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SOME CONSTRAINTS ON THE APPLICATION OF METHODS FOR DRAIN SPACING DETERMINATION IN UNSTEADY-STATE OF FLOW IN EUGLEY SOIL

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Abstract: The aim of this research was to figure out certain limitations of methods for drain spacing determination application in unsteady-state of flow rate to the drains in the eugley soil. The well-known Glover-Dumm method was taken in this analysis. The analysis was based on the results of drain discharge and water table depth measurements. Measurements were carried out on the experimental field. Three different drainage treatments were set up with three different drainage spacings such as 10 m, 20 m and 30 m. The results of analysis showed significant constraints of the method due to non-modeling dynamic of water flow to the drains. These effects are marked on the plot with the least drain spacing (10 m).

Key words: drainage, pipe drainage system, drain spacing, unsteady-state flow, discharge.

Introduction

Methods for drain spacing determination can be divided into two groups: methods applicable in steady state of water to the drains and methods applicable in unsteady-state. Methods from the latter group assume that inflow of water to the drains is changeable in time as well as water head by which drain discharge occurs. This is more complex and thorough assumption as compared with the assumption of the first group methods valid for any drainage of the soils as well as eugley one. Water table level oscillates in time due to unsteady flow to the

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drains mainly caused by precipitation. Different flow rates at any observed point of cross section directly influence variation of drains discharge. Depletion of water table from maximal to desirable depth can be achieved differently, according to agronomic criteria such as crop resistance to sufficient amount of water. Drainage intensity is determined by depletion of water table from maximal to desirable depth to be done in desirable number of days. (depletion from h_o (max) to h_t (min) in the period of time *(t)*. However, application of the methods from the second group for drain spacing determination in eugley soil is peculiar, so it can be considered as a constraint in use.

The aim of this work was to figure out certain constraints of Glover-Dumm method for the application in practice, being considered the most suitable for drain spacing determination in unsteady inflow of water to dhe drains.

Material and Methods

Experimental field was situated at Radmilovac, near Belgrade. The field was divided into three plots. Each plot covered the area of 0.5 ha representing one drainage treatment. Drainage was carried out by subsurface drainage treatment. Drainage was carried out by subsurface horizontal drainpipes. Drain spacings of 10 m, 20 m, and 30 m were set up on I, II and III drainage plots, respectively. Average drain depth was 0.9 m. Average value of hydraulic conductivity of soil was 0.6 m-day^{-1}, and equivalent drain depths *(d)* for drainage treatments I, II and III were $d_1 = 0.45$ m $d_2 = 1.06$ m $d_3 = 1.51$ m, respectively. The results of drain discharge and water table depth measurement were used in the analysis of Glover-Dumm method. The best representative method among methods using the concept of unsteady inflow to the drains is Glover-Dumm method. Dumm (1954), (cit Wesseling, 1977; ILRI I-IV, 1979-1980) used the solution of equation given by Glover. He assumed the actual horizontal water table level at a certain distance above drains in the period of time t = 0. The solution showed that the depletion of ground water table was a function of time. For the analysis of the results in this work, modified Glover-Dumm equation was used as follows:

$$L = \pi\left(\frac{Kdt}{\mu}\right)^{\frac{1}{2}}\left(\ln 1{,}16\frac{h_o}{h_t}\right)^{-\frac{1}{2}} \qquad (1)$$

where: K - hydraulic conductivity (m/day); d - equivalent drain depth); t - assumed time for soil drainage (days); μ, - drainage porosity (.); h_o - maximal level of ground water table (m); h_t desirable ground water depth at the end of drainage period (m).

Under the assumption that groundwater table before drainage (h_o) has the shape of a fourdegree parabola, equation is:

$$h_t = 1{,}16 h_o e^{-\alpha t} \qquad (2)$$

where: $$\alpha = \frac{\pi^2 KD}{\mu L^2} \qquad (3)$$

α is factor of reaction. The higher value of α, the quicker soil drainage. Quick drainage very often occurs when distance between drains is short, drains depth deep in the presence of high hydraulic conductivity.

Results and Discussion

Sequences of measurements whose results were used in the analysis of Glover-Dumm method are shown in the Table 1. To obtain the shown data, measurements were carried out to suit well the mentioned analysis. In fact, measurements were carried out in the period of expected unsteady drain discharge and water table depth variation with absence of precipitation.

