地下排水에 있어서 地下水位의 變化와 排水深과 排水間隔間의 相關關係에 關한 硏究

A Study on the Correlation Between Depth and Spacing with Observation of Water Table in Subsurface Drains

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摘 要

試驗은 카나다 퀴벡(Quebec)地方에서 低濕地改爲해 施行한 排水試驗으로 地下水位의 變化에 觀察과 地下排水深, 間隔간의 相關關係를 究明저 試圖한 것으로,

1. 퀴벡地方의 대표적인 土壤인 粘土質의 Martineau 농장과 砂質로움 土壤의 Vincent 농장을 시험포장으로 선택하였다.
2. 土管排水組織은 對角線型으로 1個의 排水深에 對해 2反覆으로 하고 粘土 試驗圃에서는 排水深 2.5ft. 3.5ft. 4.5ft.에 各各 20ft, 60ft, 120ft의 排水間隔과 砂質로움 試驗圃에서는 排水深 2ft. 3ft. 4ft.에 各各 20ft. 100ft. 200ft.의 間隔으로 施設되였다.
3. 地下水位는 배수간격이 좁고 배수심이 깊은 구即 粘質土壤에서는 4.5ft의 깊이와 20ft의간격에서 砂質로움 土壤에서는 4ft의 깊이와 20ft의 간격에서 各各 보다 빠른 水位降下를 가져왔다
4. 全 試驗區에 걸처 스프링클라灌漑에 依한 完全포화후 150시간에서 300시간이 經過되면 水位는 土管深下로 떨어지는 期待以上의 降下速度를 나타내었다.
5. 粘土質 土壤에서는 排水深 3.5ft에서 30~60ft의 排水間隔이 권장되여 왔으나 120ft의간격이 적당하다는 것이 本試驗에서 나타냈다.
6. 砂質로움 土壤에서는 排水深을 3ft로부터 4ft까지로 하고 排水間隔은 100ft에서 150ft 內外로 施設함이 좋다고 思料된다.

I. Introduction

Water table fluctuations depends on many factors such as characteristics of the water bearing stratum and of the materials under and overlying it: amount and distribution of the recharge: extent to which the river or drain penetrates into the water transmitting porous medium and the depth and spacing of subsurface drains.Many investigators have attempted to solve the problem of the design of tile drainage by means of simplified rational analysis.

Also, much theory has been published in journals and textbooks for determining the depth and spacing of subsurface drains, but as recently as Dec. 1965 it has been shown by several competent scientists and engineers that more field research information on the performance of subsur face drains is needed to permit adequate but not overly conservative drainage system designs.

We choosed soil characteristics as clay and fine sandy loam soils to help provide answers to some of the subsurface drainage questions.

Ⅱ. Review of literature

There are a great varity of drainage situations that occur in the field. It is necessary to select the conditions that seem to be prevalent in each area and apply the appropriate theory. The goal of the drainage system is to provide drainage

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for the individual farm, but in doing so it is necessary to consider the need for plant growth during the summer months of low rainfall. In the analysis of problems in humid area the Dutch have been leaders in developing techniques and methods that can be used in this analysis.

One important solution of the drainage problems is a result of the work of Hooghoudt(9), S.B. of the Netherlands. He considered the water table in equilium with the rainfall.

The problem solved by Hooghoudt is essentially this: how high will the water table rise for a given rainfall, soil permeability, depth of drain, and spacing of drain? It is also necessary to know the depth to the barrier layer which restricts the downward flow. He emphasized the following factors to know the position of the position of the water table.

1. The rainfall rate or the rate at which the irrigation water is applied.
2. The soil hydraulic conductivity.
3. The depth and spacing of the drains.
4. The depth to an impermeable layer.

For approximately a century (1862~1962) the problem of the design of tile drainage has been investigated by researchers from different lines of approach.

Etchevery,(7) B.A., Kopecky,(13) Gerhardt,(13) Neal,(14) J.H., and others have approached the problem on experimental lines and have provided design tables and graphs that are based on a limited number of experiments.

Rational formulars were derived on the basis of radial flow lines by Israelsen,(10) O.W. Assuming flow lines to be horizontal, Glover and Dumm(8) approached the problem of unsteady seepage flow towards tile drains. The velocity at any point of a vertical section was assumed to be horizontal and constant down to the impermeable stratum. If the impermeable stratum is deep, this assumption will not be applicable.

