "
SW¼, SW¼	34-11-12	J. Geers	
SE¼, SE¼, SE¼	33-11-12	J. Geers	2153 "
SW¼, SE¼	33-11-12	H. Geers	
SW¼, SE¼, SE¼	33-11-12	H. Geers	1723 "

Total .....15600 feet.

Length of drain in Kent County 8417.5'
Length of drain in Newaygo County 7182.5'

SPECIFICATIONS

STAKES

Station stakes and grade hubs are set every 100 feet and are numbered consecutively from station "0" at the lower end to station 156 plus 00 at the upper end.

The center line of drain is 15 feet to the left of the hubs going up stream.

BOTTOM

The width of bottom shall be 4 feet from station "0" to station 84 plus 17.5 (County Line) and 3 feet from station 84 plus 17.5 to station 156 plus 00.

BANKS

The slope of banks shall be 1 foot horizontal to 1 foot vertical.

Excavated material shall be placed so that spoil banks on both sides of the drain shall be the same size.

RIGHT-OF-WAY

The right-of-way shall be 50 feet on each side of the center line of the drain.

BERM

All earth shall be placed at least 15 feet from the top edge of banks.

CLEARING

All timber, brush and rubbish within the limits of the excavation and spoil banks shall be removed or burned. Under no consideration shall such debris be covered with earth excavation.

OPENINGS

Openings shall be left in the spoil bank for the discharge of such tributary creeks and farm drains as are now emptying their waters into the line of the drain.

An opening equal to the cross-section of the Gorby Drain shall be left in the west bank at the junction of said drain with the Geers Drain.

CULVERTS

Culverts will be required as follows:

Culvert #1

Highway culvert on section line between sections 2 and 3 Tyrone Township, Kent County at station 22 plus 98.

32 feet of 60 inch culvert pipe with concrete headwalls.

Culvert #2

Highway culvert on County line road at station 84 plus 17.

35 feet of 48 inch culvert pipe with concrete headwalls.

Culvert #3

Highway culvert on section line between sections 33 and 34 Grant Township, Newaygo County at station 131 plus 06.

33.6 feet of 48 inch culvert pipe with concrete headwalls.

C U T S

Cuts from grade hubs are as follows:

Station	Cut	Station	Cut
0	2' 11"	51	6' 1"
1	1' 11"	52	6' 1"
2	1' 11"	53	6' 2"
3	1' 10"	54	6' 6"
4	2' 5"	55	6' 6"
5	2' 11"	56	6' 7"
6	3' 7"	57	6' 4"
7	3' 3"	58	7' 4"
8	2' 10"	59	7' 0"
9	3' 8"	60	6' 4"
10	4' 10"	61	6' 5"
11	4' 5"	62	5' 7"
12	4' 10"	63	5'11"
13	4' 1"	64	7' 6"
14	5' 1"	65	6'10"
15	4' 5"	66	6' 6"
16	5' 6"	67	7' 0"
17	4' 11"	68	6'11"
18	5' 7"	69	6' 9"
19	5' 0"	70	6' 7"
20	4' 1"	71	6' 6"
21	4' 9"	72	6'10"
22	4' 4"	73	6'10"
23	5' 5"	74	6' 4"
24	4' 8"	75	5' 8"
25	4' 3"	76	6' 2"
26	4' 10"	77	6' 3"
27	4' 10"	78	5'10"
28	2' 5"	79	5' 9"
29	5' 9"	80	5' 8"
30	5' 0"	81	5' 6"
31	5' 3"	82	6' 6"
32	5' 6"	83	6' 6"
33	5' 8"	84	4' 4"
34	5' 8"	85	3'11"
35	5' 3"	86	4' 3"
36	5' 2"	87	4' 4"
37	5' 2"	88	4' 3"
38	6' 3"	89	4' 5"
39	5' 8"	90	4' 0"
40	4' 8"	91	4' 1"
41	4' 9"	92	4' 1"
42	5' 8"	93	4' 4"
43	6' 0"	94	4' 4"
44	6' 3"	95	4' 4"
45	8' 1"	96	4' 1"
46	6' 7"	97	4' 2"
47	5' 11"	98	4' 9"
48	6' 2"	99	4' 1"
49	6' 1"	100	4' 0"
50	6' 0"		

C U T S (cont.)

Station	Cut
101	3' 10"
102	4' 1"
103	4' 0"
104	4' 4"
105	4' 0"
106	4' 0"
107	3' 10"
108	3' 11"
109	4' 4"
110	4' 7"
111	5' 1"
112	5' 7"
113	4' 10"
114	5' 0"
115	4' 10"
116	5' 2"
117	4' 1"
118	4' 0"
119	3' 11"
120	4' 2"
121	4' 0"
122	4' 8"
123	5' 0"
124	5' 1"
125	5' 4"
126	5' 2"
127	5' 1"
128	4' 11"
129	4' 10"
130	4' 6"
131	6' 3"
132	4' 5"
133	3' 11"
134	3' 8"
135	4' 4"
136	4' 5"
137	4' 5"
138	5' 4"
139	5' 9"
140	6' 5"
141	6' 9"
142	5' 5"
143	5' 5"
144	6' 2"
145	4' 10"
146	4' 3"
147	4' 2"
148	4' 0"
149	4' 6"
150	4' 1"
151	4' 10"
152	4' 0"
153	3' 7"
154	4' 2"
155	3' 10"
156	4' 2"

Average cut in Kent County 5' 5"

Average cut in Newaygo County 4' 6"

COMPUTATION OF EXCAVATION

Estimated cubic yards

Station		Station			Cubic Yards
0	to	15	(24.9 X 1500)/27	equals	1,383
15	"	40	(45 X 2500)/27	"	4,167
40	"	84 plus 17.5	(64 X 4417.5)/27	"	10,480
			Total excavation in Kent County		16,030
84 plus 17.5	to	105	(30 X 2082.5)/27	equals	2,314
105	to	131	(35.9 X 2600)/27	"	3,452
131	"	145	(42.2 X 1400)/27	"	2,187
145	"	156	(30.2 X 1100)/27	"	1,232
			Total excavation in Newaygo County.		9,185
			Total excavation on Drain		25,215

DESIGN NOTES

SIZE OF DISTRICT

The area of the district is 2020 acres or 3 and 16/100 square miles; being divided as follows: Kent County 1760 acres and Newaygo County 260 acres.

DRAINAGE COEFFICIENT

The drainage coefficient is determined by the four following conditions:

(1) Rainfall and temperature.

(2) Topography of the area.

(3) Size and shape of the district.

(4) Character and culture of the soil.

A study of rainfall and temperature conditions of this district show that the maximum floods are caused by excessive rainstorms which are preceded by $\frac{1}{8}$ inch to 1 inch of rain, which has soaked the ground nearly to saturation. This condition occurs in early summer, when the flooding of growing crops for longer than twenty-four hours would ruin them.

The area is generally flat with a gradual rise to the south and southwest.

The district is approximately 2 and $\frac{1}{2}$ miles long by 1 and $\frac{3}{4}$ miles wide, being rectangular in shape. The district is of such size and shape that the rainfall will not vary over the area, that is, a storm encountered at one point in the district will be general over the entire watershed.

The soil is a clay loam and the greater part of the district in under cultivation.

After a careful study of all conditions "C" was chosen as .20 and the duration of the peak storm as 17 hours, this being

the length of time necessary for water from the most remote part of the district to reach the lower part of the drain.

DISCHARGE

Using the expression $Q = C \times I \times A$

Let C = 0.200

I for 17 hours $= \frac{226}{66+t} = \frac{226}{1086} = 0.208$

and A = 2020

Then $Q = 0.2 \times 0.208 \times 2020 = 84.03$ cu.ft. per second

DESIGN OF DRAIN

Using a bottom width of 4 feet with 1 to 1 side slopes on the channel and the slope of the drain being 0.0023, also assuming a 4 foot depth of water in the channel the computations for the drain are as follows:

Area of cross-section (8 X 4) = 32 square feet.

Wetted perimeter = 15.3 feet.

Hydraulic radius (32/15.3) = 2.09 feet.

Using Kutter's formula to derive a value for "C" in Chezy's formula $V = C\,(RS)^{\frac{1}{2}}$ we have, by using a value for "N" (in Kutter's formula) of 0.04, a value for "C" of 39. Now substituting in the formula $V = C\,(RS)^{\frac{1}{2}}$ we have as follows:

$V = C\,(RS)^{\frac{1}{2}} = 39\sqrt{2.09 \times 0.0023} = 2.69$ ft. per second.

q = av = discharge in cubic feet per second.

When a = cross section of stream in square feet.

and v = velocity of stream in feet per second.

Therefore:

$q = av = 32 \times 2.69 = 86.08$ cubic feet per second which is ample carrying capacity for the channel which has to handle a maximum load of 84.03 cubic feet per second.

REMARKS

When construction is about to start on the culverts it is advisable to have them staked in order that they will cross the highways at the proper angle and grade.

Since all culverts are crossing highways at a rather sharp angle with the center line of the road, any slight difference in the placing of these pipes may cut down the prescribed width of roadway.

