RESULTS OBTAINED IN DRAINAGE ARRANGEMENTS DESIGN BY USING DRAINSPACE APPLICATION

REZULTATE OBȚINUTE ÎN PROIECTAREA AMENAJĂRILOR DE DRENAJ PRIN UTILIZAREA APLICAȚIEI DRAINSPACE

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Abstract: *Romania's territory presents numerous areas with humidity excess from different sources and which supposes a proper water management for a durable administration of these lands with the purpose of promoting a sustainable agriculture. An efficient agriculture, taking into consideration Romania's climatic conditions, can be practiced only with the support of land reclamation and improvement systems which are presenting technical and economical characteristics. Manual methods are becoming less used because they present risks in computing different indicators, supposes high volumes of manual work and they are considering long periods of time in reaching the targets (systems design). The software, which are modelling the hydric relations and interactions from soil active layer, present efficiency because they are taking into consideration numerous elements involved in these processes. WaSim is a computer-based training package for the teaching and demonstration of issues involved in irrigation, drainage and salinity management. WaSim simulates the soil water salinity relationships in response to different management strategies and environmental scenarios. WaSim contains 3 complementary design modules to aid sub-surface pipe drain design. Each of the 3 modules, for drain spacing, pipe sizing for field drains, and for collector drains, can be used separately from WaSim. DrainSpace module includes both Steady State (Hooghoudt) and Unsteady State (Glover-Dumm) equations are included in this module for calculating subsurface pipe drain spacing.*

Rezumat: *Teritoriul României prezintă numeroase zone cu exces de umiditate din diferite surse şi care presupun un management potrivit al apei pentru o administrare durabilă a acestor arii, scopul fiind promovarea unei agriculturi sustenabile. O agricultură eficientă, luând în considerare condițiile climatice din România, poate fi practicată numai cu ajutorul sistemelor de îmbunătățiri funciare acestea trebuind să prezinte caracteristici tehnico-economice performante. Metodele manuale de proiectare au devenit mai puțin folosite deoarece prezintă riscuri în calculul diferiților indicatori, presupun volume mari de muncă manuală şi se derulează pe perioade mari de timp. Programele care modelează relațiile hidrice şi interacțiunile din stratul de sol activ prezintă un grad de eficiență crescut deoarece iau în considerare numeroase elemente implicate în aceste procese. WaSim este un pachet de programe pentru studiul şi demonstrarea fenomenelor din sfera irigațiilor, drenajului şi a managementului salinității. WaSim simulează relațiile referitoare la salinitatea apei solului ca răspuns la diferite strategii de mediu aplicate. Wasim conține 3 module de proiectare suplimentare. Fiecare din cele 3 module (pentru calculul distanței între drenuri, dimensionarea tuburilor de drenaj şi a celor colectoare) poate fi utilizat separat de WaSim. Modulul DrainSpace include atât ecuații pentru regimul permanent (Hooghoudt) cât şi pentru regimul nepermanent (Glover-Dumm) necesare calculului distanței între drenuri.*

Key words: *DrainSpace,WaSim, software, relations, pipe drain spacing*
Cuvinte cheie*: DrainSpace, WaSim, program de calcul, relații de calcul, distanțe între tuburile de dren*

INTRODUCTION

Developed by HR Wallingford and Cranfield University (with support from the UK Department for International Development), WaSim is a computer-based training package for the teaching and demonstration of issues involved in irrigation, drainage and salinity management. WaSim is a daily water balance model that simulates the soil water / salinity relationships in response to different management strategies (e.g. drainage designs and water management practices) and environmental scenarios (e.g. weather data, soil types, cropping patterns).

Computer simulation models are increasing being used as teaching tools as a replacement for, or adjunct to traditional field or laboratory exercises. Many benefits have been cited: Speed in resolving the issues, controlling the 'environment', performing impossible or undesirable experiments, Focus on the learning experience, Substituting for physical resources and tutor's time, Synthesizing expertise, Gaming and sensitivity analysis, Distance and self-learning, observing obscure processes. There are very many water balance simulation models commonly used world-wide, which benefit from many years of development and validation. However, different purposes (applications) require different packaging of the models. Many of the existing models were developed for research use where the emphasis is on the validity of the output and rigor in the scientific understanding. Packages for educational use have a much greater demand on the ease of use of the interface, simple parameterization and clear visualization of results, and less on the accuracy of the prediction. It is important that a model responds to simulated conditions in the right direction and the correct order of magnitude, but relative changes in output are more important in conveying the understanding of the system than absolute predictions. Many of the existing models therefore are unsuitable for educational use, or can only be used once extensive training in the use of the software has been completed.

