RECOMMENDED SUPPORTIVE TOOL FOR THE DESIGN OF THE SUBSURFACE DRAINAGE SYSTEM IN EGYPT

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ABSTRACT

In Egypt, the drain spacing design is based upon the steady state theory of Hooghoudt. It assumes that the watertable above the drains is constant, the irrigation has a constant intensity, which is equal to the drainage rate, a horizontal impermeable layer underlies the system and the soil is homogenous and isotropic. However, the non-steady state approach offers major advantages compared with the steady state approach. It considers the movement of the water-table through the soil as a transient condition and the hydraulic head at any point in the soil is not constant and changing with time. But, there are some various assumptions restrict the use of the unsteady state equations. So far the biggest restriction, however, is the introduction of the drainable pore space into consideration as one of the main factors in the flow concept. The results of this research is developing software for calculating the drainable porosity from the hydraulic conductivity measurements, this make the non-steady state flow equations more easier to be solved. Also, general software for calculating the spacing between drains for both, steady and unsteady state conditions was introduced.

INTRODUCTION AND GENERAL BACKGROUND

Subsurface drainage by means of buried pipe systems is probably the most comprehensively studied subject in land drainage. As a result, the relationships between the variables and parameters were well established. The remaining design problems are mostly due to the great variability in the geometry and in the hydraulic properties of the soil, and due to the many other interactions between the soil and the system. It has been designed to control the watertable depth at a level, which will allow optimum root development for crops, and prevent the capillary movement of salts into the root zone at levels, which are harmful to the crops. The proper depth to be achieved by the drainage system is dependent on soil type, climate, crops, cropping intensity and water management (Dieleman, 1980). The interaction between depth and spacing is very significant and selection of a drain depth and spacing must satisfy the drainage requirements at the least possible cost (Abu-Zeid, 1992).

The design of the drainage system in Egypt is based on steady state theory (Luthin, 1957). Acknowledging the transient nature of the groundwater flow to drains in irrigated fields, a non-steady state equation was used for a short time at the beginning of the implementation of the drainage projects (Amer-Luthin 1967). Then, the design was switched back to the steady-state concept claiming difficulties in obtaining the design input data, especially the drainable porosity.

In spite of the theoretical computations, a limit was imposed on the maximum and minimum drain spacing. A minimum spacing of 30 m was justified by economy, and a maximum of 60 m was claimed to be a practical upper limit. However, in 1986, these criteria for the spacing were changed to adopt the spacing as obtained from the theory but with a minimum of 20 m (Amer and Ridder, 1989).

The spacing equations for the design of subsurface drainage system were based upon two main approaches. The first approach was called the Dupuit-Forchheimer assumption. It applies the continuity principle which states that the flow through the sides of a vertical column of an infinitesimal cross sectional area must be compensated by a corresponding drop of the groundwater table at the top of the column. The second approach is based upon the requirement assuming that there is no accumulation of water in any elementary cubical volume located in the zone of complete saturation.

For the design of subsurface drainage system, there are two approaches: steady state concept and unsteady state concept. In 1940, Hooghoudt developed a steady state drain spacing formula for pipe drainage. In this formula the head-losses due to horizontal and radial flow to the pipe were considered. Hooghoudt considered that a parallel open ditch system with the ditches reaching to the impermeable layer. In 1967, Amer and Luthin developed a drain spacing equation of second kind based on actual potential distribution of soil water pressure around the drains. Amer-Luthim unsteady state equation was derived for a system of tile drains equally spaced a distance (S) and underlain by impermeable layer at a distance from the center-line of the drains.

OBJECTIVES

The objectives of this research are directed to develop especial software to calculate the drainable porosity from the hydraulic conductivity measurements, this make the unsteady state flow equations more easier to be solved and leads to make a general software for calculating the spacing between drains for both, steady and unsteady state conditions. Also a comparison between the two concepts will be carried out.

STUDY AREA

The study catchment's area is called Qahbouna and El-Saada area which located at the Eastern Delta as shown in figure-1. The total gross area is 3000 feddans. The soil texture of the area varies from clay to sand. The pre-investigation of this area was carried out since 1997. It was designed by the Egyptian Public Authority for Drainage Project (EPADP) (Shnouda, et al., 2006). The area was divided into a suitable grid system. The Auger Hole of 2.0 m depth and 8.0 cm diameter was made to measure the hydraulic conductivity at each node point of the grid system. Soil sample were collected each 0.25 m from the surface up to 1.5 m to determine the salinity and the need for envelope material.