ESTIMATE

Administrative Cost:		
Drainage Board	$50.00	
Serving and Posting Notices	15.00	
Survey, plans, report & Inspection	500.00	
Total administrative cost		$ 565.00
Construction Cost:		
25,215 cubic yds. excavation @ .30	7564.50	
Culvert # 1	419.00	
Culvert # 2	531.00	
Culvert # 3	435.50	
Total construction cost.		$ 8950.00
		$ 9515.00
Incidental Expenses 10%		951.50
Total cost of Drain		$10466.50

DRAINAGE DISTRICT

Kent County

County Road on E. line of N½ Section 9, Tyrone Twp. and on E and N lines of E½ Section 4, Tyrone Twp.

Tyrone Township - Kent County

Tyrone Township at Large

Section 2.

S. 100 a. of S.W. ¼ west of Rogue River

S½, S½, NW¼ and N 3/8, SW¼

Section 3.

N.W.¼, N.E.¼

S.W.¼, N.E.¼

S.W.¼, N.E.¼ & S.½, S.½, N.W.¼

N.½, S.½, N.W.¼

N.W.¼, N.W.¼

N.E.¼, N.W.¼

N.3/8, W.½, S.W.¼ & N.E.¼, S.W.¼

S.5/8, W.½, S.W.¼

W.½, S.E.¼, S.W.¼

E.½, S.E.¼, S.W.¼

N.W.¼, S.E.¼

N.E. ¼, S.E.¼

S.W.¼, S.E.¼

S.E.¼, S.E.¼

Section 4.

N. 30.11 a., N.W.¼, N.E.¼ & N. 27.28a., N.E.¼, N.E.¼

S. 17.5 a., N.W.¼, N.E.¼ & S. 20 a., N.E.¼, N.E.¼ &

N.½, S.E.¼, N.E.¼

S.W.¼, N.E.¼ & S.½, S.E.¼, N.E.¼ (ex. 2.5 a. in S.E. cor)

Commencing S.E. corner S.E.¼, N.E.¼, thence N. 22 R., thence

Tyrone Township - Kent County (cont.)

W. 18 R., thence S. 22 R., thence E. 18 R.

N.½, N. W.¼, N.W.¼ & E.½, N.W.¼

S.½, N.W.¼, N.W.¼

E.½, S.W.½

N.W.¼, S.E.¼

N.E.¼, S.E.¼ (ex. S. 14 a.)

S.E.¼,S.E.¼ & S. 14 a., N.E.¼, S.E.¼ (ex. N. 1 R.)

W. 25 a., S.W.¼, S.E.¼

E. 15 a., S.W.¼, S.E.¼

Section 9.

N.½, E.½, N.W.¼

N.½, W.½, N.W.¼

N.E. ¼, N.E.¼ (ex. 3 a. in N.E. corner)

Piece of land 1 sq. a. S. of School lot in N.E.¼

School Lot 2 a. in N.E. corner of N.E.¼

Section 10.

N.½, N.W.¼, N.W.¼

S.½, N.W.¼, N.W.¼

S.½, N.W.¼

N.E.¼, N.W.¼ & N.W.½, N.E.¼

N.E.¼, N.E.¼

S.½, N.E.¼

Section 11.

N.W.¼, N.W.¼

DRAINAGE DISTRICT (cont.)

Newaygo County

Grant Township - Newaygo County

Grant Township at Large

Section 33.

E.½, S.E.¼, S.W.¼ & S.W.¼, S.E.¼ also S.W.¼, S.E.¼, S.E.¼

N.½, S.E.¼, S.E.¼

S.E.¼, S.E.¼, S.E.¼

Section 34.

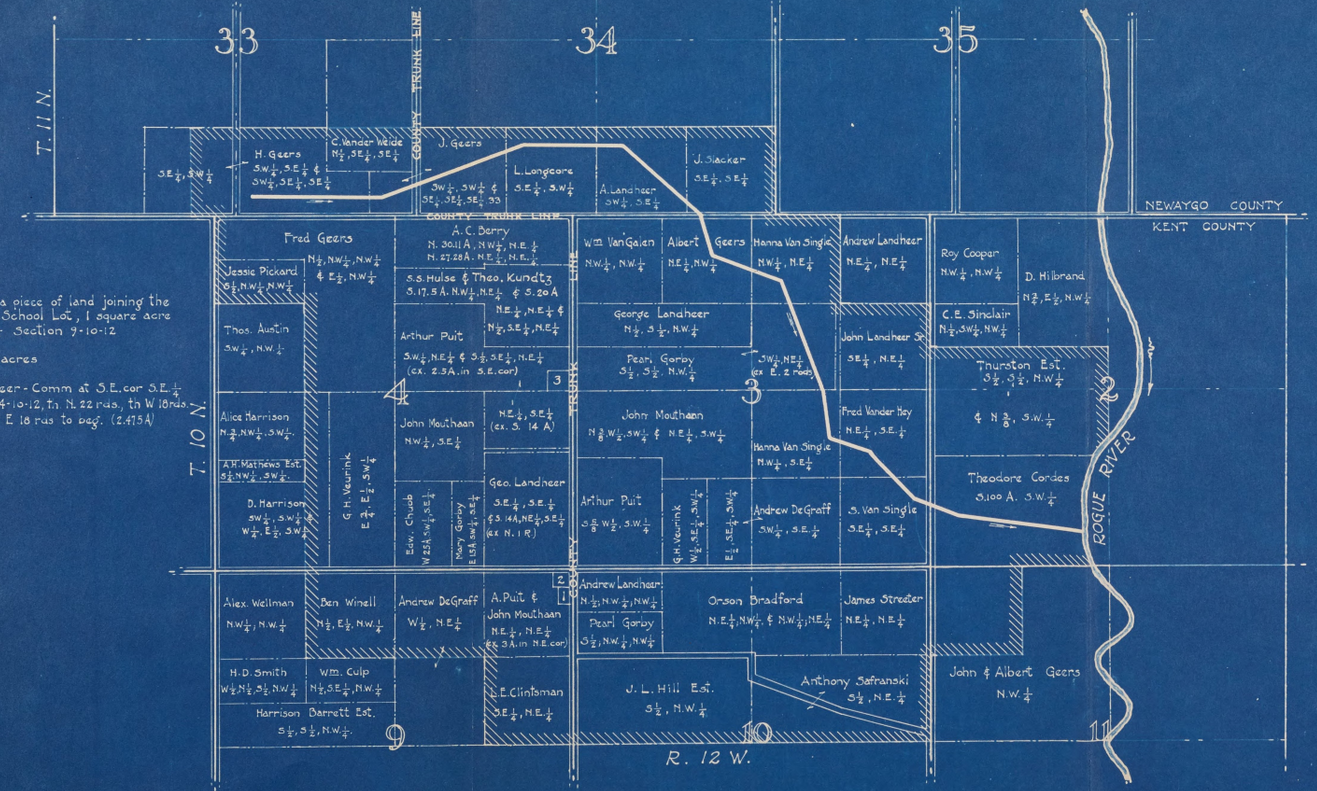
S.W.¼, S.W.¼

S.E.¼, S.W.¼

S.W.¼, S.E.¼

S.E.¼, S.E.¼

MAP OF
ASSESSMENT DISTRICT OF GEERS DRAIN
TYRONE TOWNSHIP, KENT COUNTY
GRANT TOWNSHIP, NEWAYGO COUNTY
MICHIGAN



(1) Chas. Heath - a piece of land joining the South line of School Lot, 1 square acre in N.E ¼, N.E ¼ Section 9-10-12

(2) School Lot - 2 acres

(3) Andrew Landheer - Comm at S.E. cor S.E ¼ N.E. ¼ Section 4-10-12, Th N. 22 rds., th W 18 rds., th S. 22 rds., th E 18 rds to beg. (2.475 A)

Scale: 4" = 1 Mile

E. L. HUNTER
R. B. PATTERSON
O. A. RHODES
} Drainage Board

T. O. WILLIAMS ~~~ Surveyor

12/30/29

D.B.# 42

S. VAN SINGLE (64')

H. VAN SINGLE (65')

THEO. CORDES (229')

FRED VANDERHEY (99')

PEARL GORBY (139')

872' to S.W. Cor. Sec. 2-10-12

Section line 438' between Sections 2 & 3-10-12

Culvert #1 See detail sheet #5

Old Drain

Area = 55 sq ft

Cross Section at Sta. 45+00

B.M. #1
El. 94.34
Nail-24" Del. Elm
7' rt. Sta 1+00

B.M. #2
El. 95.14
Nail - 6" Ash
3' rt. Sta 5+03

B.M. #3
El. 97.15
Nail - 12" Wild Cherry
44' rt. Sta 11+67

B.M. #4
El. 100.26
Nail - 6" Wild Cherry
2' rt. Sta. 15+60

B.M. #5
El. 100.02
Nail-24" Elm
50' rt. Sta 21+60

B.M. #6
El. 100.68
Nail-15" Ash
8' rt. Sta. 28+00

B.M. #7
El. 105.23
Nail-6" Elm
18' rt. Sta 40+00

B.M. #8
El. 106.71
Nail - 18" "Dead" Elm
9' Rt. Sta. 50+80

Commencing; 305.32' North and 2225.28' East of the S.W. corner of Section 2, T. 10 N., R. 12 W.