The objective of the WaSim project was therefore to develop a computer package focused primarily on teaching and learning that is easy to use, it has minimal data requirements, good visualization of model calculations, a reasonable level of accuracy and is flexible in term of the range of water management situations that can be simulated.

Among the attributes of WaSim model we can mention the following: WaSim is principally aimed at simulating the effectiveness of subsurface tile (pipe) drains; the simulation algorithm adopts a mass-balance approach, calculating results for a unit area of land at mid-drain spacing (calculated results include water contents and salt concentrations at different points in the soil profile, along with drainage flows and water table depths); WaSim runs on a daily time-step using actual rainfall and reference evapotranspiration data; simulation runs of up to 30 years in duration can be undertaken; only single layered soils can be simulated; WaSim can also be run as an unsaturated water balance simulation with irrigation, drainage/water table and salinity options selected/deselected independently as required.

The water balance model is a one-dimensional, daily, soil water balance. It aims to simulate the soil water storage and rates of input (net rainfall and irrigation) and output (evaporation, transpiration and drainage) of water in response to climate. The upper boundary is the soil surface and the lower boundary is the impermeable layer. Water is stored between these two boundaries in five stores (layers): the surface (0 – 0.15m) layer, the active root zone (0.15m – root depth), the unsaturated layer below the root zone (root depth – water table), the saturated layer above drain depth (water table – drain depth), the saturated layer below drain depth (drain depth –impermeable layer).

The boundary between layers 2 and 3 will change as the roots grow. Before plant roots reach 0.15m, layer 2 will have zero thickness. Similarly the boundary between layers 3 and 4 will fluctuate with the water table. Soil water moves from upper layers to layers below only when the soil water content of the layer exceeds field capacity but the rate of drainage is a function of the amount of the excess water. Upward capillary rise occurs from the water table to the root zone.

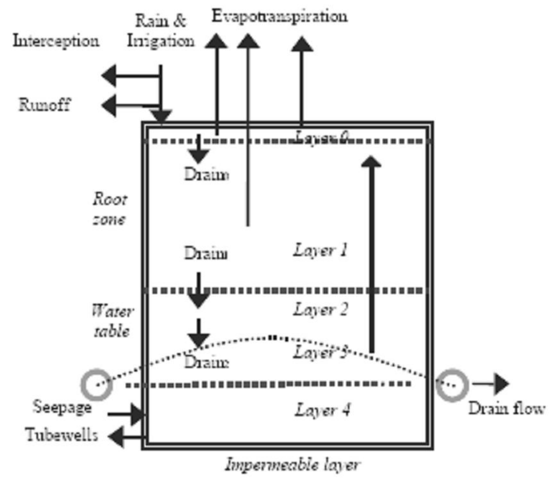

Figure 1. Water balance model used in WaSim

MATERIAL AND METHODS

DrainSpace program allows the computation of distances between drains in steady-state approach (with the help of Hooghoudt equation) and also to verify the results which were obtained using unsteady-state equations (Glover-Dumm equation).

Hooghoudt equation is based on the Dupuit-Forchheimer assumptions which allow reducing the two-dimensional flow to a one-dimensional flow by assuming parallel and horizontal stream lines. Such a flow pattern will occur as long as the impervious subsoil is close to the drain. If the impervious layer does not coincide with the bottom of the drain, the flow in the vicinity of the drains will be radial and the Dupuit-Forchheimer assumptions cannot be applied. Hooghoudt solved this problem by introducing an imaginary impervious layer to take into account the extra head loss caused by the radial flow.