The method of Glover and Dumm has been further developed by Brook(2) S, R. H.

Donnan(6) and his collagues, as a result of extensive experimentation in the Imperial Valley of California, list the following factors as having an influence on depth of drainage water.

1. Irrigation head
2. Slope
3. Soil type
4. Infiltration rate
5. Evapotranspiration
6. Seepage into or out of the area
7. Artesian pressure
8. Frequency of irrigation
9. Soil moisture control at the time of irrigation.

In 1967, Jutras(11) showed that about 60% of the 5,213,302 acres suffici sufficiently improved for cultivation in Quebec needs subsurface drainage installation if its potential for food production is to be realized. Until 1965 only 42,000 acres had been subsurface drained in Quebec. Similar data might be presented for other regions in the Northeastern United States and Canada. Thus there is a tremendous area remaining for which subsurface drainage would be beneficial.

Ⅱ. Materials and Methods

1. The experiment sites

The expreiment sites were located near St.clet in Soulanges county, Quebec, Canada, about twenty miles southwest of McGill university. A map of the regions is shown in Figure 1.

2. The experimental field layout

A diagonal drain layout was installed on Ste. Rosali clay and Soulanges fine sandy loam soils on the Martineau and Vincent farms respectively To minimize the field area needed, spacing between subsurface drains was varied linearly over a wide range. Three different depths of drains were used on each of the two soils, as shown in Figures 2 and 3. Each diagonal tile line between two parallel lines provided two replicates at one depth. The depths investigated were 2.5ft., 3.5ft. and 4.5ft. on clay and 2ft., 3ft., and 4ft. on fine sandy loam soil. Spacings increase from 20ft. to 120ft. on the clay soil and from 20ft. to 200ft. on the fine sandy loam soil. The range of spacings was selected for the following reasons:

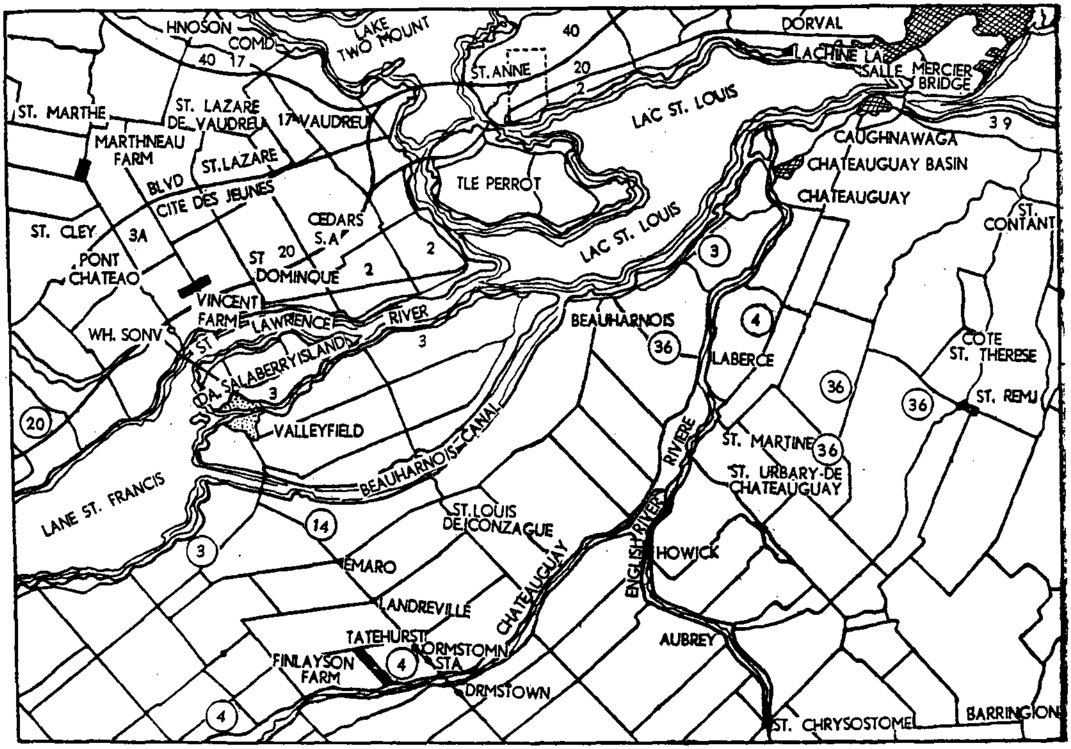


Fig. 1. Map Showing the Location of the Vincent farm and the Martineau farm.