Tab. 1.- Data of groundwater table depth and drain discharge measurements in the chosen period

Number	Date	h_1 (m)	q_1 (m/day)	h_2 (m)	q_2 (m/day)	h_3 (m)	q_3 (m/day)
	Jan. 13, 1995	0.66	0.02461	0.76	0.2231	0.83	0.02142
1	Jan. 17, 1995	0.47	0.01721	0.64	0.01636	0.60	0.01403
2	Jan. 21, 1995	0.32	0.00801	0.41	0.00641	0.50	0.00643
3	Jan. 24, 1995	0.27	0.00681	0.32	0.00422	0.39	0.00396
	Nov. 22, 1995	0.47	0.01749	0.64	0.01602	0.69	0.01164
4	Nov. 26,1995	0.42	0.01146	0.5	0.00983	0.53	0.00844
	Jan. 8, 1996	0.56	0.02047	0.71	0.02086	0.79	0.01871
5	Jan. 11,1996	0.51	0.02006	0.66	0.01815	0.76	0.01525
6	Jan. 15, 1996	0.43	0.01279	0.51	0.01144	0.62	0.01003
7	Jan. 18, 1996	0.15	0.01001	0.25	0.0317	0.36	0.00811
	March 5, 1996	0.43	0.01515	0.54	0.01079	0.56	0.01166
8	March 8, 1996	0.30	0.01397	0.49	0.00822	0.48	0.00764
9	March 12, 1996	0.11	0.01144	0.38	0.00401	0.40	0.00535
	March 21, 1996	0.15	0.00612	0.19	0.00235	0.25	0.00209
10	March 25, 1996	0.11	0.00343	0.11	0.0004	0.15	0.00218
	Nov. 2, 1996	0.11	0.0031	0.09	0.00052	0.07	0.00091
11	Nov. 5, 1996	0.09	0.0019	0.02	0.00011	0.03	0.00042
12	Nov. 9, 1996	0.09	0.00098	0.02	0.00009	0	0.00009
13	Nov. 16, 1996	0.02	0.00081	0	0.00003	0	0.00001
	Feb. 22, 1997	0.52	0.00699			0.44	0.00631
14	Feb. 26, 1997	0.41	0.00844	0.50	0.00906	0.41	0.00398
15	March 2, 1997	0.15	0.00413	0.46	0.00712	0.33	0.00419
16	March 8, 1997	0.14	0.00407	0.23	0.00261	0.15	0
17	March 11, 1997	0.10	0.00161	0.12	0.00091	0.01	0.00009
18	March 14, 1997	0.05	0.00099	0.05	0.00011	0	0.00001

Note: $h_{1,2,3}$ - data of groundwater table above drain axle obtained under drainage treatment I, II and III, respectively, $q_{1,2,3}$ - recharge obtained under drainage treatment I, II and III, respectively.

Figures 1, 2 and 3 show the approximation of drain spacing by applying the results of measurement in Glover-Dumm equation. Figure 1 shows the results of approximation of drain spacing for the first drainage treatment (10 m). It is obvious that the approximation of drain spacing moved toward higher values. Two peaks are marked. Its standard error achieved the value of 16 m. Corresponding index of measurement for the first peak is k = 12 and second one is k = 16. The data that correspond to the peaks were obtained in the period of small variation of groundwater table depth (Table 1).

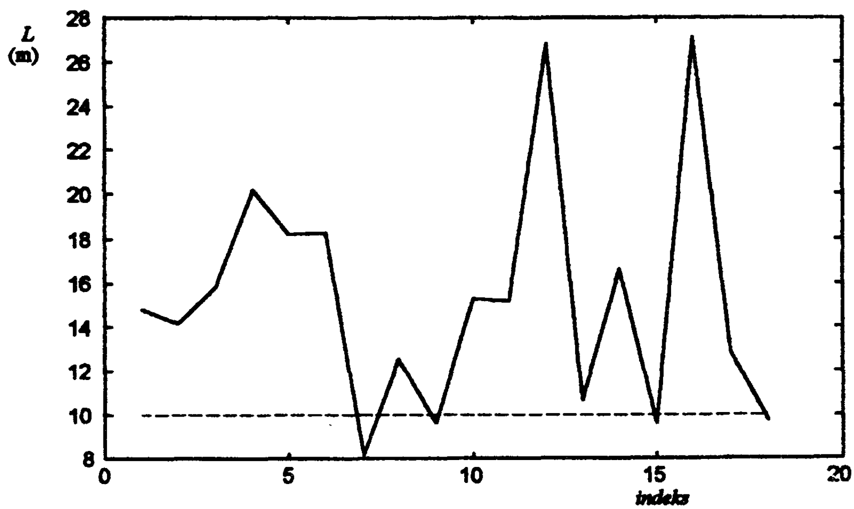


Fig. 1.- Approximation of drain spacing by Glover-Dumm method (L = 10 m)

