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CALCULATION OF A HYDRODYNAMIC MODEL FOR CONTROLLING THE MOISTURE TRANSFER REGIME

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Abstract
The most important task of hydrodynamic forecasts in connection with land reclamation is to predict changes in the groundwater regime and control the moisture transfer regime in the upper layers of the aeration zone. In this regard, for the development of hydraulic models of moisture transfer, it is necessary to take into account the physico-mechanical properties of soil, hydrophysical characteristics of soil type, conditions for moisture entry into soil [1,2].
It is known that the soil is a dispersed body, i.e. it consists of a large number of particles of different sizes, mostly small and very small. The consequence of this is the well-known fact that the soil is a porous body, i.e. permeated in all directions by a large number of interconnected gaps between particles. It is in these gaps-pores that the moisture that enters the soil or into the ground accumulates [3,4]. The article describes comprehensively study of the processes of forecasting changes in the groundwater regime and control of the moisture transfer regime in the upper layers of the aeration zone.

Keywords Moisture transfer regime, aeration zone, soil moisture, hydraulic model of moisture transfer, Prandtl number, Peclet criterion, Reynolds criterion.

INTRODUCTION

Due to the fact that soil pores are mostly small in size, the effect of water entering the pores differs in a number of features. In this regard, the only thing that can be established by simple observation is that the larger the pore size, the coarser the mechanical composition, i.e. these are large particles that make up the soil. [5,6]. During the simulation, it was assumed that the particles are evenly spaced with respect to each other. In other words, we presented the soil porosity in the form of a spatial three-dimensional grid consisting, as it were, of nodules (pores) of various shapes and sizes connected to each other by constrictions (narrower passages between the pores).

The purpose of the research was to create a hydraulic model describing the relationship of the moisture transfer regime using the full-scale parameters of the object of study, the dynamics of moisture changes in hydromorphic media for an arbitrary moment of time caused by changes in the groundwater level and the establishment of its adequacy were considered [7,8]. Since the problem of establishing the relationship between surface and groundwater in the tasks of land reclamation and engineering hydrology arises quite often, conducting field research to establish this relationship is a time-consuming and expensive undertaking. Therefore, an urgent task is to develop a hydraulic model that adequately describes this relationship. Numerical verification of the simulation results was carried out on the basis of data obtained during field research in the farm "Karshiev Temurbek" located in Kashkadarya region

MATERIALS AND METHODS

In the numerical implementation of the hydraulic model of moisture transfer (1), developed during scientific research, the full-scale parameters of the object of study were used. That is, field studies have established that the area of the experimental site is 6 hectares, the mechanical composition of the soil is light and medium loam, the fractional composition is from 0.001 to 0.25 mm. It was also found that within the study area, the depth of groundwater is on average one and a half meters. Capillary rise height $H = 149\,sm$. Using the formula for determining the capillary rise height for unsaturated rocks $H = -\psi + z$; by $z = 150\,sm$, we find the suction height $\psi = 1$. The suction height at full saturation is zero. With decreasing humidity, the suction height increases in absolute value.

$$\theta\left(\hat{z},\tau\right) = \frac{e^{-\gamma\tau}}{\Delta_0}\left\{\left[exp\left(\frac{Pe(1-\sqrt{D})}{2}\overset{\wedge}{\psi}\right) - exp\left(\lambda\overset{\wedge}{\psi}\right)\right]exp\left(\frac{Pe(1+\sqrt{D})}{2}\hat{z}\right) + + \left[exp\left(\lambda\overset{\wedge}{\psi}\right) - exp\left(\frac{Pe(1-\sqrt{D})}{2}\overset{\wedge}{\psi}\right)\right]exp\left(\frac{Pe(1-\sqrt{D})}{2}\hat{z}\right)\right\} \quad (1)$$

where: $D = Pe^2 - 4\gamma Pr$, here, $Pr = \frac{Pe}{Re}$ - the Prandtl diffusion number, $Re = \frac{u_{фил}l}{\kappa_0}$ Reynolds number and $Pe = \frac{u_{фил}l}{\kappa}$ - the Peclet number, empirical coefficients: $\gamma = 3{,}5$ and $\lambda = 1$

Dependence of the suction height on humidity $\psi(\theta)$ is different in different breeds and is determined experimentally. For our calculations, this dependence is presented in the form of the following relations:

$$\psi = 2H_k(1-\theta) + H_0 \qquad \overline{\theta} = \frac{\theta-\theta_0}{\theta_m-\theta_0} \qquad (2)$$

Where: θ - soil moisture; θ_m - full moisture capacity; θ_0 - humidity corresponding to the maximum molecular; H_k - the reduced height of the capillary rise; H_0 - pressure surge at full saturation.