1. Some text books and technical bulletins recommend spacings of 30 to 60ft. for clay soils.
2. Much of the subsurface drainage tile is installed in Canada as shallow as 2.5ft., or less,due to tradition carried over from time when tile trenches were dug by hand. But now trenching machines are now avaiable which can easily dig to 5.5ft. in stoneface soils.
3. On the clay soil 20 ft. spacings could be considered a practical minimum for almost any soil and cropping situation, even though calculations using hydraulic conductivity values obtained by Warkentin and the spacing formular given by Glover and reported by Dumm indicates that spacings even less than 20ft. might be needed.

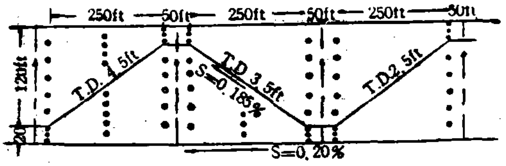
3. water table

Water table pipes were installed in fields as shown in Figure 2 and 3. In each replicates three spacings were chosen for the water table measurements. For each spacing, three and five water table pipes were in stalled, one at the midplane and the other same spacing from each tile line. All water table pipes were made of 1/2 inch standard steel pipe. The bottom of the pipes were sealed with corks. The pipe were perforated with four rows of 3/16 inch holes at 6 inch intervals along their length, alternate rows being displaced by 3 inches.

To avoid sealing of holes with, the tubes were covered with muslin cloth. 6ft. long water table pipes were used in order to trace the water table below the tile depth at most pipe locations.

4. The measurements of water table

The measurements were made by a blow tube cm. and inch scale were mounted on a 1/4 inch O.D. copper tube, this assembly was then inserted in a 1/4 inch I.D. tygon clear plastic tube which covered the whole copper tube and extended a few feet to a mouthpiece. In measuring the water table, the copper tube was inserted in the water table pipe and lowered slowly while blowing thr-



Legend
—— : Subsurface tile line
——→ : Cross Furrow
◉ : Water table pipe
T.D. : Tile depth
S : Slope of tile line

Fig. 2. Subsurface drain experiment laylout, Martineau field(clay soil)

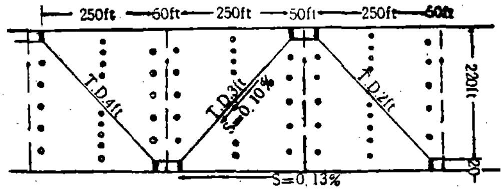


Fig. 3. Subsurface drain experiment layout, Vincent field (fine sandy loam)