Stations 0 5 10 15 20 25 30 35 40 45 50 54

Cut from Hub 1'0" 1'1" 1'11" 1'6" 2'5" 2'11" 3'7" 3'3" 2'10" 3'8" 4'6" 4'5" 4'10" 4'1" 5'1" 4'5" 5'6" 4'11" 5'7" 5'0" 4'1" 4'9" 4'4" 5'5" 4'0" 4'3" 4'10" 4'6" 2'5" 5'9" 5'0" 5'3" 5'4" 5'8" 5'8" 5'3" 5'2" 5'3" 6'3" 5'8" 4'0" 4'3" 5'8" 6'0" 6'3" 6'1" 6'7" 5'11" 6'7" 6'1" 6'0" 6'1" 6'1" 6'2" 6'4"

Width of Bottom 4'-0" Bottom

Place 60" Tube, See detail of Culvert #1

Road

Bottom of old drain

105 100 95 90

92.75

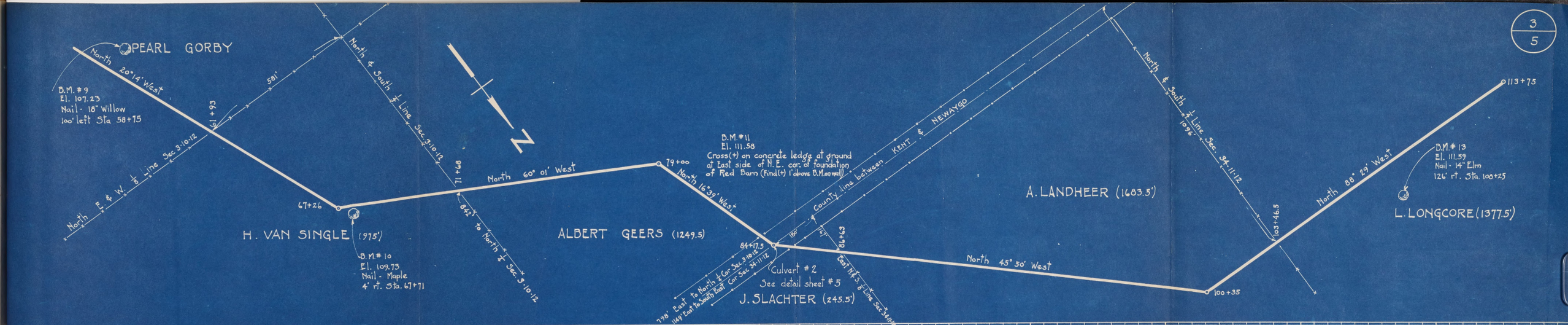
98.5

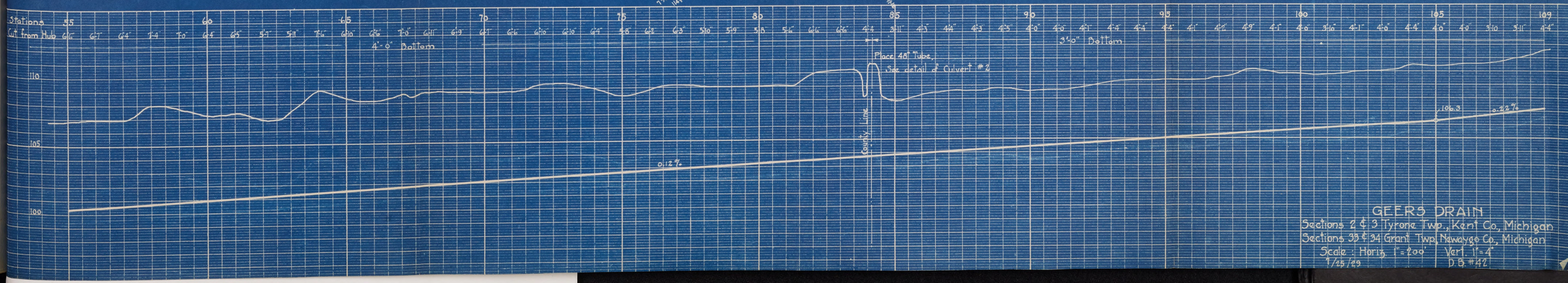
0.05%

0.23%

0.12%

GEERS DRAIN
Sections 2 & 3 Tyrone Twp., Kent Co., Michigan
Sections 33 & 34 Grant Twp., Newaygo Co., Michigan
Scale; Horiz. 1"=200' Vert. 1"=4'
7/25/29
D.D. #42





GEERS DRAIN
Sections 2 & 3 Tyrone Twp., Kent Co., Michigan
Sections 33 & 34 Grant Twp. Newaygo Co., Michigan
Scale: Horiz. 1" = 200' Vert. 1" = 4'
1/25/29
D.B. #42

L. LONGCORE

J. GEERS (2153')

C. VANDER WEIDE

H. GEERS (1723')

North 88° 29' West

113+75

South 70° 51' West

117+24

972'

West N. & S. 1/8 Line Sec 34 11-1E

Section Line between Sections 33 & 34 11-1E

481.2'

B.M. # 14
El. 121.13
Nail - 6" Wild Cherry
162' South of Sta 131+15

131+06

Culvert #3 - see detail sheet #5

137+07

266'

138+77

B.M. # 15
El. 123.79
Big stone on North side of stone-pile
75' North of Sta. 137+85

North 88° 29' West

East N. & S. 1/8 Line Sec 33 11-1E

B.M. # 16
El. 123.68
Nail - 8" Dbl. Elm
48' rt. Sta. 145+63

156+00 (End)

206'

B.M. # 17
El. 125.51
Nail in stump
45' rt. Sta. 156+00

282'

North & South 1/4 Line Sec 33 11-1E

Area = 40 ☐

3'-6"

1:1 slope

3'-0"

Cross Section at Sta. 142+00

N

Road

Place 48" Tuve. See detail of Culvert #3

120

115

110

118.18

120.2

112.02

0.18%

0.44%

0.22%

3'-0" Bottom

Stations
Cut from Hub

110 115 120 125 130 135 140 145 150 155

GEERS DRAIN

Sections 2 & 3 Tyrone Twp., Kent Co., Michigan
Sections 33 & 34 Grant Twp., Newaygo Co., Michigan