The soil hydraulic conductivity (K) varied from 0.1 to 4.5 m/day, with an average value 1.5 m/day. The K values were calculated by using the SSDP program as illustrated at table-1. The drain discharge was considered as 0.0010 m/day and depth of the impermeable layer is 5.0 m from the soil surface. The average ground water depth was calculated as 0.60 m from the soil surface and its salinity was measured as 1.50 dS/m.

The steady state criteria require a dewatering zone of 1.0 m depth below the soil surface which was assumed necessary for the cotton crop. An average depth of 1.4 m was considered to be an optimum choice for lateral drains. Thus, the design water table height midway between drains was 0.40 m above drain level.

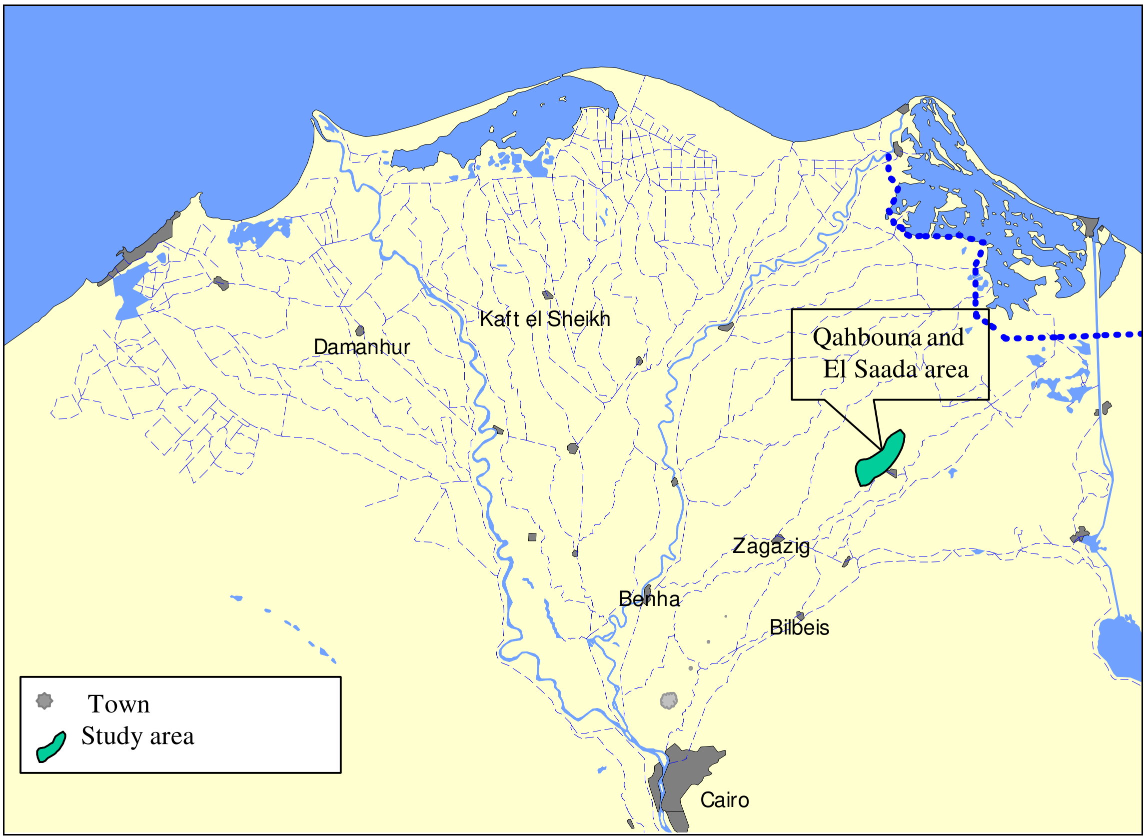

Figure 1. The location of the study area.

Table-1. Data of pre-drainage investigations and the design spacing between drains computed by the SSDP-program.

