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CALCULATION OF DISTANCE BETWEEN DRAINS USING ENDRAIN PROGRAM

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Abstract: *EnDrain program, realized by Prof. Oosterbaan (Netherlands), computes the distances between drains and also determines shape of water-table level of by using the formula of flow's energy balance. Oosterbaan, Boonstra and Rao (1994) introduced the energy balance of groundwater flow. It is based on equating the change of hydraulic energy flux over a horizontal distance to the conversion rate of hydraulic energy into to friction of flow over that distance. The energy flux is calculated on the basis of a multiplication of the hydraulic potential and the flow velocity, integrated over the total flow depth. The conversion rate is determined in analogy to the heat loss equation of an electric current. By using EnDrain program we can compute the flow discharged by drains, the head losses and the distance between drains also obtaining the curve described by water-table level. These calculations are necessary to design a drainage system in the frame of an irrigation system for water-table control, salts control and respective for soil's humidity control. The calculation of distances between drains is based on the concept of underground flow's energy balance. There also used the traditional concepts based on theories of Dupuit, water balance and mass conservation. The program allows the utilization of three different soil layers, each of them with their own permeability and hydraulic conductivity, on layer being above and two layers below drains level. This paper will present the results obtained in computing the distances between drains with EnDrain program for some soils with humidity excess from Bihor County, western Romania, and, very important, will present graphs with the shape of water-table level for the analyzed soils.*

Key words: *EnDrain, underground's flow energy balance, water-table level shape*

INTRODUCTION

EnDrain program, realized by Prof. Oosterbaan (Netherlands), computes the distances between drains and also determines shape of water-table level of by using the formula of flow's energy balance

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The energy balance of groundwater flow developed by Oosterbaan, Boonstra and Rao and used for the groundwater flow in unconfined aquifers, is applied to subsurface drainage by pipes or ditches with the possibility to introduce entrance resistance and/or soils with anisotropic hydraulic conductivities. Owing to the energy associated with the recharge by downward percolating water, it is found that use of the energy balance leads to lower water table elevations than when it is ignored. The energy balance cannot be solved analytically and a computerized numerical method is needed. An advantage of the numerical method is that the shape of the water table can be described, which was possible with the traditional methods only in particular situations, like drains without entrance resistance, resting on an impermeable layer in isotropic soils. [2]

MATERIAL AND METHODS

Assuming fluxes in permanent regime, two-dimensional vertical flow, the horizontal component of flow being constant in a vertical cross-section and the fact that the soil has a constant hydraulic conductivity from place to place, Oosterbaan, Boonstra and Rao (1994) discover that:

$$\frac{dJ}{dX} = -\frac{Vx}{Kx} - \frac{R(J - Jr)}{Vx \cdot J}$$

where: J is the level of the water table at distance X, taken with respect to the level of the impermeable base of the aquifer (m); Jr is a reference value of level J (m); X is a distance in horizontal direction (m); Vx is the apparent flow velocity at X in horizontal X-direction (m/day); Kx is the horizontal hydraulic conductivity (m/day); R is the steady recharge by downward percolating water stemming from rain or irrigation water (m/day); dX is a small increment of distance X (m); dJ is the increment of level J over increment dX (m); dJ/dX is the gradient of the water table at X (m/m). [2, 3]

The last term of Equation 1 represents the energy associated with the recharge R. When the recharge R is zero, Equation 1 yields Darcy's equation. The negative sign before Vx indicates that the flow is positive when the gradient dJ/dX is negative, i.e. the flow follows the descending gradient, and vice versa. [2, 3]

Figure 1 shows the vertically two-dimensional flow of ground water to parallel pipe drains with a radius C (m), placed at equal depth in a phreatic aquifer recharged by evenly distributed percolation from rainfall or irrigation (R>0, m/day). The impermeable base is taken horizontal with a depth D>C (m) below the centre point of the drains. At the distance X=N (m), i.e. midway between the drains, there is a water divide. Here the water table is horizontal. [2]