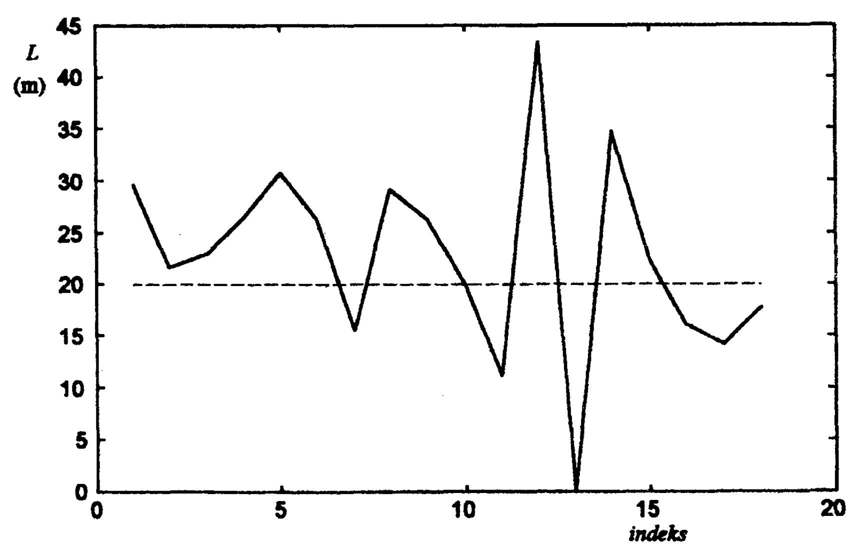


Fig. 2. - Approximation of drain spacing by Glover-Dumm method (L = 20 m)

Figures 2 and 3 show the results of approximation of drain spacing for I and II drain treatments. Better drain spacing approximation is obtained on wider drain spacing, rather than on a shorter one. For the $k = 12$, which corresponds to the data measured on Nov. 9, 1997 (Table 1), approximation of drain spacing was $L = 0$. This value has to be omitted knowing that $h_t = 0$, in equation 1 has no sense.

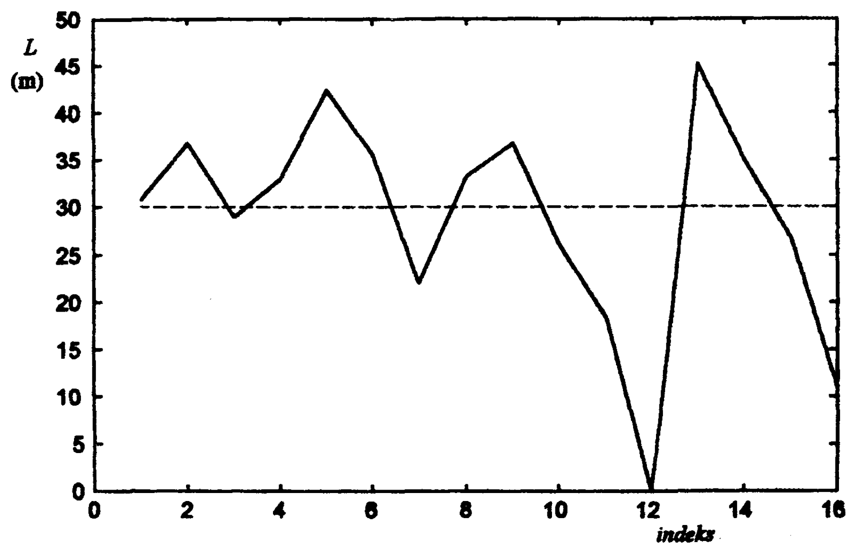


Fig. 3.- Approximation of drain spacing by Glover-Dumm method (L = 30 m)

Further analysis was based on the data obtained in a short time interval. It reflects the comparison of coefficient α (equation 3) obtained both mathematically and experimentally. Figure 4 (a-c) points out that both data series yield exponential regression, but with significantly different coefficients. Namely, for each of three drainage treatments, mathematically obtained values α are multiple higher in regard to those obtained from regression curves based on chosen experimental data. The diminishing trend of regression curves is slighter at any point as well. That could be explained as follows: Entrance of sufficient amount of water could be considered as uncontrolled. The soil already contains a huge amount of groundwater. There are some effects which this method simply doesn't take into account. Depletion of groundwater table during the period free of precipitation is very slow, but it could be expected without recharge. The effect of non-modeling dynamics of recharge has much higher influence on a shorter drain spacing (Figure 4a). The effect of non registered inflow is slightly noticeable on the drainage treatment III with drain spacing L = 30 m. (Figure 4c). This feature of Glover-Dumm method is very significant in practice, so it can be considered unsuitable for drain spacing determination in eugley soil. These results are in concordance with those obtained in different regions. (Murashima and Ogino, 1991), where priority was given to the methods of steady flow water assumption.