Scale Horiz. 1" = 200' Vert. 1" = 4'
7/25/29
D.B. # A2

MAP OF KENT COUNTY SHOWING 171 COUNTY DRAINS

KENT COUNTY DRAINS

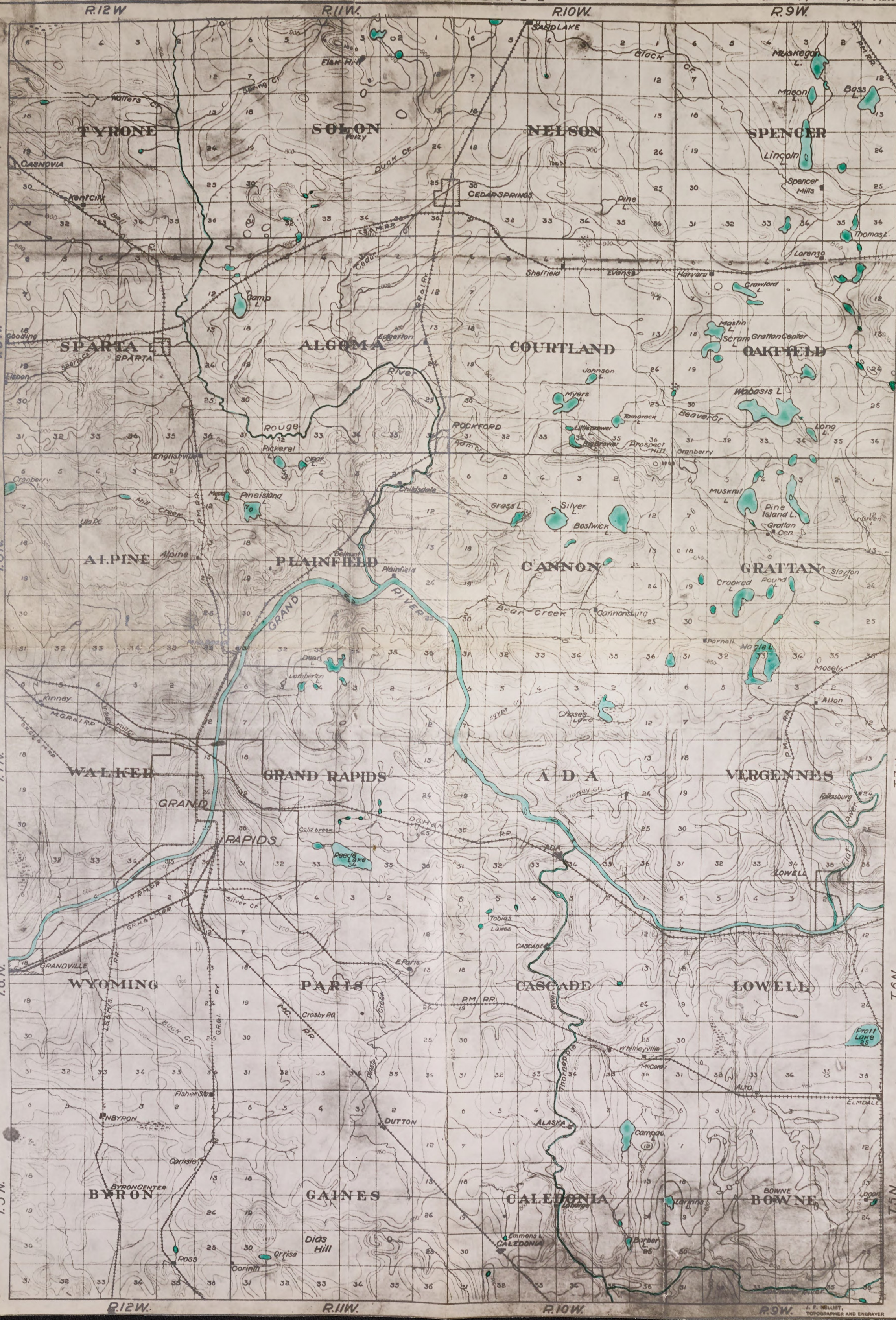
Reference No.	Name of Drain.	Township.
35	Alder Creek	Nelson
82	Alder Creek Extension	Nelson
43	Anderson	Gaines and Paris
40	Barnes	Bowne
12	Basin	Algoma
146	Bayou	Wyoming
19	Bear Swamp	Bowne
44	Beaver Dam	Court and Nelson
61	Beaver Dam Extension	Courtland and Nelson
51	Beak	Cascade and Paris
134	Beesing	Gaines and Caledonia
77	Behan and Foley	Wyoming
53	Bennett	Courtland
24	Bergy Extension	Caledonia
11	Black Lake	Algoma
39	Black Creek	Nelson and Spencer
78	Blanchard	Alpine
157	Bookey	Grattan
30	Boss	Wyoming
66	Boulard and Thompson	Bowne
117	Bowler	Bowne
103	Bradshaw	Spencer
156	Brewer	Gaines
110	Buck Creek	Byron
168	Buck Creek Extension	Wyoming and Byron
171	Bunn	Byron
3	Byron and Dorr	Byron
69	Caledonia	Caledonia
28	Caledonia	Caledonia
106	Cannonsburg Village	Cannon
50	County Line	Nelson
131	Carmody	Grand Rapids
116	Chase	Sparta
16	Church Lake	Grand Rapids
71	Clark and Bunker	Bowne
74	Crimnion Creek	Nelson, Courtland Oakfield
80	Cobb and Miller	Bowne
142	Cole	Wyoming
85	Cooley	Spencer
97	Colby and Livingston	Bowne
98	Colby and Livingston Extension	Bowne
104	Crippen	Wyoming and Paris
138	De Boer	Sparta
100	Downs	Vergennes
95	Driscoll	Walker
15	Dunnean Lake	Gaines and Caledonia
49	Dunnean Lake Extension	Gaines
87	Durfy	Nelson
27	Dutch	Algoma
70	Emmons Lake	Caledonia
125	Emmons St.	Caledonia
76	Fairchild	Vergennes
25	Farmer	Alpine
124	Finch	Solon and Algoma
119	Fisk	Paris and Gaines
1	Fresheter	Alpine
133	Guger	Bowne
135	Girgle	Walker
129	Goose Creek	Byron
150	Goose Creek and Buck Creek	Byron
153	Graham and Warden	Walker
86	Grandy	Byron
58	Gorby	Tyrone
166	Goorhouse	Byron
128	Heintzelman	Cascade and Paris
141	Heir and Thomas	Bowne
31	Heyboer	Paris
91	Herps	Byron
65	Hill	Ada
164	Homerich	Byron
18	Hopkins Lake	Alpine
76	Howard and Doyle	Grattan and Vergennes
84	Hudson	Byron
88	Hinzenga and Branches	Wyoming
23	Irving and Bowne	Bowne
169	Irwin	Byron
22	Jewel	Wyoming
73	Johnson, Branch of Clark Bunker	Bowne
63	Johnson and Godfrey	Bowne
102	Kilgus and Mud Lake	Bowne
132	Klopfenstein	Gaines
52	Knight	Byron
41	Kroft	Caledonia
64	Lally	Vergennes
21	Lamberton Lake	Grand Rapids
79	Lanback	Alpine
93	Lanback Extension	Alpine
99	Layer	Bowne
60	Lockwood	Nelson and Solon
143	Maloney and Wade	Caledonia
89	Maloney	Caledonia
32	Martin	Ada and Cascade
13	Mason and Slayton	Grattan
122	McDowell	Gaines
126	McGee	Vergennes
161	McIntosh	Gaines
29	McKnight	Cascade
4	Medema	Grand Rapids
163	Miller Jct. Co.	Byron
42	Miller	Byron
144	Miller and Stewart	Bowne and Lowell
72	Miller and Wright	Bowne
8	Mill Pond	Sparta
37	Mink Creek	Byron
140	Mink Creek Extension	Byron
112	Mullins	Walker
6	Myler	Grand Rapids
154	Morris	Courtland
155	Morman	Byron
148	Mosher and Farnum	Caledonia
151	Mosley	Grattan
7	Nason	Walker
170	Nichols	Byron
96	Nolan	Walker
105	Oatman	Lowell
54	O'Neil	Walker
90	Osbourne	Tyrone
51	Overlie	Nelson
101	Parker	Vergennes
33	Parnell	Grattan
10	Pickerel Lake	Plainfield and Algoma
149	Phelps	Sparta
162	Phelps Extension	Sparta
38	Pine Island	Plainfield
137	Plainfield	Plainfield and Algoma
158	Potter	Solon
20	Pratt Lake	Lowell and Bowne
167	Ratigan Lake	Grattan
40	Reeds	Walker
94	Remington	Grand Rapids
5	Rettinger	Lowell and Bowne
111	Rexford Lake	Tyrone
9	River Side	Walker and Wyoming
59	Roth	Gaines
147	Richardson and Beatty	Courtland
2	Rogue River	Plainfield
83	Roys	Wyoming
14	Saddle Bag	Grand Rapids
55	Sand Lake	Nelson
130	Scese	Nelson
118	Schindler Swamp	Alpine
45	Shuman	Paris and Cascade
68	Schooley	Gaines
145	Scot Lowe	Bowne
115	Scotch Lake	Plainfield
34	Sexton	Walker
152	Spaulding	Cascade
47	Tobias and Waldren	Cascade
139	Troy	Caledonia
121	Voss Parker	Gaines
161	Veenstra	Plainfield
26	Wagar and Bayless	Nelson
114	Wagner	Byron
136	Waldron Lake	Cascade
109	Walker No. 4	Wyoming and Walker
48	Warner	Byron
67	Waters	Grand Rapids
62	Waring	Grand Rapids
127	Weaver	Byron
113	Wells	Grand Rapids
92	West Caledonia	Caledonia
160	Winchester	Byron
165	Williams	Nelson
36	Winger and Nulty	Gaines and Caledonia
120	Winslow	Bowne
108	Winters	Gaines
81	Woods	Bowne
123	Warden	Walker
17	Wright and Alpine	Alpine
56	Wyoming	Wyoming

GRAND RAPIDS

T. 7 N. R. 11 W.

WELLS
PLAINFIELD
GRAND RIVER
NORTH PARK
MUD LAKE
SOFT WATER L.
BUTTON LAKE
LAMBERTON LAKE
PERCH LAKE
LAMBERTON
BALL LAKE
Sunny creek
LAMBERTON
CREEK
MUD LAKE
MASON LAKE
N
Scale: 1" = 1500'
RAPIDS
WARING
MYLER & MEDEMA
HAVEN BRANCH
GRAND TRUNK R.R.
TWIN LAKES
DRAIN
CARMODY BRANCH
REMINGTON
TENCKINCK LAKE
ROBINHOOD
LAPPIN LAKE
WATERS
CASCADA POINT
DEWEY LAKE
SADDLE BAG
FISK LAKE
REEDS LAKE
GILLETT
EAST GRAND RAPIDS
MARTIN & BEAK
GRAND
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36

KENT COUNTY


R.12W.
R.11W.
R.10W.
R.9W.
T.10N.
T.9N.
T.8N.
T.7N.
T.6N.
T.5N.
TYRONE
SOLON
NELSON
SPENCER
SPARTA
ALGOMA
COURTLAND
OAKFIELD
ALPINE
PLAINFIELD
CANNON
GRATTAN
WALKER
GRAND RAPIDS
ADA
VERGENNES
WYOMING
PARIS
CASCADE
LOWELL
BYRON
GAINES
CALEDONIA
BOWNE
SAND LAKE
CASNOVIA
Kent City
CEDAR SPRINGS
Spencer Mills
Sheffield
Evans
Harvard
Lorenzo
Rockford
Englishville
Alpine
Belmont
Plainfield
Cannonsburg
Parnell
Alton
Kinney
GRAND RAPIDS
ADA
LOWELL
Fallasburg
GRANDVILLE
Cascade
Whitneyville
ALTO
ELMDALE
DUTTON
ALASKA
Campau
Carlisle
BYRON CENTER
Ross
Corinth
Dias Hill
CALEDONIA
Bowne
GRAND RIVER
Rouge River
Wabasis L.
Reeds Lake
Pratt Lake
J. F. NELLIST, TOPOGRAPHER AND ENGRAVER

U. S. DEPARTMENT OF AGRICULTURE
WEATHER BUREAU

ANNUAL METEOROLOGICAL SUMMARY

WITH COMPARATIVE DATA

1930

GRAND RAPIDS, MICHIGAN.