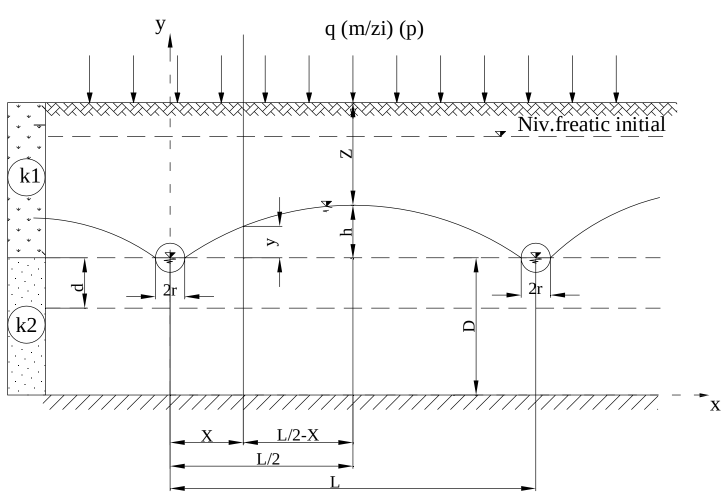

Figure 1. Hooghoudt scheme

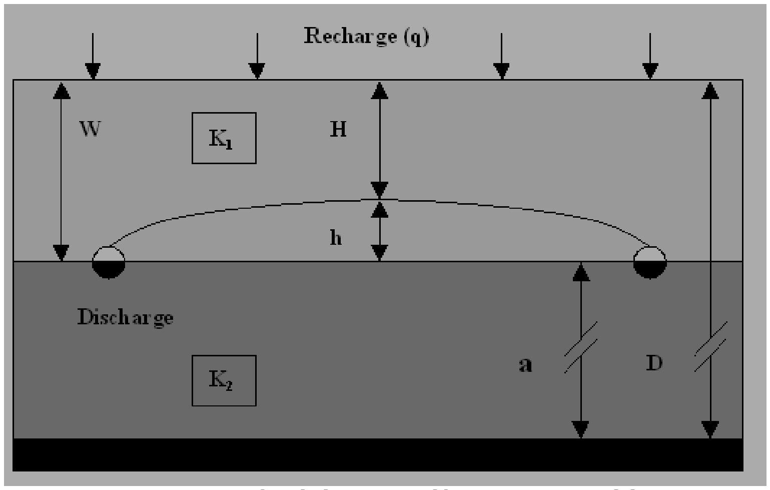

Figure 2. Hooghoudt diagram used by Drainspace module

The Hooghoudt equation uses a function, reduced depth (dr), to replace the depth to the impermeable layer below the drain (a). If the calculated drain spacing is not larger than the depth from the drainage base to the impermeable layer by a factor of 4 (L > 4a) then the calculation of the reduced depth (dr) is not valid and the results from the equation should not be assumed accurate.

$$q = \frac{\left(8K_2 d_r h + 4K_1 h^2\right)}{L^2}$$

where, L is the drain spacing (m), K1 - weighted hydraulic conductivity above the drains (mm/hr), K2 - weighted hydraulic conductivity below the drains (mm/hr), h - water table head above drain at midpoint between drains (m), a - depth of barrier (impermeable layer) below drains (m), d_r - reduced equivalent depth to impermeable layer (m), q = drainage rate (mm/hr). The equivalent depth (dr) is calculated from one of the following equations:

$$d_r = \frac{a}{1 + \frac{8a}{\pi \cdot L} \ln \frac{a}{u}}; \; for \frac{a}{L} < 0.25$$

$$d_r = \frac{\pi \cdot L}{8\left[\ln\left(L/u\right)\right]}; \; for \frac{a}{L} > 0.25$$

u – wetted perimeter of the drain (m).

In the case of unsteady flow, a rise or fall in the water table occurs as water is stored in or released from the soil. The Glover-Dumm equation can be used to estimate the drain spacing required to lower the water table to a desired level in a given time period. By introducing Hooghoudt's reduced depth into the Glover-Dumm formulation, the resistance caused by the converging flow towards the drains is taken into account.

The Glover-Dumm equation is:

$$L = \pi\left(\frac{Kd_r t}{\mu}\right)^{1/2}\left(\ln 1.16\frac{h_0}{h_t}\right)^{-1/2}$$

where L - drain spacing, K - hydraulic conductivity (m/day), dr - reduced equivalent depth (m) to impermeable layer (as in the Hooghoudt formulation), t - time after instantaneous rise of the water table, m - drainable pore space, h_0 - initial height of the water table above drain level at time t=0, h_t - height of the water table above drain level at time t.

In this paper DrainSpace module was used for the calculation of distances between drains in Caraş-Severin County. The first studies were realized a few years ago and used for the calculation of distance between drains the Ernst formula completed with an indicator ζ_{if} which represents the head pressure loss at water entrance in drains.

$$h=\frac{q\cdot D_v}{K_1}+\frac{q\cdot L^2}{8\cdot K_1\cdot T_e}+\frac{q\cdot L}{K_1}\cdot\ln\frac{\alpha\cdot D_0}{U}+\frac{q\cdot L}{K_1}\cdot\zeta_{if}$$

RESULTS AND DISCUSSIONS

The parameters for the Houghoudt equation are defined on the interactive diagram. When elements of the full sized picture are selected with the mouse, a description appears for a few seconds below the diagram.