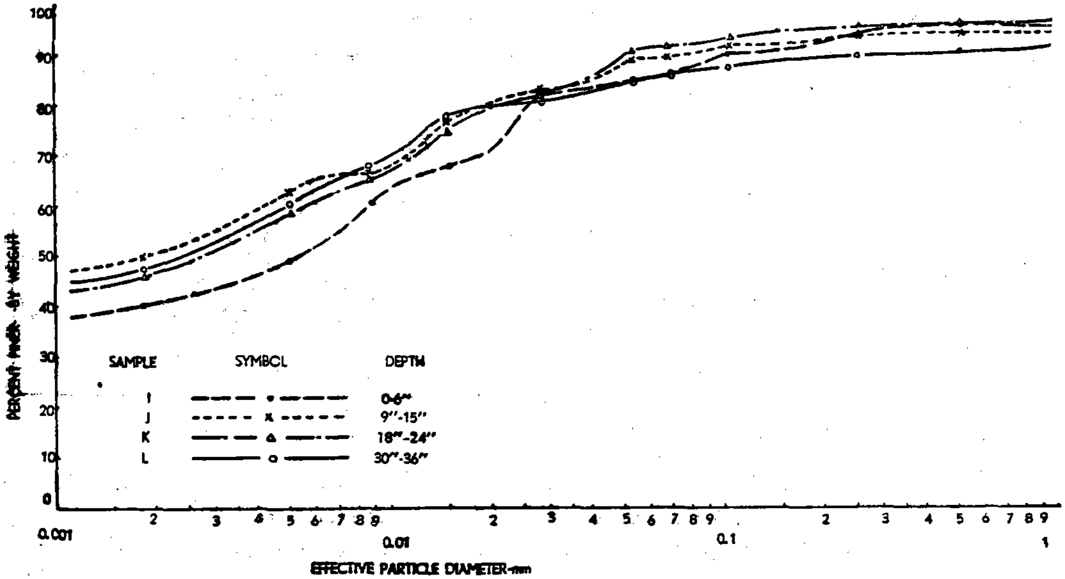


Fig. 4. Particle size analysis, Clay soil, Martineau farm. P.Q.

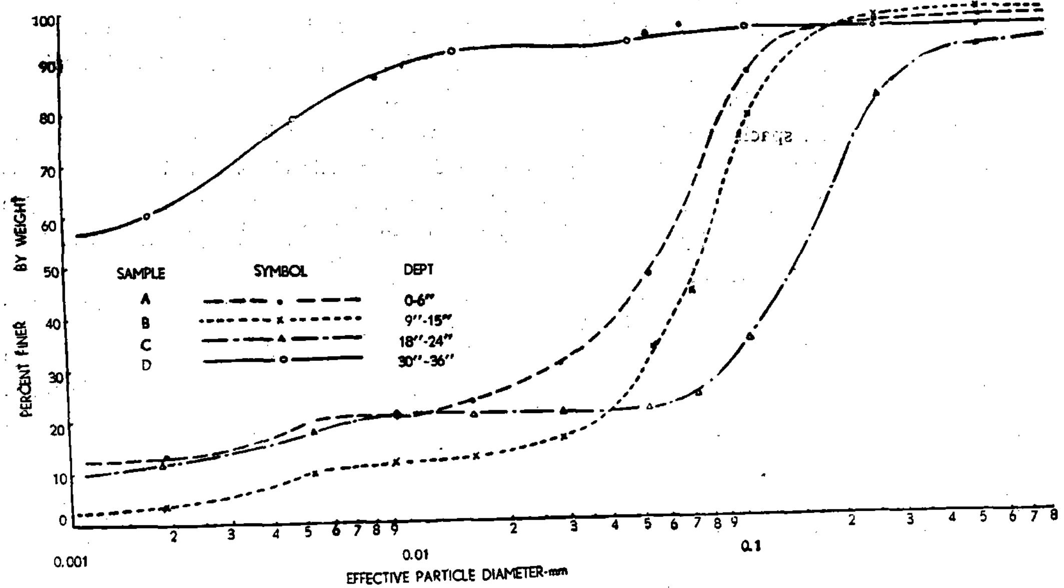


Fig. 5. Partical size analysis, fine sandy loam, Vincent farm. P.Q.

ough the tygon tube. The location of the water table was sensed by the sound of air bubbling through the water and the change in pressure upon entering the water. The depth through soil to the water able was measured by reading the scale on the copper tube. This techniques of measuring of the water table can obtain a repeatability of 0.5 cm. or 0.2 inch.

Photo. 1. Measuring scene of water table with blow tube by writer in the experiment site.

5. Bulk densites and particle size distribuion

Bulk densities were measured in the fields by taking three samples at each depth, as shown in Table 1.

Table 1. Bulk density

Depths (inches)	Fine sandy loam	Clay
0—4	1.30	1.18
4.5—7.5	1.33	1.29
7.5—10.5	1.50	1.51

Particle size distribution were determined using the hydro meter method. The results are shown in Table 2. The data is also presented graphically in Fig. 4 and 5.

Table 2. Particle size distribution

Depth	Vincent field			Martineau Field		
(inch)	clay (%)	silt (%)	sand (%)	clay (%)	silt (%)	sand (%)
0—6	13.0	12.0	75.0	40.5	30.5	29.0
9—15	3.5	9.5	87.0	50.5	29.5	20.0
18—24	11.5	9.0	79.5	46.0	33.0	21.0
30—36	62.0	30.0	8.0	48.0	31.5	20.5

6. Weather summary

Weather stations were installed on both farms and provided climatic data for use in this project and other research work in the area.