COMPILED BY
WILLIAM H. TRACY,
METEOROLOGIST

GRAND RAPIDS, MICHIGAN.
1931

ANNUAL METEOROLOGICAL SUMMARY, GRAND RAPIDS, MICH., YEAR 1930

Month	Temperature (degrees Fahrenheit)							Rel. humidity (per cent)			Precipitation (inches)				Sunshine		Wind				Number of days											
	Mean			Extremes															Highest														
	Maximum	Minimum	Monthly	Highest	Date	Lowest	Date	Mean at 7 a. m.	Mean 12 noon	Mean at 7 p. m.	Total	Greatest in 24 hours	Date	Snowfall (unmelted)	Number of hours	Per cent of possible	Average hourly velocity	Prevailing direction	Velocity	Direction	Date	Gales (33 miles per hour or over)	Clear	Partly cloudy	Cloudy	Precipitation (0.01 in. or over)	Snow (depth of .01 in. or over, melted)	Thunderstorms	Fog, dense	Maximum temperature 90° or above	Maximum temperature 32° or below	Minimum temperature 32° or below	Minimum temperature zero or below
January	27.2	15.6	21.4	50	6	−4	18	85	76	78	3.21	0.53	24	37.3	121	41	5.	sw.	20	nw.	28	0	1	8	22	17	14	0	1	0	22	29	1
February	39.8	26.0	32.9	67	22	3	15	82	71	77	1.83	0.64	22	5.9	148	50	5.6	sw.	26	nw.	9	0	3	9	16	13	8	2	1	0	7	20	0
March	41.7	25.5	33.6	69	16	15	2	74	56	59	1.20	0.71	25	14.3	230	62	7.4	nw.	25	sw.	31	0	12	6	13	9	6	0	0	0	6	29	0
April	57.3	38.0	47.6	84	10	27	23	72	52	54	2.07	1.30	15-16	T	238	59	11.1	n.	38	n.	7	2	7	10	13	10	0	2	1	0	0	10	0
May	69.5	50.2	59.8	88	9	35	30	71	52	56	2.39	0.67	1-2	T	289	64	11.2	sw.	54	sw.	2	6	8	12	11	14	0	9	0	0	0	0	0
June	79.6	57.8	68.7	94	23	47	7	68	45	52	2.66	0.63	8	0	336	73	11.4	sw.	44	sw.	14	3	7	13	10	9	0	7	0	1	0	0	0
July	84.7	62.5	73.6	99	20	50	2	68	42	41	0.56	0.32	26	0	358	77	9.4	sw.	35	sw.	20	3	13	10	8	5	0	2	0	10	0	0	0
August	84.4	61.5	73.0	95	3	50	12	69	38	44	0.40	0.17	4	0	300	70	8.2	ne.	34	sw.	3	1	11	13	7	6	0	8	0	9	0	0	0
September	75.4	54.8	65.2	89	12	39	30	76	46	50	1.48	0.47	26	0	224	60	10.4	sw.	54	sw.	26	3	9	11	10	8	0	4	1	0	0	0	0
October	57.8	42.0	49.9	84	12	25	19	81	59	65	2.27	1.01	7-8	0.4	97	28	8.1	se.	33	w.	17	1	5	8	18	9	3	1	5	0	0	7	0
November	49.9	34.5	42.2	74	19	9	28	80	66	68	1.51	0.77	29-30	3.7	64	22	11.8	sw.	38	sw.	21	3	5	5	20	9	3	1	3	0	4	12	0
December	33.8	23.5	28.6	49	10	8	2	81	74	76	1.34	0.39	18-19	18.0	52	18	10.0	sw.	27	s.	2	0	4	3	24	14	10	0	1	0	13	22	0
Year	58.4	41.0	49.7	99	July 20	−4	Jan. 18	76	56	60	20.92	1.30	Apr. 15-16	79.6	2,457	52	9.	sw.	54	sw.	May 2	22	85	108	172	123	43	36	13	20	52	129	1

MISCELLANEOUS AVERAGES AND EXTREMES

(1903 to 1930 except as indicated)

Month	Temperature, Fahr.								Rel. Hum. Per cent			Precipitation, Inches									Percentage of possible sunshine	Wind		Average Number of Days									
	Adopted normals, 46 years	[1]Monthly mean	Warmest month		Coldest month		[1]Monthly mean maximum	[1]Monthly mean minimum	Mean at 7 a. m.	[2]Mean at 12 noon	Mean at 7 p. m.	Adopted normals 50 years	[3]Average monthly	Wettest month		Driest month		[4]Average snowfall	Greatest depth snow on ground			Average hourly velocity (miles per hour)	Prevailing direction	†Gales (33 miles per hour or over)	Clear	Partly cloudy	Cloudy	Precipitation 0.01 inch or more	Thunderstorms	Fog, dense	Maximum temperature 90° or above	Maximum temperature 32° or below	Minimum temperature 32° or below	Minimum temperature zero or below
			[1]Mean	Year	[1]Mean	Year								Amount	Year	Amount	Year		Amount	Year													
January...	**24.5**	24.0	31.6	1906	11.8	1912	30.4	17.6	85	73	80	**2.35**	2.45	6.00	1897	0.30	1919	15.1	22.0	1918	28	8.7	w.	1	3	7	21	14	0	1	0	17	29	2
February..	**23.7**	23.3	32.9	1930	14.6	1904	30.4	16.3	85	71	77	**2.24**	2.09	7.87	1881	0.02	1877	10.9	19.0	1905	37	8.5	w.	1	4	7	17	12	0	1	0	15	26	2
March.....	**33.4**	33.9	45.0	1910	25.0	1912	42.4	25.6	80	62	70	**2.48**	2.51	6.88	1882	0.08	1910	7.4	15 0	1904	49	8.6	nw.	1	6	10	15	12	2	1	0	6	23	0
April	**47.0**	46.7	53.8	1915	37.6	1907	56.5	36.8	74	52	60	**2.77**	2.74	8.29	1909	0.60	1887	1.6	4.0	1926	53	8.8	w.	2	7	10	13	12	3	0	0	0	10	0
May	**58.0**	57.8	65.2	1896	50.7	*1907	68.5	47.3	72	49	58	**3.44**	3.36	7.18	1911	0.87	1870	0.4	5.5	1923	59	7.7	e-w	1	9	11	11	11	5	0	0	0	1	0
June.....	**67.8**	67.5	74.2	1919	61.9	1928	78.4	56.6	74	50	58	**3.48**	3.62	13.22	1892	0.83	1908	0.0	0.0	....	64	6.7	w.	1	9	12	9	9	6	0	2	0	0	0
July	**72.3**	72.6	79.8	1921	68.9	*1920	83.3	61.9	74	47	54	**2.92**	2.89	9.35	1883	0.25	1894	0.0	0.0	....	68	6.3	w.	1	10	13	8	9	7	0	5	0	0	0
August	**69.7**	70.1	76.2	1900	65.2	1915	80.6	59.5	78	49	60	**2.61**	2.54	7.44	1882	0.11	1883	0.0	0.0	....	63	6.0	w.	0	10	12	9	9	6	0	2	0	0	0
September.	**62.7**	63.1	68.1	1908	56.2	1918	73.2	53.3	82	55	67	**3.53**	3.46	10.03	1872	0.27	1890	0.0	T.	1928	54	6.3	e.	1	9	11	10	10	5	1	1	0	0	0
October ...	**51.2**	51.2	59.2	1900	42.9	1917	60.3	42.5	83	58	69	**2.81**	2.84	6.81	1884	0.23	1924	0.4	2.5	1925	44	7.0	s.	1	7	9	15	11	2	1	0	0	3	0
November.	**38.4**	39.0	44.4	1909	34.7	1898	45.7	32.2	82	68	75	**2.77**	2.69	6.82	1883	0.06	1904	5.1	7.5	1921	28	8.4	nw.	2	4	6	20	12	1	1	0	2	14	0
December .	**28.5**	28.1	36.6	1923	21.1	1917	33.7	22.5	85	75	80	**2.57**	2.50	6.95	1893	0.31	1913	12.2	14.0	1929	20	8.3	w.	1	3	5	23	14	0	1	0	13	26	0
Year.....	4.81	48.1	79.8	July 1921	11.8	Jan. 1912	57.0	39.3	80	59	67	**33.97**	33.73	13.22	June 1892	0.02	Feb. 1877	53.1	22.0	Jan. 1918	47	7.6	w.	13	81	113	171	135	37	7	10	53	132	4

[1]For period 1894 to 1930. [2] For period 1917 t o1930. [3] For period 1870 to 1930. [4] For period 1893 to 1930. † Recorded by 4-cup anemometer prior to 1928. * Also 1924