RESEARCH RESULTS

It should be noted that the relationship between suction height and humidity is ambiguous. Thus, when draining a pre-fully saturated rock, the relationship between humidity and suction height is characterized by a curve, where each value ψ corresponds to the maximum possible humidity value.

In the reverse process, when dry soil is moistened, minimum humidity values are characteristic for the same suction heights. These two curves form two main branches of hysteresis. We all know that the sorption of water vapor by soil, like many other adsorbents, is accompanied by the phenomenon of so-called hysteresis. This phenomenon consists in the fact that if we saturate the same canopy of any soil with moisture at the beginning, placing it sequentially in a series of spaces with increasing relative humidity and bringing it to full equilibrium in each space, and then we will dehydrate the same canopy by placing it in the same space, but in the reverse order, i.e. with decreasing relative humidity, then in the second case (i.e. during dehydration), the amount of sorbed moisture at the same relative humidity will always be higher than in the first (i.e., during watering). The change of drying and humidification processes forms an infinite set of hysteresis sweep curves in the area bounded by the main branches of dependence $\psi(\theta)$.

The moisture transfer coefficient is also significantly dependent on humidity. This dependence relates the moisture transfer coefficient and humidity to a power function:

$$\kappa = \kappa_0 \overline{\theta^n} \qquad (3)$$

Where: κ_0- filtration coefficient.

For homogeneous soil, n varies from 1 to 4. However, in heterogeneous soil, the degree index can be significantly higher.

To determine the value of the filtration coefficient, there are various methods:

a) the method of field research;

b) the method of laboratory research;

c) the method of using empirical formulas.

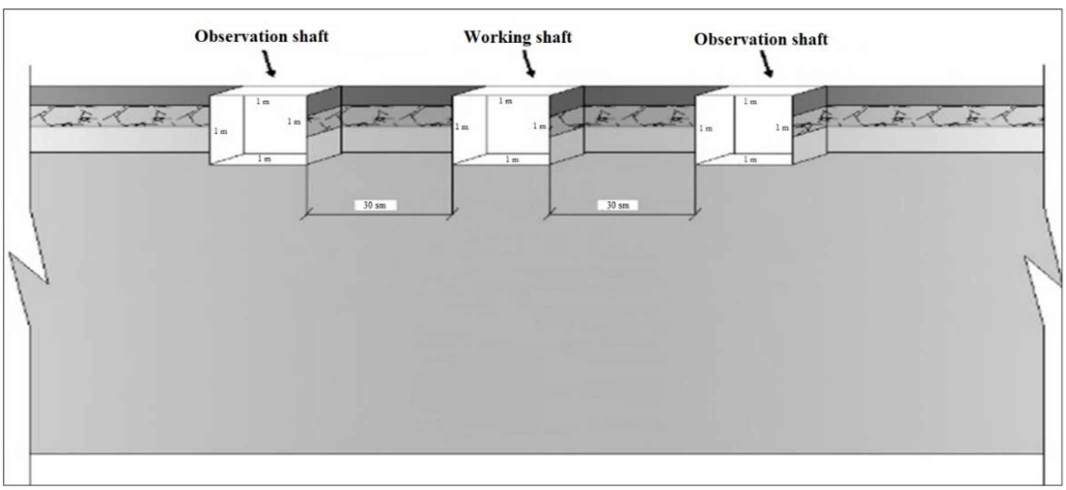

Fig. 1 - Schematic view of field research

The field research method was used to find the value of the filtration coefficient. To do this, we drilled 3 shafts in the form of a single cube (with a volume of 1 m^3) to the studied soil at an experimental site with a distance of 0.30 meters (Fig.1).