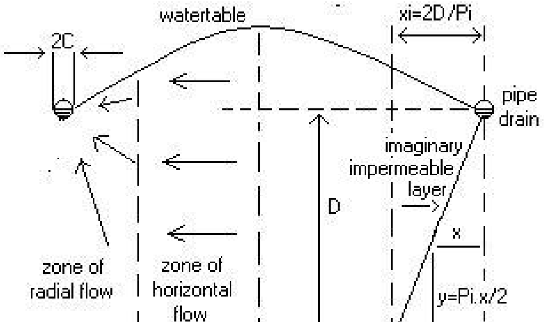

Figure 1. Vertically two-dimensional flow of ground water to parallel pipe drains placed at equal depth in a phreatic aquifer recharged by evenly distributed percolation from rainfall or irrigation. [2]

Oosterbaan, Boonstra and Rao considered only the radial flow approaching the drain at one side, because the flow at the other side is symmetrical, and also only the flow approaching the drain from below drain level. [2]

According to the principle of Hooghoudt (1940), the ground water near the drains flows radially towards them. In the area of radial flow, the cross-section of the flow at a distance X from the drains is formed by the circumference of a quarter circles with a length ½πX. This principle is conceptualized in Figure 1 by letting an imaginary impermeable layer slope away from the centre of the drain at an angle with a tangent ½π. [2, 3]

RESULTS AND DISCUSSIONS

The results obtained for Tileagd area, affected by humidity excess, from Bihor County, with the help of EnDrain program are:

1.1 Tileagd drain of 5 cm diameter, alluvial soil

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Time average recharge or discharge              R    (m/day) :        0.0070
 Bottom depth of 1st layer below s.s.           D1       (m) :        2.00
 Bottom depth of 2nd layer below s.s.           D2       (m) :        2.00
 Depth water level in drain below s.s.          Dw       (m) :        1.42
 Depth of drain bottom below s.s                Db       (m) :        1.45
 Entrance resistance at the drain               E    (day/m) :        0.507
 Max. width of water body in the drain          W        (m) :        0.050
 Hydraulic permeability, above drain level      Ka   (m/day) :        0.011
 Horizontal permeability, 1st soil layer        Kb1  (m/day) :        0.011
 Vertical permeability, 1st soil layer          Kv1  (m/day) :        0.011
 Horizontal permeability, 2nd soil layer        Kb2  (m/day) :        0.0000
 Vertical permeability, 2nd soil layer          Kv2  (m/day) :        0.0000
 Depth water-table midway between drains        Dm       (m) :        0.80

Output sequence :

  X     F*      G*/p       F      G/p       T1            T2

Output data:
 0.03   0.1701  16.1246  0.1650  15.6190  16.1246        -0.5056
 0.31   0.5135  0.6037   0.5096  0.6061   0.6061         0.0000
 0.62   0.6476  0.3278   0.6442  0.3287   0.3287         0.0278
 1.24   0.7451  0.0043   0.7419  0.0043   0.0043         13.1284
 #

 The drain spacing (energy, m) is:    2.49
Midway hydr. head (energy, m) is:   0.742
 Midway hydr. head (Darcy,  m) is:   0.745
 Midway W.T. depth (energy, m) is:    0.800
 Midway W.T. depth (Darcy,  m) is:   0.680
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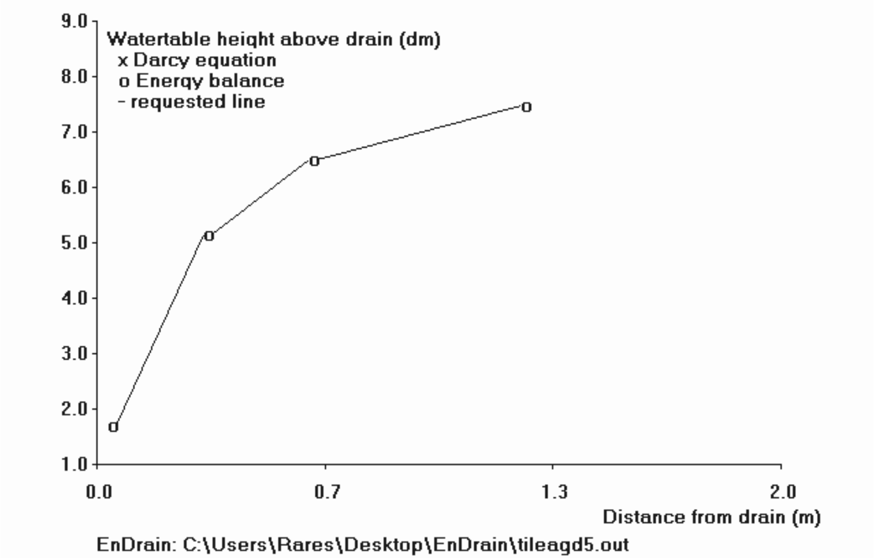