Hooghoudt Results

	Input Parameters								Intermediates		Results
Run	q(mm/day)	K1(m/day)	K2(m/day)	H(m)	W(m)	D(m)	U(m)	S(%)	h(m)	a(m)	L(m)
1	7.0	0.20	0.20	0.60	1.20	2.50	0.30	100	0.60	1.30	13.08
2	7.0	0.03	0.03	0.60	1.20	2.80	0.30	100	0.60	1.60	4.41
3	7.0	0.03	0.03	0.60	1.20	1.70	0.30	100	0.60	0.50	3.87
4	7.0	0.09	0.09	0.60	1.20	2.80	0.30	100	0.60	1.60	8.57
5	7.0	0.03	0.03	0.60	1.20	2.50	0.30	100	0.60	1.30	4.33

Figure 3. Table with Hooghoudt results

In the situation of applying Ernst formula were obtained distances smaller than in the case of Hooghoudt. A diagram with the comparison between these two methods is presented in the following picture.

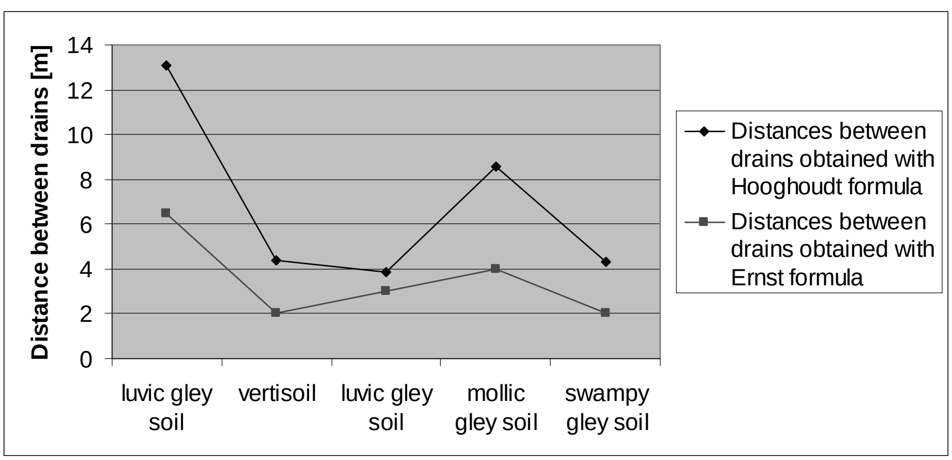

Figure 4. Comparisons between the results obtained with Hooghoudt and Ernst formulas

Glover Dumm Results

	Input Parameters									Intermediates			Results
Run	T(days)	K(m/day)	P(%)	H0(m)	HT(m)	W(m)	D(m)	U(m)	S(%)	h0(m)	hT(m)	a(m)	L(m)
1	2	0.05	0.10	0.30	0.60	1.20	2.50	0.30	100	0.90	0.60	1.30	1.43
2	3	0.05	0.10	0.30	0.60	1.20	2.50	0.30	100	0.90	0.60	1.30	1.84
3	4	0.05	0.10	0.30	0.60	1.20	2.50	0.30	100	0.90	0.60	1.30	2.22

Figure 5. Results obtained with Glover-Dumm formula for vertisols case

From the previous table we can observe that for unsteady flow situation (real situation) the distances between drains are smaller, almost at half in comparison with steady flow case. Generally, the water table level must be lowered in maximum 2 days without any crops losses. That means that we have to use smaller distances between drains. If we will apply the Ernst formula and the drains will be covered by filtering materials, the distance between drains increase from 1,43 m to 3m. There are necessary in this case an analysis for determining the most economical solution.

Over time the flow capacity of pipe drains will decrease because of sedimentation, chemical deposits or intrusion of roots. There are various ways of incorporating safety factors to compensate for reduction in pipe capacity. A traditional method is to reduce the pipe discharge by a reduction factor, R, according to the following guidelines: · For small diameter pipes (field drains, $d < 100$ mm), take 60% of the theoretical capacity ($R = 0.60$); · For larger diameters (generally collectors, $d > 100$ mm, take 75% of the theoretical capacity ($R = 0.75$)

CONCLUSIONS

Romanian researchers, even they had a rich experience in drainage field, must improve their efficiency in drainage design work by developing or adopting more complex programs. With 8 million hectares affected by humidity excess, Romania is a country which imperative requests sustainable, efficient and effective drainage arrangements. These systems must improve the hydric soil conditions and in the same time must offer prognosis regarding water-table fluctuations in order to avoid damages on environment.

DrainSpace module can be a useful toll for drainage systems designers but it has some limitations, one of them being that the drains line must correspond to separation line between two soil layers. The option of using the Glover-Dumm formula is a major advantage because the real situation corresponds to unsteady-flow case which is resolved by this mentioned formula.

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