No.	Loc.	ho	ht	Hydrulic conductivity K (m/day)	Drainable porosity f c.c	Drain discharge q (mld)	Depth of imperm. layer D (m)	Dia. of drain Pipe (m)	Time of irr. t (d)	Hooghoudt spacing (m)	Amer spacing (m)	Glover spacing (m)
1	R-14	---	Dry	---	---	---	---	---	---	---	---	---
2	S-14	1.2	0.600	2.5284	0.077	0.001	3.6	0.10	7	238	89	90
3	T-12	1.2	0.500	0.033	0.020	0.001	3.6	0.10	7	15	20	19
4	T-13	1.2	0.625	3.7944	0.088	0.001	3.6	0.10	7	301	107	110
5	U-11	---	Dry	---	---	---	---	---	---	---	---	---
6	U-12	1.2	0.548	1.1587	0.060	0.001	3.6	0.10	7	88	60	62
7	U-13	1.2	0.480	0.5278	0.044	0.001	3.6	0.10	7	87	41	42
8	U-14	1.2	0.534	0.996	0.057	0.001	3.6	0.10	7	134	56	58
9	V-10	---	Dry	---	---	---	---	---	---	---	---	---
10	V-11	1.2	0.470	0.5273	0.043	0.001	3.6	0.10	7	87	42	43
11	V-12	1.2	0.633	4.5253	0.093	0.001	3.6	0.10	7	333	116	113
12	V-15	1.2	0.465	0.4521	0.041	0.001	3.6	0.10	7	179	39	40
13	V-16	1.2	0.360	0.1251	0.022	0.001	3.6	0.10	7	30	22	23
14	W-10	1.2	0.590	2.0996	0.073	0.001	3.6	0.10	7	213	80	81
15	W-11	---	Dry	---	---	---	---	---	---	---	---	---
16	W-13	1.2	0.580	1.8718	0.070	0.001	3.6	0.10	7	199	76	77

THE SUBSURFACE DRAINAGE DESIGN PROGRAM (SDDP)

The SDDP program was developed by using Delphi 3.0 with object Pascal as the underlying computer language. Pascal has been designed with scientific applications in mind and is therefore one of the best computer languages currently available for developing such a program. In addition, Delphi 3.0 has the advantage of being able to produce native Windows executable programs that do not need auxiliary libraries to run. As a result, a subsurface drain comes as a small digital executable program which could be readily run on any personal computer running Windows 98 or later.

The SDDP is a modular computer program for the design of subsurface drains. The program consists of four modules: (1) the hydraulic conductivity module, (2) the drainable porosity module, (3) the steady state design module, and (4) the non-steady state design module. The objective of developing this program was to create a simple and easy-to-use, yet powerful, computer solution to the exercise of subsurface drain design. In particular, the program makes available the design of subsurface drains using two unsteady state equations: Amer's and Glover-Dumm equations. Those equations are typically difficult to calculate manually and hence they may practically be used only if they were computerized. The SDDP should therefore encourage design engineers to use non-steady state design methods instead of using the steady state methods only. A help system and the default values for some parameters are available in the program in order to assist the users while using the program if required (for the source code and the detailed explanation (Nasralla, 2003).

The hydraulic conductivity module calculates the hydraulic conductivity values by using the field data collected by using the Auger Hole method. The required input data are the radius of the hole (r), the hole depth from ground surface (D), the depth of groundwater from soil surface (W), the depth of the impermeable layer below the bottom of the hole (S), the distance between groundwater level and the water surface in the hole after removal of water at the time of the first reading (y_o), the same definition of y_o at the end of measurement (y_n) and the time taken for rise of water table during measurements (Δt).

The drainable porosity module calculates the drainable porosity according to the equations obtained by Nasralla, 2003. These equations depend on the values of the hydraulic conductivity and the draw down ratio (H/Ho). The required input data are the hydraulic conductivity value (K) which obtained from the above module, the highest water table position (Ho it can be considered as 0.90) and the lowest value of the water table (H it depends on a series of factors such as irrigation period, type of crop, climate, and type of the soil, It is generally assumed to range from 0.5 to 0.3m).

Steady state design module calculates the spacing between the laterals based on the steady state conditions (Hooghoudt equation). The required input data are the discharge rate (q) which equal to 0.001 m/day according to the EPADP-standard, the depth of the water table midway between the drains (h), which equal to 1.0 m according to the EPADP-standard, the drain diameter (r_o), which equal to 0.1 m according to the EPADP-standard, the hydraulic conductivity (K), which obtained from the hydraulic conductivity module and the depth of the impermeable layer (D).