Tab. 2.- Selected data of groundwater table depth above drain axle

a) Drainage treatment I

Data	t (days)	α	αt	h_t^* (m)	h_t (m)
Jan. 13, 1995	0			h_o=0.66	0.66
Jan. 17, 1995	4	0.34	1.36	0.2	0.47
Jan. 21, 1995	8	0.34	2.72	0.05	0.32
Jan. 24, 1995	11	0.34	3.74	0.02	0.27
Nov. 12, 1995	0			h_o=0.71	0.71
Nov. 15, 1995	3	0.34	1.02	0.30	0.66
Nov, 18, 1995	6	0.34	2.04	0.11	0.5
Nov. 22, 1995	10	0.34	3.4	0.03	0.47
Nov. 26, 1995	14	0.34	4.76	0.01	0.42
Nov. 29, 1995	17	0.34	5.78	0	0.35
Feb. 22, 1997	0			h_o=0.52	0.52
Feb. 26, 1997	4	0.34	1.36	0.15	0.41
Feb. 2, 1997	8	0.34	2.72	0.04	0.15
March 8, 1997	14	0.34	4.76	0.01	0.14
March 11, 1997	17	0.34	5.78	0	0.10
March 14, 1997	20	0.34	6.80	0	0.05

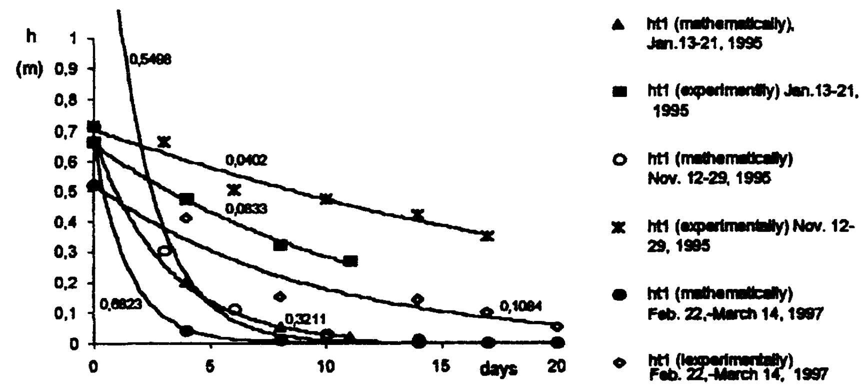
b) Drainage treatment II

Data	t (days)	α	αt	h_t^* (m)	h_t (m)
Jan. 13, 1995	0			h_o=0.76	0.76
Jan. 17, 1995	4	0.29	1.16	0.28	0.64
Jan. 21, 1995	8	0.29	2.32	0.09	0.41
Jan. 24, 1995	11	0.29	3.19	0.04	0.32
Nov. 15, 1995	0	0.29		h_o=0.76	0.76
Nov. 18, 1995	3	0.29	0.87	0.37	0.63
Nov. 22, 1995	7	0.29	2.03	0.12	0.64
Nov. 26, 1995	11	0.29	3.19	0.04	0.50
Feb. 26, 1997	0	0.29		h_o=0.50	0.50
March 2, 1997	4	0.29	1.16	0.18	0.46
March 8, 1997	10	0.29	2.9	0.03	0.23
March 11, 1997	13	0.29	3.77	0.01	0.12
March 14, 1997	16	0.29	4.64	0.01	0.05

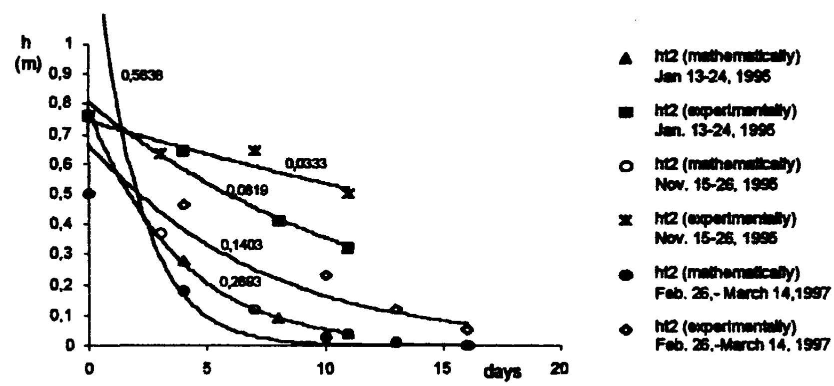
c) Drainage treatment III

Data	t (days)	α	αt	h_t^* (m)	h_t (m)
Jan. 13, 1995	0			h_o=0.83	0.83
Jan. 17, 1995	4	0.22	0.88	0.4	0.6
Jan. 21, 1995	8	0.22	1.76	0.16	0.5
Jan. 24, 1995	11	0.22	2.42	0.08	0.39
March 2, 1997	0			h_o=0.33	0.33
March 8, 1997	6	0.22	1.32	0.1	0.15
March 11, 1997	9	0.22	1.98	0.05	0.01
March 14,1997	12	0.22	2.64	0.03	0