Monthly and Annual Mean Temperatures

Year	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1894....	30.2	24.4	41.0	50.2	58.3	71.4	73.8	69.2	64.7	51.0	35.9	32.4	50.2
1895....	19 3	17.2	29.8	52.4	61.3	72.3	72.2	71.7	67.2	43.3	35.4	29.0	47.6
1896....	25.0	25.0	28.8	52.7	**65.2**	69.9	71.8	71.4	59.1	46.4	38.4	30.6	48.7
1897....	23.5	26.1	31.3	44.0	55.4	64.4	76.2	67.6	65.4	53.8	36.1	27.2	47.6
1898....	27.6	24.8	35.7	44.3	58.4	69.6	73.8	70.8	65.7	49.3	**34.7**	25.1	48.3
1899....	21.4	14.9	26.9	51.8	60.7	70.8	72.5	73.4	60.6	55.9	43.6	29.6	48.5
1900....	28.0	20.8	26.8	49.8	61.8	68.0	72.2	**76.2**	66.1	**59.2**	37.8	29.7	49.7
1901....	24.8	17.7	32.4	49.0	58.2	70.8	78.1	71.2	63.2	52.8	37.2	24.4	48.3
1902....	24.2	22.7	39.0	46.6	58.8	63.6	72.1	67.0	58.8	51.2	43.0	26.6	47.8
1903....	24.6	24.7	40.2	46.4	59.5	64.2	71.0	65.6	62.4	51.5	35.6	22.7	47.1
1904....	17.3	**14.6**	32.2	40.9	58.4	66.4	69.9	65.9	62.2	49.8	40.6	24.6	45.2
1905....	19.8	17.7	35.6	44.8	56.2	67.2	70.7	70.0	64.6	50.2	36.8	30.4	47.0
1906....	**31.6**	23.8	25.2	48.4	57.4	66.6	70.6	73.4	67.4	50.2	39.2	28.2	48.7
1907....	23.7	22.2	38.5	**37.6**	**50.7**	66.2	70.4	68.2	60.9	46.8	37.6	29.7	46.0
1908....	26.4	22.4	35.1	45.2	58.4	68.0	73.0	69.1	**68.1**	53.2	40.2	28.4	49.0
1909....	27.4	27.5	32.1	42.8	55.7	67.1	71.1	71.7	60.6	47.2	**44.4**	24.0	47.6
1910....	24.4	22.8	**45.0**	50.2	52.8	66.9	73.7	70.6	61.8	54.0	35.0	25.2	48.5
1911....	26.9	29.2	35.2	45.8	64.6	70.4	73.7	69.4	62.4	49.6	35.2	32.8	49.6
1912....	**11.8**	18.2	**25.0**	46.8	58.8	64.8	70.8	66.9	64.0	52.2	40.5	32.8	46.0
1913....	28.2	21.0	32.8	48.3	57.4	69.8	72.8	72.5	63.2	51.8	43.8	35.1	49.7
1914....	29.0	15.8	32.0	45.6	60.0	67.6	73.8	71.0	62.6	56.5	39.6	24.6	48.2
1915....	23.3	31.1	31.4	**53.8**	53.3	63.4	69.4	**65.2**	64.4	52.8	41.6	27.0	48.1
1916....	28.7	21.1	28.8	46.7	57.8	62.5	78.8	72.8	61.4	51.1	39.8	25.4	47.9
1917....	22.8	17.4	35.0	43.1	51.7	62.6	71.6	68.6	60.3	**42.9**	38.2	**21.1**	**44.6**
1918....	12.5	22.4	38.4	44.0	61.8	66.2	71.6	74.1	**56.2**	53.8	42.2	34.5	48.1
1919....	30.0	28.5	35.4	45.6	56.4	**74.2**	75.7	69.8	65.3	54.6	37.2	21.4	49.5
1920....	16.0	21.2	36.1	41.1	57.1	69.2	**68.9**	69.9	65.9	58.2	38.2	32.0	47.9
1921....	30.5	30.0	41.0	52.6	62.2	73.4	**79.8**	70.6	60.8	46.6	36.7	30.2	**52.2**
1922....	23.6	27.5	36.7	48.0	64.0	69.6	71.2	71.2	65.2	53.0	42.4	27.7	50.0
1923....	26.2	19.6	28.7	45.0	56.8	71.8	73.4	68.2	63.0	49.6	40.4	**36.6**	48.3
1924....	20.3	24.0	32.2	45.6	**50.7**	65.2	**68.9**	68.0	58.2	56.4	39.7	23.2	46.0
1925....	22.2	28.8	36.4	51.8	53.8	70.4	70.9	71.6	66.2	**42.9**	37.0	26.7	48.2
1926....	25.6	26.1	27.7	40.4	58.0	62.2	72.3	71.2	61.2	49.4	37.4	25.0	46.4
1927....	23.3	31.1	39.8	46.4	55.9	64.2	71.2	65.7	67.2	55.5	41.8	28.0	49.2
1928....	26.0	27.0	33.4	43.2	58.0	**61.9**	72.6	71.3	59.6	54.2	40.8	31.7	48.3
1929....	18 8	20.6	39.6	48.6	54.8	64.8	72.6	68.2	62.9	49.4	35.3	26.9	46 9
1930....	21.4	**32.9**	33.9	47.6	59.8	68.7	73.6	73.0	65.2	49.9	42.2	28.6	49.7
Means	24.0	23.3	33.9	46.7	57.8	67.5	72.6	70.1	63.1	51.2	39.0	28.1	48.1

NOTE—Bold-faced figures indicate highest and lowest temperatures.

Extremes of Precipitation and Wind

Month	Precipitation 1903—1930			Wind 1903—1930			
	Greatest in 24 hours	Year	Day	Highest velocity	Direction	Year	Day
				†			
January	1.88	1907	18—19	41	W	1907	19
February	1 60	1918	11—12	* 36	SW	1908	5
March	1.80	1929	31-A.1	45	W	1906	21
April	2.94	1922	17	43	SW	1909	7
May	3.22	1911	20—21	54	SW	1930	2
June	4.58	1905	5—6	44	SW	1930	14
July	2.93	1922	10—11	46	SW	1903	4
August	2.84	1910	22—23	40	W	1908	3
September	2.55	1923	1—2	54	SW	1930	26
October	2.49	1905	17—18	40	W	1905	20
November	2.17	1921	18—19	54	SW	1906	21
December	1.82	1921	16—17	43	SW	1909	5

* Also 36 west, February 15, 1910.

† Corrected to agree with 3-cup anemometer record.

Monthly and Annual Mean Maximum Temperatures

Year	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1894....	36.4	31.8	50.5	61.7	70.6	85.6	87.9	82.8	75.7	59.8	42.6	38.0	60.3
1895....	27.7	25.2	39.7	63.9	74.7	**87.0**	85.6	83.9	78.3	54.2	43.7	35.2	58.2
1896....	30.1	31.6	36.2	62.7	**76.0**	81.7	82.4	81.7	68.0	56.7	44.5	36.1	57.3
1897....	30.3	31.2	39.7	53.9	67.3	75.4	88.2	80.1	79.4	66.2	43.4	33.3	57.4
1898....	33.9	31.4	46.6	55.9	70.7	83.4	87.6	82.4	76.6	59.7	43.4	31.8	58.6
1899....	30.4	24.7	35.4	**64.8**	72.5	82.7	83.0	**87.0**	71.9	65.8	50.9	35.6	58.7
1900....	34.3	28.5	34.5	60.6	72.7	79.2	83.2	**87.0**	76.7	**70.2**	45.0	36.0	59.0
1901....	32.2	24.8	40.1	60.0	68.5	82.4	89.2	81.4	74.1	63.3	44.3	30.6	57.6
1902....	32.6	32.1	48.6	57.2	69.3	73.1	81.2	77.9	69.8	62.3	**54.1**	33.3	57.6
1903....	33.7	34.8	50.8	57.0	73.6	77.8	80.7	**74.0**	71.6	59.8	42.6	27.9	57.0
1904....	23.9	**22.9**	38.7	49.5	68.3	76.2	79.4	76.0	70.6	57.5	48.1	31.0	53.5
1905....	25.6	24.5	44.7	53.4	65.9	77.6	79.7	79.2	73.9	58.6	43.9	35.8	55.2
1906....	**37.5**	32.0	34.7	58.8	67.2	76.3	80.9	83.0	79.1	58.6	45.1	34.3	57.3
1907....	29.6	30 4	47.4	**46.0**	60.4	76.3	80.0	78.7	68.2	55.8	43.8	35.0	54.3
1908....	32.5	29.2	43.4	55.2	68.0	78.7	83.5	79.9	**79.6**	63.2	47.4	34.3	57.9
1909....	33.7	34.5	38.2	51.5	66.1	76.4	81.7	82.0	70.2	55.5	52.8	29.5	56.0
1910....	30.1	29.2	**55.2**	61.4	62.7	78.2	85.3	81.4	71.6	63.1	**39.9**	30.3	57.4
1911....	33.3	35.3	43.9	54.4	74.8	80.5	84.0	79.4	72.0	56.7	41.1	38.0	57.8
1912....	**17.2**	24.5	**33.5**	56.9	68.8	75.8	80.3	75.5	72.7	61.5	46.8	38.8	54.4
1913....	34.8	28.1	41.9	58.5	67.7	81.9	83.4	83.2	73.8	59.4	50.1	40.7	58.6
1914....	35.0	24.0	39.5	55.7	70.3	77.9	83.7	80.9	72.5	64.9	46.5	29.4	56.7
1915....	28.6	37 2	38.9	63.8	62.9	73.8	**78.1**	**74.0**	74.2	61.0	48.6	32.5	56.1
1916....	35.9	27.1	37.2	55.5	67.5	71.7	90.4	83.1	70.4	60.0	46.6	31.3	56.4
1917....	29.4	25.1	42.9	51.6	61.0	72.4	80.6	78.9	70.4	49.1	45.8	26.9	**52.8**
1918....	18.4	30.7	48.0	53.9	72.1	77.1	82.9	85.4	**65.2**	62.8	47.8	39.1	57.0
1919....	35.7	34.2	44.0	54.3	66.6	84.4	87.1	79.5	74.4	63.5	43.2	**26.8**	57.8
1920....	22.4	28.3	45.0	48.9	67.9	80.0	79.9	80.7	76.5	68.2	43.4	36.9	56.5
1921....	36.4	35.6	50.9	61 5	72.7	84.2	**91.0**	79.8	77.1	59.8	41.9	35.5	**60.5**
1922....	30.9	33.9	44.3	57.9	74.6	80.3	80.8	81.8	75.3	61.6	47.7	33.8	58.6
1923....	31.8	26.1	36.9	55.1	69.1	82.8	84.5	78.7	71.8	58.3	47.4	**42.4**	57.1
1924....	27.6	30.3	38.4	54.4	**59.6**	75.0	79.1	78.0	66.9	67.8	47.3	29.1	54.5
1925....	28.9	36.0	45.5	63.0	65.1	80.7	81.1	82.2	74.8	**49.0**	43.0	31.7	56.8
1926....	31.8	32.0	35.1	49.9	70.1	72.4	83.2	80.5	70.0	56.6	43.8	31.4	54.7
1927....	29.1	37.2	47.3	55.4	65.3	74.9	81.6	77.7	76.6	64.5	48.2	33.7	57.6
1928....	31.4	34.0	41.3	51.9	68.4	**70.8**	82.2	81.4	69.1	62.1	46.2	36.6	56.3
1929....	25.1	27.2	47.6	57.5	64.9	74.9	83.5	79.4	73.6	57.9	40.7	31.5	55.3
1930....	27.2	**39.8**	41.7	57.3	69.5	79.6	84.7	84.4	75.7	57.8	49.9	33.8	58.4
Means	30.4	30.4	42.4	56.5	68.5	78.4	83.3	80.6	73.2	60.3	45.7	33.7	57.0