Table 3 and 4 show the weather summary of the Martineau field and the Vincent field in1970

Table 3. Weather summary of the Martineau field (1970)

Month	Precipitation (in.)	Mean. temp. (°F)	Max. temp. (°F)	Min. temp. (°F)
May	2.64	52.4	64.5	64.2
June	2.05	69.2	85.0	38.0
July	2.54	68.4	79.3	57.6
August	1.41	66.6	78.9	54.3

Table 4. Weather summary of the Vincent field (1970)

Month	Precipitation	Mean Temp. (°F)	Max. Temp. (°F)	Min. Temp. (°F)
May	2.54	51.2	67.4	43.6
June	1.72	56.3	73.7	51.9
July	1.73	66.8	78.7	62.7
August	1.85	68.4	78.7	57.3

Precipitation of 1970 was less than that of previous year.

7. Splinkler Irrigations

In order to trace the water table drawdown starting from the soil surface, sprinkler irrigation was applied on both fields to saturate the soil and bring the water table up to the surface.The rate of drawdown of the water table was measured at four hour intervals for the first two days, then at twelve hour intervals for the next few days until the water table fell below the subsurface drains.

Photo 2. Splinkler irrigationto the Martineau field

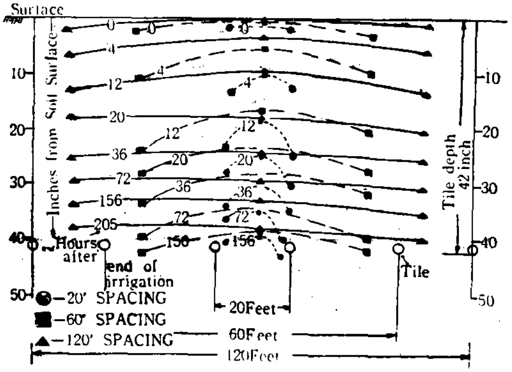


Fig. 6. Water table positions at successive times after stopping irrigation. Clay soil. Data are the average of two replication.

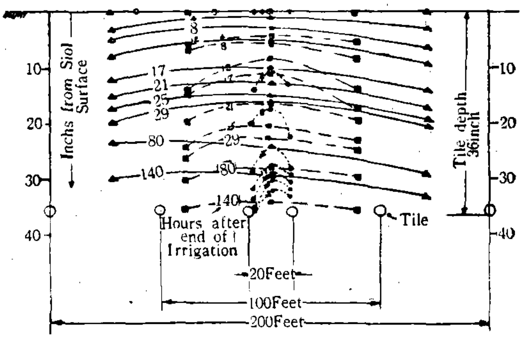


Fig. 7. Water table Position at sucessive times after stopping irrigation. Fine sandy loam soil. Data are the averae of two replication.

Ⅳ. Results and Discussions

1. Field measurements following irrigation.

In August 1970, water was applied in Martineaus field (clay) by sprinkler irrigation. Water table were brought up to the ground surface. The water table draw down was measured and the average of two replication were calculated.

The water table drawdown after irrigation in three spacing for the 3.5ft. depth is shown in Figure 6. Similar data are available but not reproduced graphically for the 2.5 ft. and 4.5 ft. depths.

In August 1970, irrigation were applied to the Vincent field(fine sandy loam)to bring the water table up to the ground surface. The results of water table observations are shown in Figure 7 for the 3 ft. depth. Similar results were obtained for the 2 ft. and 4 ft. depths.

2. Water table drawdown at midplane

The rate of water table drawdown at midplane is faster in the sandy loam soil than in the clay soil.

In the sandy loam soil, considering the 2 ft. tile depth at 20 ft. spacing recession of water table is more rapid than 100ft. and 200ft. spacing. with spacing of 100ft. and 200ft., the water table was still above the tile level more than two days after irrigation. Even at the wider spacings, the water table receded very rapidly. The maxmum time to recede 1 ft. is 15.5 hours on the clay and 36 hours on the sandy loam.