Fig. 2 Water-table level variation according to energy balance equation

1.2 Tileagd drain of 6,5 cm diameter, alluvial soil

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Time average recharge or discharge          R    (m/day) :        0.0070
 Bottom depth of 1st layer below s.s.       D1      (m) :         2.00
 Bottom depth of 2nd layer below s.s.       D2      (m) :         2.00
 Depth water level in drain below s.s.      Dw      (m) :         1.43
 Depth of drain bottom below s.s            Db      (m) :         1.47
 Entrance resistance at the drain           E   (day/m) :         0.532
 Max. width of water body in the drain      W       (m) :         0.065
 Hydraulic permeability, above drain level  Ka   (m/day) :        0.011
 Horizontal permeability, 1st soil layer    Kb1  (m/day) :        0.011
 Vertical permeability, 1st soil layer      Kv1  (m/day) :        0.011
 Horizontal permeability, 2nd soil layer    Kb2  (m/day) :        0.0000
 Vertical permeability, 2nd soil layer      Kv2  (m/day) :        0.0000
 Depth water-table midway between drains     Dm      (m) :        0.80

 Output sequence:
   X     F*       G*/p      F       G/p       T1       T2
 Output data:
  0.04  0.1340  12.4253  0.1291  11.9354  12.4253  -0.4899
  0.32  0.5022   0.6358  0.4985   0.6382   0.6382   0.0000
  0.65  0.6539   0.3463  0.6507   0.3472   0.3472   0.0230
  1.30  0.7621   0.0065  0.7591   0.0066   0.0066   9.1675

 The drain spacing (energy, m) is:   2.62

 Midway hydr. head (energy, m) is:   0.759
 Midway hydr. head (Darcy,  m) is:   0.762
 Midway W.T. depth (energy, m) is:   0.799
 Midway W.T. depth (Darcy,  m) is:   0.671
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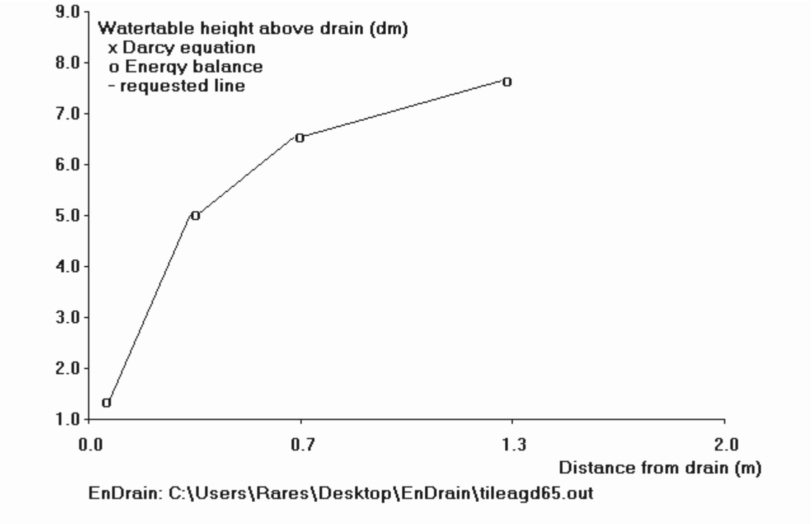

Fig. 3 Water-table level variation according to energy balance equation

1.3 Tileagd drain of 8 cm diameter, alluvial soil

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Time average recharge or discharge               R    (m/day) :          0.0070
 Bottom depth of 1st layer below s.s.            D1       (m) :          2.00
 Bottom depth of 2nd layer below s.s.            D2       (m) :          2.00
 Depth water level in drain below s.s.           Dw       (m) :          1.44
 Depth of drain bottom below s.s                 Db       (m) :          1.48
 Entrance resistance at the drain                E    (day/m) :          0.607
 Max. width of water body in the drain           W        (m) :          0.080
 Hydraulic permeability, above drain level       Ka   (m/day) :          0.011
 Horizontal permeability, 1st soil layer         Kb1  (m/day) :          0.011
 Vertical permeability, 1st soil layer           Kv1  (m/day) :          0.011
 Horizontal permeability, 2nd soil layer         Kb2  (m/day) :          0.0000
 Vertical permeability, 2nd soil layer           Kv2  (m/day) :          0.0000
 Depth water-table midway between drains         Dm       (m) :          0.80