NOTE—Bold-faced figures indicate highest and lowest temperatures.

Extremes of Temperature, 1880—1930

Month	Highest	Year	Day	Lowest	Year	Day
January	64	1906	20	−20	1899	31
February	67	1930	22	−24	1899	13
March	82	1910	29	−10	1890	6
April	90	1899	29	13	1897	20
May	98	1895	30	21	1903	1
June	99	1895	3	35	1889	1
July	103	1916	29	42	1898	12
August	102	1918	6	41	1888	25
September	98	1913	2	30	1887	24
October	89	1897	1	17	1887	26
November	74	1930	19	−9	1880	26
December	61	1913	1	−7	1917	15

Monthly and Annual Precipitation

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1870....	3.36	1.66	2.71	1.88	**0.87**	6.15	5.55	2.04	3.10	4.84	0.80	3.89	36.85
1871....	5.34	1.44	3.51	3.40	1.39	3.77	1.68	2.35	0.76	2.71	2.10	2.50	30.95
1872....	1.10	0.68	2.00	2.23	3.57	3.18	1.93	3.99	**10.03**	0.90	2.03	1.80	33.44
1873....	3.53	1.50	2.94	2.65	4.14	2.02	6.23	1.55	3.44	3.77	1.96	2.08	35.81
1874....	4.78	0.93	3.60	1.18	2.02	6.44	1.74	0.52	2.70	1.92	2.38	1.01	29.22
1875....	1.68	3.66	2.25	1.62	2.91	1.29	2.72	3.74	4.64	5.16	1.28	2.72	33.67
1876....	2.64	1.76	2.64	1.97	4.71	7.82	3.74	0.76	4.39	0.57	2.32	1.92	35.24
1877....	1.37	**0.02**	3.81	3.70	1.31	3.35	3.23	3.81	0 68	4.01	5.59	0.95	31.83
1878....	1.02	1.69	4.05	5.54	3.90	2.32	3.21	2.08	3.25	5.20	0.98	3.41	36.65
1879....	1.25	2.01	0.85	1.27	2.50	1.94	2.40	1.28	4.53	1.93	6.46	3.49	29.91
1880....	3.13	3.72	1.42	6.00	5.11	4.34	3.83	6.75	3.75	3.47	1.84	1.82	45.18
1881....	2.87	**7.87**	2.60	2.44	2.10	3.99	2.02	1.53	2.80	6.45	4.34	4.17	43.18
1882....	2.26	2.50	**6.88**	1.94	2.53	7.53	1.70	**7.44**	0.49	3.65	1.95	2.86	41.73
1883....	3.52	6.00	0.88	1.97	5.47	10.67	**9.35**	**0.11**	2.10	4.41	**6.82**	0.84	**52.14**
1884....	2.51	4.95	2.96	1.22	3.28	5.28	4.18	1.62	3.18	**6.81**	2.20	5.25	44.07
1885....	3.72	2.35	1.83	2.57	1.54	4.37	2.78	5.85	4.55	3.03	2.05	3.40	38.04
1886....	2.94	2.51	3.20	1.54	3.21	2.47	1.37	4.31	6.08	1.93	3.57	1.90	35.03
1887....	5.44	3.28	1.25	**0.60**	1.69	1.14	3.05	1.49	4.79	2.59	2.19	3.47	30.98
1888....	3.57	2.18	3.40	1.54	5.55	2.36	2.18	1.43	2.07	0.73	2.89	2.48	30.40
1889....	3.46	1.68	0.45	1.90	3.43	5.78	2.38	0.83	2.34	0.48	1.41	3.49	27.63
1890....	2.03	1.05	1.21	3.41	5.33	3.42	1.31	2.89	**0.27**	3.23	1.46	0.99	26.60
1891....	2.15	1.49	2.50	2.00	1.60	3.30	2.00	2.00	1.00	1.25	6.33	3.27	28.89
1892....	2.77	1.47	1.21	3.60	4.15	**13.22**	2.89	2.28	1.78	1.26	3.20	3.00	40.83
1893....	4.25	2.25	2.50	5.34	4.15	3.50	3.00	0.60	3.27	3.26	3.50	**6.95**	42.57
1894....	3.08	1.65	2.60	2.16	5.58	2.45	**0.25**	0.38	3.45	2.38	1.53	0.67	26.18
1895....	4.42	2.03	1.34	1.27	2.57	1.12	1.01	3.24	2.07	0.39	5.40	6.25	31.11
1896....	0.80	1.11	1.45	2.67	1.90	1.85	3.66	2.53	6.97	1.26	3.96	1.34	29.50
1897....	**6.00**	1.17	4.69	3.07	1.66	1.91	1.72	1.06	1.11	0.97	2 56	3.77	30.69
1898....	4.04	5.77	2.91	1.33	1.37	2.04	0.54	1.87	4.13	3.84	3.26	3.51	34.61
1899....	2.56	1.76	3.60	0.77	3.83	1.27	3.96	0.13	3.90	2.92	1.81	3.04	29.55
1900....	2.42	4.60	2.02	1.81	2.59	2.38	3.63	5.92	1.87	2.27	4.91	0.88	35.30
1901....	2.41	2.30	3.64	1.45	3.47	4.94	5.12	2.08	3.40	3.24	1.64	2.38	36.07
1902....	0.40	2.40	4.48	1.46	5.61	6.30	5.91	0.40	4.09	1.50	4.62	2.69	39.86
1903...	1.11	1.08	2.48	4.80	2.28	4.21	4.14	4.83	5.22	2.31	0.85	2.29	35.60
1904....	1.47	1.78	4.39	2.37	4.14	1.00	2.24	2.26	4.18	2.32	**0.06**	1.72	27.93
1905....	1.64	1.89	2.81	2.23	5.97	7.10	5.33	5.48	4.07	4.41	2 30	1.13	44.36
1906....	2.93	2.04	1.67	1.94	2.99	1.58	2.52	1.83	3.19	2.94	3.21	2.05	28.89
1907....	3.74	0.21	2.74	2.94	2.49	1.82	5.34	2.40	5.49	1.44	2.18	2.60	33.39
1908....	1.49	2.69	2.44	4.87	5.34	**0.83**	1.46	5.55	1.09	0.39	3.14	1.88	31.17
1909....	2.20	3.06	1.37	**8.29**	2.36	7.50	0.96	4.39	2.11	1.14	3.23	3.10	39.71
1910....	2.04	1.15	**0.08**	3.16	3.88	1.04	1.41	3.28	1.58	3.17	1.37	1.37	23.53
1911....	1.57	2.38	0.73	4.20	**7.18**	4.76	1.27	2.29	7.58	6.71	3.88	2.56	45.11
1912...	1.49	1.77	1.52	2.46	4.91	1.02	7.47	3.16	3.42	3.97	2.69	1.32	35.20
1913....	1.86	1.27	3.57	2.45	1.76	1.50	1.96	0.97	2.25	2.92	2.86	**0.31**	23.68
1914....	3.24	0.75	1.59	1.97	3.06	6.13	1.18	3.49	2.34	2.72	1.47	1.89	29.83
1915....	1.57	2.59	1.13	0.85	2.61	1.86	4.00	2.87	8.11	0.60	1.52	1.22	28.93
1916....	3.90	0.74	3.16	2.52	4.13	6.56	1.07	4.41	2.43	3.73	2.12	3.81	38.58
1917....	1.40	0.67	1.87	4.03	4.48	3.44	6.91	0.46	3.59	4.57	1.21	0.82	33.45
1918....	3.24	3.81	2.37	2.22	4.03	1.17	1.17	0.84	2.01	3.59	2.63	4.02	31.10
1919....	**0.30**	2.16	4.93	2.60	4.78	1.84	0.66	1.67	3.86	3.91	2.30	1.19	30.20
1920....	1.19	0.85	3.42	2.95	1.92	4.09	3.60	0.76	3.68	1.82	1.54	4.19	30.01
1921....	0.59	1.13	4.77	4.39	1.23	3.62	2.38	6.15	4.33	3.61	3.64	4.14	39.98
1922....	0.71	2.25	3.18	4.50	2.64	3.16	4.05	2.96	5.04	2.87	2.39	1.40	35.15
1923....	1.25	0.99	2.36	2.19	3.70	1.67	0.95	2.07	5.77	3.30	1.09	2.18	27.52
1924....	2.00	1.41	2.08	3.29	3.72	3.18	3.37	2.51	3.48	**0.23**	1.60	1.66	28.53
1925....	0.59	1.31	1.39	3.17	0.98	1.13	4.58	2.56	4.35	3.52	2.08	1.52	27.18
1926....	1.77	2.93	1.99	1.99	3.44	2.66	2.93	2.64	4.80	3.04	3.55	1.86	33.60
1927....	1.05	1.34	2.20	3.05	3.81	1.45	1.43	0.66	4.55	3.03	4.55	3.16	30.28
1928....	1.32	1.54	2.04	2.66	3.09	8.03	0.81	4.46	3.14	3 27	4.47	2.79	37.62
1929....	4.00	0.66	2.06	5.61	6.31	2.18	2.30	0.70	0.99	3.40	1.29	2.71	32.21
1930....	3.21	1.83	1.20	2.07	2.39	2.66	0.56	0.40	1.48	2.27	1.51	1.34	**20.92**
Means	2.45	2.09	2.51	2.74	3.36	3.62	2.89	2.54	3.46	2.84	2.69	2.50	33.73