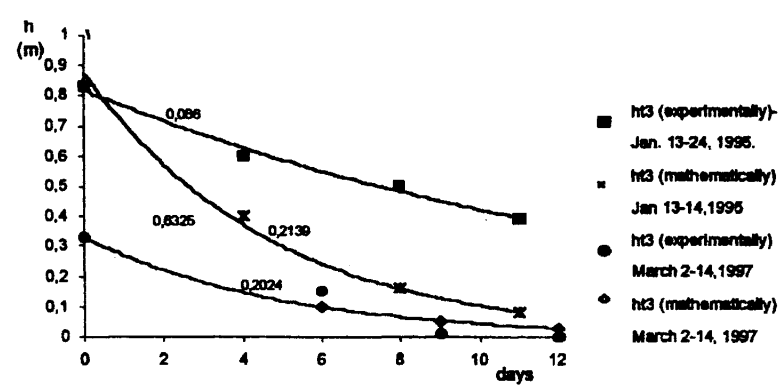
Note: *ho* - groundwater table depth above drain axle obtained mathematically, (equation 1); *ht* - groundwater table depth above drain axle obtained experimentally



a) Drainage treatment I



b) Drainage treatment II



c) Drainage treatment III

Fig. 4. - Approximation by Glover-Dumm method with mathematically and experimentally determined values of coefficient α

Conclusion

Methods from the second group assumed that water recharge to the drains depends on precipitation only. In eugley soil there are some other sources of inflow, which have not been taken into consideration. The Glover-Dumm method explains the depletion of groundwater table fictively by wider drain spacing. The Glover-Dumm method needs exact value of the recharge water. Therefore, this feature was shown to be a great constraint in application. In the drainage treatment with wider drain spacing (plot III), the effect of non-modeling dynamics of flow was meaningless, so it could be used in practice.

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NEKA OGRANIČENJA PRIMENE METODA ZA ODREĐIVANJE MEĐUDRENSKOG RASTOJANJA U NESTACIONARNOM REŽIMU FILTRACIJE NA MOČVARNO-GLEJNOM ZEMLJIŠTU

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Rezime

Cilj ovog rada je da prikaže izvesna ograničenja primene metoda za određivanje rastojanja između drenova u nestacionarnom režimu filtracije na močvarno-glejnim zemljištima. Analiza je izvedena na primeru metode Glover-Dumm-a kao glavnog predstavnika ove grupe metoda, a na osnovu eksperimentalnih rezultata merenja drenažnog isticanja i dubine nivoa podzemnih voda na drenažnom sistemu sa tri varijante rastojanja između drenova: 10, 20 i 30 metara. Metode primenljive u uslovima nestacionarnog režima filtracije podrazumevaju da doticaja osim merenog, dakle padavina ili navodnjavanja, nema. S obzirom da močvarno-glejno zemljište obiluje podzemnim vodama, postoje doticaji koji nisu obuhvaćeni niti kroz padavine, niti kroz navodnjavanje. Metoda Glover-Dumm-a smanjenje dubine podzemnih voda pokušava da obrazloži fiktivnim, većim rastojanjem između drenova. Poređenjem podataka o dubini podzemne vode dobijenih računskim putem i podataka dobijenih merenjem uočava se da i jedni i drugi podaci podležu eksponencijalnoj regresiji, ali da su koeficijenti značajno različiti. Naime, na svim varijantama merenja računski su dobijene vrednosti koeficijenta reakcije α koje su višestruko veće od koeficijenata regresionih krivih sekvence merenja. Na svim izdvojenim segmentima uočljivo je mnogo blaže opadanje regresione linije nego što to sračunava metoda. Ova osobina pokazaće se kao veliko ograničenje u primeni, jer zahteva egzaktno merenje i poznavanje svih doticaja. U sistemima sa većim međudrenskim rastojanjima efekat nemodelirane dinamike doticaja ima manje uticaja, te se metoda pod izvesnim ograničenjima može sa više uspeha primenjivati.

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