The slow rates were for the very wide spacings and shallow depth. On the contrary, the drawdown was most rapid in the sections with the deepest drains. We can see the time of water table drawdown at midplane between drains after the finish of soil saturating irrigation in the clay and the sandy loam soils at Table 5. Water table positions at midplane at various times with three spacings of drains in the clay soil at 4.5 ft. depth and the sandy loam soil at 4 ft. depth are shown in Figure 8 and 9.

Table 5. Time of drawdown of water table at midplane between drains after the finish of soil saturating irrigation

Drawdown (ft.)	clay			Sandy loam		
	Drain depth (ft.)	Drain spacing (ft.)	Time (hrs)	Drain depth (ft.)	Drain spacing (ft.)	Time (hrs)
	2.5	20	7.5	2	20	5.5
	2.5	60	8.5	2	100	31.5
	2.5	120	15.5	2	200	36.0
	3.5	20	4.0	3	20	6.0
	3.5	60	11.0	3	100	16.0
	3.5	120	12.5	3	200	21.0
	4.5	20	3.0	4	20	5.0
	4.5	60	8.0	4	100	24.0
	4.5	120	12.0	4	200	29.0
	2.5	20	32.0	2	20	12.0
	2.5	60	49.0	2	100	95.0
	2.5	120	96.5	2	200	97.5
	3.5	20	19.5	3	20	13.0
	3.5	60	21.0	3	100	69.0
	3.5	120	47.5	3	200	82.0
	4.5	20	9.0	4	20	40.0
	4.5	60	16.0	4	100	52.5
	4.5	120	20.0	4	200	70.0
	2.5	20	—	2	20	—
	2.5	60	—	2	100	—
	2.5	120	—	2	200	158
	3.5	20	162	3	20	101
	3.5	60	155	3	100	—
	3.5	120	—	3	200	—
	4.5	20	19	4	20	84
	4.5	60	26	4	100	115
	4.5	120	70	4	200	116

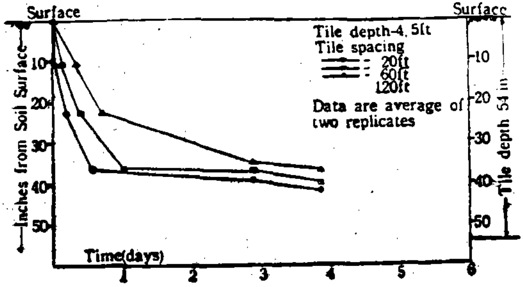


Fig. 8. water table changes ai midplane after stopping irrigation. Martineau field (clay soil).

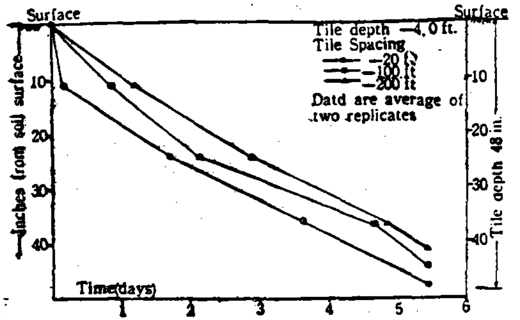


Fig. 9. water table changes at midplane after stopping irrigation. vincent field (fine sandy loam).

Ⅴ. Summary and Conclusions

In order to solve some problems of low lands by subsurface drainage, We mainly observed fluctuations of ground water level and correlation between depth and spacing of tile drains in Quebec, Canada.

We installed tile drains on clay and fine sandy loam soils on the Martineau and Vincent farms respectively, because of these two soils represent in physical characteristics large acres of important soils in the flat lands of Quebec province. Obtained results of this experiment are as follows,

1. Following a period of irrigation, the water table at the midplane receded more slowly on wide spacings and shallow depths than on narrower spacings and greater depths respectively.
2. It appears that drain spacings as wide as 120 ft. may provide adequate drainage if depths of 3.5 feet or more are used for clay soils.
3. The following water tables were found flatter between drains in wide spacing than in narrow spacing.
4. It is recommended that on some farms with sandy loam soils of subsurface drainage systems be installed with spacings of 100 ft.and 150 ft. and depths from 3 to 4 ft.
5. The depth and spacing of subsurface drains had a significant effect on the rate of water table drawdown at midplane. However, for all spacings and depths used. the rate of drop of the water table was faster than expected.

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