NOTE.—Bold-faced figures indicate greatest and least monthly amounts.

Seasonal Snowfall

Season.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Season
1893-94.....	0	0	10.0	**31.9**	12.2	6.8	4.8	2.0	0	67.7
1894-95.....	0	0	7.2	0.6	41.0	12.5	7 8	0	0	69.1
1895-96.....	0	0.4	**28.2**	**T**	.....	8.5	2.0	0	0	.....
1896-97.....	0	0.2	8.0	8.0	.....	10.6	12.0	T	0	.....
1897-98.....	0	0	1.4	7.5	15.5	29.5	**0**	T	0	53.9
1898-99.....	0	T	18.5	18.0	20.0	3.4	16.0	0	0	75.9
1899-1900...	0	0	1.5	7.2	12.0	**35.5**	19.0	3.5	0	78.7
1900-01.....	0	0	8.0	5.5	23.0	23.0	5.5	T	0	65.0
1901-02.....	0	T	0.5	9.0	4.0	11.0	3.0	0.2	**5.5**	33.2
1902-03.....	0	0	2.5	5.1	7.0	5.3	**0**	2.5	0	22.4
1903-04.....	0	T	5.0	22.1	15.6	11.9	**20.0**	3.2	0	77.8
1904-05.....	0	T	0.6	15.7	14.5	18.8	2.4	1.7	0	53.7
1905-06.....	0	T	0.1	5.3	5.6	2.7	6.3	T	T	**20.0**
1906-07.....	0	2.6	**T**	3.8	13.1	**2.4**	5.1	3.1	T	30.1
1907-08.....	0	0	**T**	13.8	11.7	17.6	0.2	0.1	T	43.4
1908-09.....	0	0	4.8	7.4	9.0	8.4	2.8	2.9	0.3	35.6
1909-10.....	0	0.2	1.8	24.2	10.3	4.9	T	T	0	41.4
1910-11.....	0	0.1	4.0	18.4	7.8	7.0	3.0	0.6	T	40.9
1911-12.....	0	T	6.2	15.9	14.7	17.0	13.7	3.0	0	70.5
1912-13.....	0	T	7.1	2.3	13.1	9.9	9.6	T	0	42.0
1913-14.....	0	0.3	1.0	2.3	27.0	14.6	7.5	4.5	0	57.2
1914-15.....	0	T	9.2	17.6	6.0	5.1	9.8	0.4	0.2	48.3
1915-16.....	0	0	3.6	12.6	10.4	13.3	15.9	T	T	55.8
1916-17.....	0	T	1.0	23.1	16.1	8.4	3.2	0.1	T	51.9
1917-18.....	0	3.0	3.6	9.7	**45.0**	5.6	5.0	T	0	71.9
1918-19.....	0	0	0.3	7.6	4.6	6.2	18.2	5.0	0	41.9
1919-20.....	0	0	3.5	15.0	15.8	12.2	3.4	6.5	0	56.4
1920-21.....	0	T	6.5	13.6	**1.1**	8.5	1.8	0	0	31.5
1921-22.....	0	T	9.7	10.7	5.4	9.1	8.8	T	0	43.7
1922-23.....	0	T	2.0	7.4	13.1	13.2	9.6	3.7	**5.5**	54.5
1923-24.....	0	1.5	0.8	9.0	18.5	9.0	8.7	4.0	T	51.5
1924-25.....	0	0	7.1	12.5	7.7	6.1	7.0	0	T	40.4
1925-26.....	0	**7.5**	8.4	17.1	15.5	16.9	12.9	**11.2**	T	89.5
1926-27.....	0	T	6.6	13.3	12.0	3.0	1.0	1.5	0	37.4
1927-28.....	0	0	0.1	17.0	10.4	9.6	11.2	0.8	0	49.1
1928-29.....	T	T	3.5	8.0	30.8	8.2	1.8	T	3.0	55.3
1929-30.....	0	0	9.1	28.9	37.3	5.9	14.3	T	T	**95.5**
1930-31.....	0	0.4	3.7	18.0	.....	.....	.....	.....	.....	.....
Means	0	0.4	5.1	12.2	15.1	10.9	7.4	1.6	0.4	52.9

NOTE—Bold-faced figures indicate greatest and least monthly amou nts

Annual Frost Data

Year.	Date of last killing frost in spring.	Date of first killing frost in autumn	Length of growing season—last killing frost to first killing frost (days).	Latest date with temperature 32° or lower in spring.	Earliest date with temperature 32° or lower in autumn.
1903	.....	Oct. 24	.....	May 8	Oct. 24
1904	Apr. 17	Oct. 6	172	Apr. 21	Oct. 30
1905	May 1	Oct. 25	177	May 1	Oct. 24
1906	Apr. 16	Oct. 10	176	Apr. 23	Oct. 10
1907	May 11	Oct. 14	156	May 10	Oct. 14
1908	Apr. 30	Oct. 12	165	May 2	Oct. 12
1909	May 4	Oct. 19	168	May 4	Oct. 12
1910	Apr. 12	Oct. 29	200	Apr. 24	Oct. 28
1911	Apr. 23	Nov. 3	194	May 3	Oct. 26
1912	Apr. 23	Oct. 24	184	Apr. 23	Oct. 24
1913	May 10	Oct. 19	162	May 10	Oct. 31
1914	Apr. 21	Oct. 27	189	Apr. 21	Oct. 26
1915	Apr. 13	Oct. 10	180	Apr. 13	Oct. 10
1916	Apr. 10	Sept. 30	173	Apr. 10	Nov. 5
1917	May 3	Oct. 24	174	Apr. 16	Oct. 23
1918	May 1	Oct. 1	152	May 1	Nov. 15
1919	Apr. 26	Nov. 2	190	Apr. 29	Nov. 2
1920	May 14	Oct. 30	169	May 14	Oct. 29
1921	May 16	Oct. 13	150	Apr. 18	Nov. 2
1922	Apr. 28	Oct. 20	175	Apr. 27	Oct. 20
1923	May 9	Oct. 22	166	May 9	Oct. 22
1924	May 20	Oct. 21	153	May 1	Oct. 22
1925	May 25	Oct. 10	138	Apr. 6	Oct. 9
1926	May 4	Oct. 8	156	May 4	Oct. 31
1927	Apr. 25	Oct. 18	170	Apr. 25	Nov. 5
1928	Apr. 28	Oct. 26	181	Apr. 28	Oct. 29
1929	Apr. 18	Oct. 5	170	May 2	Oct. 9
1930	May 30	Oct. 18	141	Apr. 26	Oct. 17
Averages	May 1	Oct. 18	170	Apr. 28	Oct. 24

Flood Crests

March 27, 1904	20.4	March 18, 1918	16.4
June 9, 1905	18.1	March 20, 1919	16.4
January 26, 1906	11.5	March 17, 1920	14.9
January 24, 1907	18.5	December 21, 1921	11.2
March 15, 16, 1908	15.2	*April 17, 1922	10.2
May 19, 1908	10.3	May 20, 1923	7.2
May 4, 1909	14.8	April 2, 1924	7.5
March 8, 1910	12.4	March 23, 1925	5.7
February 18, 1911	8.0	March 25, 1926	13.3
April 7, 8, 1912	15.8	December 19, 1927	11.7
March 13, 1913	14.0	April 8, 1928	11.4
May 17, 1914	6.6	March 7, 1929	13.9
February 17, 1915	9.7	February 28, 1930	13.3
March 30, 1916	15.8	.....	.....
April 10, 1917	8.7	.....	.....

*U. S. Enginer's gage; Weather Bureau gage not in commission

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