The non-steady state module calculates the spacing between the lateral based on the differential equations for non-steady flow in which, Amer equation was used for the calculation. There is another option to use other equation such as Glover-Dumm equation and the input data is the hydraulic conductivity (K), the drainable porosity (f), the drain diameter (r_o) the depth of the impermeable layer (D), the highest water table position (ho), the lowest value of the water table (h_t) and the time needed to lower the water table from h_o to h_t (t) as shown in (Figure 2).

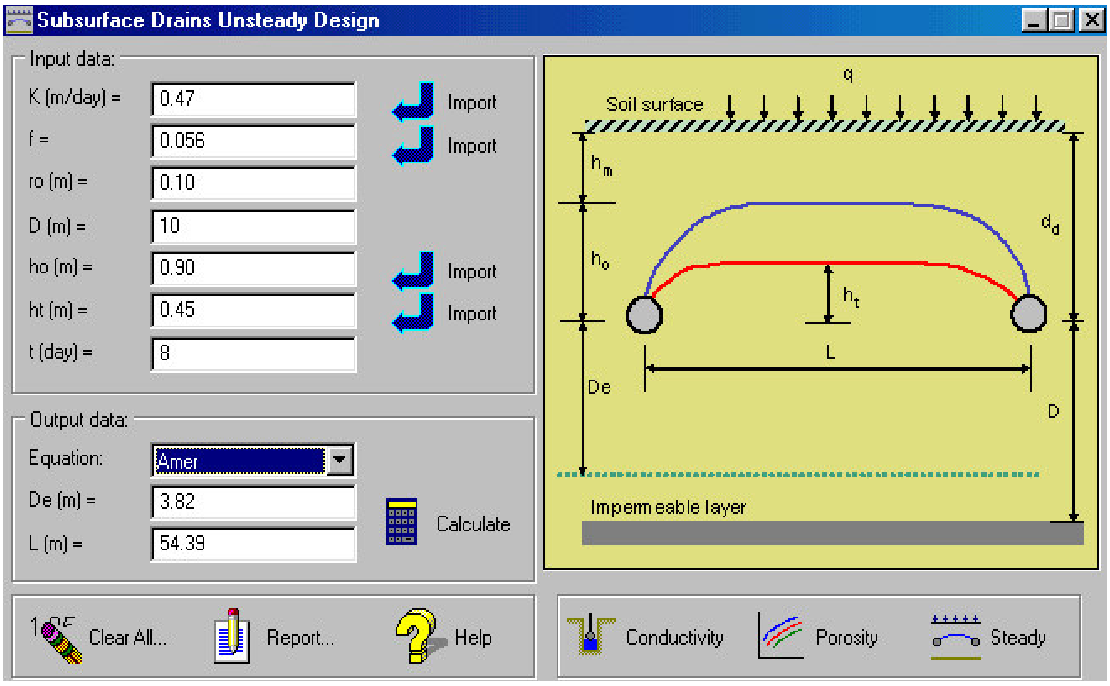

Figure 2. The unsteady state design module.

RESULTS AND DISCUSSION

The work process of design and preparation of drainage project was divided into a number of partial processes from planning to the actual design. In the design process, a number of different separate stages can be distinguished: planning of the design activities, preparing maps, field investigation, processing field data and design spacing between field drains and overall activities. In this study, it will concentrate on the processing of the data and the design of the spacing between lateral drains. Especially, for that, it was designed supportive tool which is called SSDP-programme. It has calculating the hydraulic conductivity and drainable porosity which used for the design the spacing between the lateral drain by the equation of the steady and non-steady state condition.

The hydraulic conductivity measured in the study area varied from 0.12 to 2.50 m/day (unreliable values were omitted). Consequently, the calculated spacing between lateral drain by using the steady state equation ranged from 30 to 238 m and by using the non-steady state equation from 20 to 113 m (as shown in table 1). When an average value of hydraulic conductivity was considered (1.12 m/day), the calculated spacing was 230 m by using steady state equation while it was 65 m by using non-steady state equation.

On the other hand, the actual spacing which applied by the EPADP for this area was rounded of 50, 55 and 60 m, which was justified by economy and a practical use. This was nearly close with the theoretical design by the non-steady state equations of Amer and Glover-Domm as shown in table-1.