 Output sequence:
   X     F*      G*/p      F      G/p      T1       T2
 Output data:
  0.05  0.1129  10.1364  0.1081  9.6568  10.1364  -0.4796
  0.33  0.4937  0.6544   0.4901  0.6567  0.6567   0.0000
  0.67  0.6568  0.3611   0.6537  0.3620  0.3620   0.0181
  1.35  0.7737  0.0045   0.7709  0.0045  0.0045  13.9605

 The drain spacing (energy, m) is:   2.71

 Midway hydr. head (energy, m) is:   0.771
 Midway hydr. head (Darcy,  m) is:   0.774
 Midway W.T. depth (energy, m) is:   0.801
 Midway W.T. depth (Darcy,  m) is:   0.666
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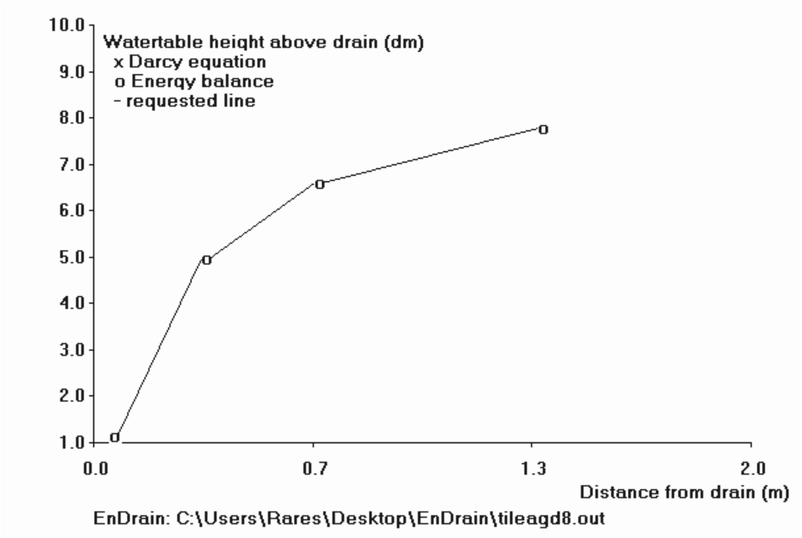

Fig. 4 Water-table level variation according to energy balance equation

CONCLUSIONS

Application of the energy balance of groundwater flow to pipe and ditch drains leads to lower elevations of the water table or, if the elevation is fixed, to wider drains spacing. Also, it can give the shape of the water table. Further, it can take entrance resistance and anisotropy of the soil's hydraulic conductivity into account. Calculations with the energy balance need be done on a computer because of the cumbersome iterative, numerical procedure required.

BIBLIOGRAPHY

1. BOUMANS, J.H. (1979). Drainage calculations in stratified soils using the anisotropic soil model to simulate hydraulic conductivity conditions. In: J.Wesseling (Ed.), Proceedings of the International Drainage Workshop, p. 108-123. Publ. 25, ILRI, Wageningen, The Netherlands.
2. OOSTERBAAN, R.J., J.BOONSTRA AND K.V.G.K.RAO (1996). The energy balance of groundwater flow. In: V.P.Singh and B.Kumar (Eds., Subsurface-Water Hydrology, p. 153-160. Kluwer Academic Publishers, The Netherlands. (Reprint available at ILRI, e-mail ilri@ilri.nl)
3. RITZEMA, H.P. (1994). Subsurface flow into drains. In: H.P. Ritzema (Ed.), Drainage Principles and Applications, p. 263-304. Publ 16, ILRI, Wageningen, The Netherlands.
4. *** Scientific Research Contracts numbers 116/1978, 351/1979, 207/1990, 127/1991, 106/1982, 4004/1995, 5004/1996, 249/1998, 35034/1999, 33501/2002, „Politehnica” University of Timisoara.