The drain spacing calculated from the steady state equation is very far from the actual spacing taken from the EPADP and also very far from the spacing calculated by the non-steady state equation. This in fact because the irrigation processes is generally distinctly unsteady in nature. Steady state criteria are also unsatisfactory in situations where the soil hydrological conditions are such that water-tables and drain-outflow respond directly and quickly to recharge, rather than the response being moderated. In all of these cases the unsteady drainage formulae are of value. Also, it can be seen from the table that, for lower values of hydraulic conductivity, 0.001 m/day, (heavy clay soil or poorly soil), the calculated spacing by the steady state equation are near to the value of the spacing calculated by the unsteady state equation. This in fact that, the flow motion of the drainage water is very slow and the draw down ratio h_o/h_t is very small. In the opposite of that, for higher value of the hydraulic conductivity, 4.5 m/day, (coarse sand), the calculated spacing by the steady state equation are very far from the value of the spacing calculated by the non-steady state equation.

From the aforementioned results, it can be concluded that, the unsteady state approach is more practical and near to the concepts of the EPADP design. So, it must be applicable for the general design in Egypt especially after the SSDP introduced.

Recently, the design in Egypt focused on reducing the manual computations and the errors related to the design of the drainage system and the storage and retrieval of data. The quality of the maps was further improved by using digital basic maps and by upgrading drawing techniques. After the preparation of personal computers, a group of computations programs SSDP, DESIGN, PLOT and LIST was developed. These programs focused on the computations of the vertical components in the drainage design, the longitudinal profile, lists of quantities, topographic levels in the design of drainage digital data had to be available and the boundary conditions for the set of the application had to be made.

CONCLUSIONS AND RECOMMENDATIONS

1- The SSDP program consists of four separate modules: the hydraulic conductivity module, the drainable porosity module, the steady state design spacing equation module and the unsteady state design spacing module. It is simple and easy-to-use, yet powerful, computer solution to the exercise of the subsurface drainage system in Egypt.

2- The actual spacing must be adopted as the spacing obtained from the theory of unsteady state concept. It is nearly close to the spacing used by the EPADP.

3- The SSDP program is the easiest way for the design of the drainage system by both steady and unsteady state concept. This encourages the designer engineers to use the unsteady state equation for the design of the drain spacing under the actual field conditions.

4- By using the SSDP program, it can be compared with the design spacing of steady and unsteady state equation. Also, it can be compared with the different equations of the unsteady states.

5- From the aforementioned results, it can be recommend that, the unsteady state approach is more practical and close to the concepts of the EPADP design. So, it must be applicable for the general design in Egypt especially after the SSDP had been introduced.

REFERENCES

1. Amer, M.H. 1965. Proposed drain spacing equation for transient the drainage and Comparison with existing equations, unpublished thesis for Ph.D., University of California, Devis.
2. Amer, M.H. and Luthin, J.N., 1967. Proposed drain spacing equation and an experimental check of transient equations, with the Hele-Show model. International Soil Water Symposium, Czechoslovak National Committee, ICID, Prague.
3. Amer, M.H., and Ridder, N.A., 1989. Land Drainage in Egypt. Cairo, Egypt, pp. 74-93.
4. Abu-Zeid, M., 1992, 5th Annual Workshop- Subsurface Drainage on Proplematic Irrigated Soils: Sustainability and Cost Effectiveness Feb. 8-15, Lahore, Pakistan.
5. Dielman, P.J. (Chairman), 1980. Expert conclusion on Drainage Design Factors. FAO, Irrigation and Drainage paper no. 38. Rome Italy.
6. Luthin, J.N., 1957 (Editor). Drainage of Agricultural lands. The American Soc. of Agronomy, Madison, Wisconsin: 81-91.

7. Nasralla, M.R., 2003. Development of Hydrophysical Parameters for Design of drainage system in Egypt. Ph.D. thesis, Ain Shams University, Cairo, Egypt.
8. Ritzema H.P., 1990. Subsurface flow to drains. Drainage Principals and Applications. ILRI Publication 16. Second Edition, pp. 263-304.
9. Shenouda, N. et al., 2006. Computer Aided Design of Subsurface Drainage Design Systems. Unpublished Lectures on Farm Water Management Course, Cairo, Egypt.