The slope of the bottom of the observation shafts was lowered by 10 sm. by leveling. Then a 40 cm layer of water was poured into the working pit and a constant level was maintained by supplying water (in a volume of 0.2 liters). The research was carried out until water (a wet spot) appeared on the walls of the observation pits. That is, 39 hours later, a wet spot appeared on the walls of the observation shafts. Using a well-known formula to determine the filtration rate:

$$u_{filtration} = \frac{s}{t} = \kappa_0 \frac{H}{l} \qquad (4)$$

where: $t = 39\ hours$- time of appearance of water (humidity) on the wall of the observation shaft;

$H = 39{,}5\ sm$- the difference between the marks of the water surface in the working pit and the wet spot in the observation shaft;

$l = 30\ sm$- the distance between the walls of the working and observation shafts;

$s = \sqrt{l^2 + h^2} \approx 30\ sm$- the shortest path traveled by water from the working shaft to the observation shatf;

$h = 0{,}5\ sm$- the difference between the marks of the bottom of the working shaft and the wet spot.

DISCUSSION

Considering the full-scale data and formulas (3) and (4), for medium loamy soils, the following values were obtained:

$$u_{filtration} = 0{,}77\frac{sm}{hour}\ , \kappa_0 = 0{,}585\frac{sm}{hour} = 0{,}14\frac{m}{day}, \overline{\theta} = 20{,}44\ , \kappa = 11{,}96\frac{sm}{hour} \quad (5)$$

Before proceeding to the numerical implementation of equation (1), it is necessary to determine the numerical values of geohydrodynamic similarities. In this regard, using the parameters of field studies and (5), we obtain:

$$Pr = 0{,}49\ , Re = 39{,}5 \text{ and } Pe = 19{,}31. \quad (6)$$

Given the equations (1), (5), (6) after the appropriate mathematical transformations, we obtain the solution of equation (1). They are presented in the form of graphs (Fig.2-9).

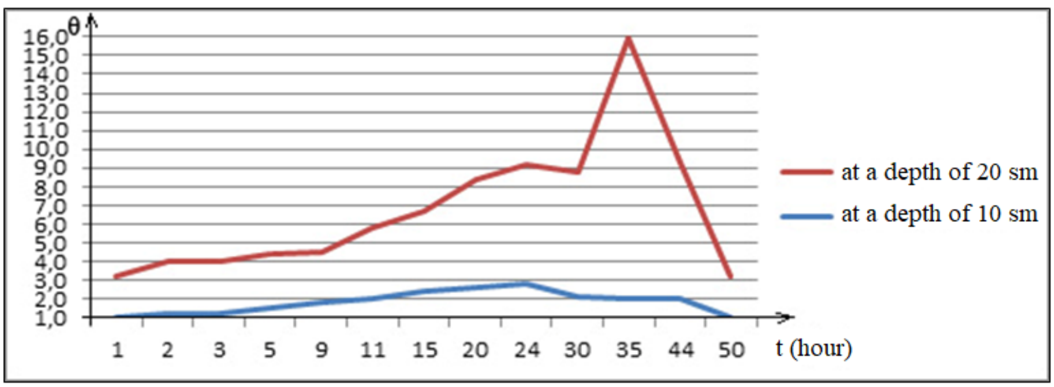

Fig 2. - Graph of the function $\theta(\tau, z)$ at a depth of up to 20 cm.

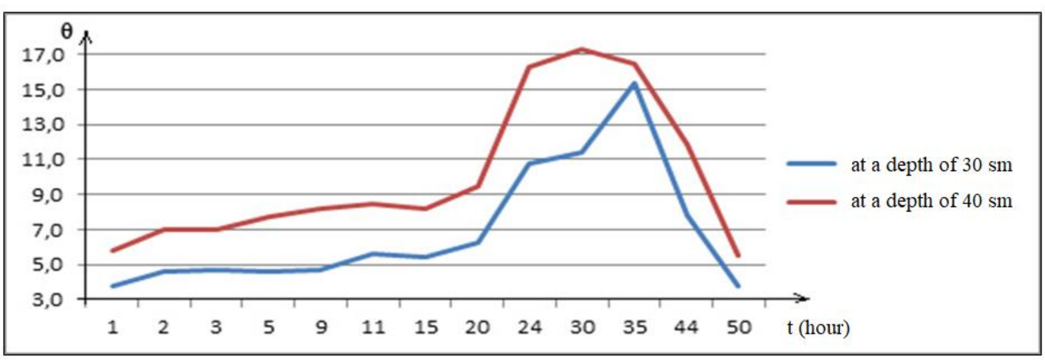

Fig 3. - Graph of the function $\theta(\tau, z)$ at a depth of up to 40 cm.

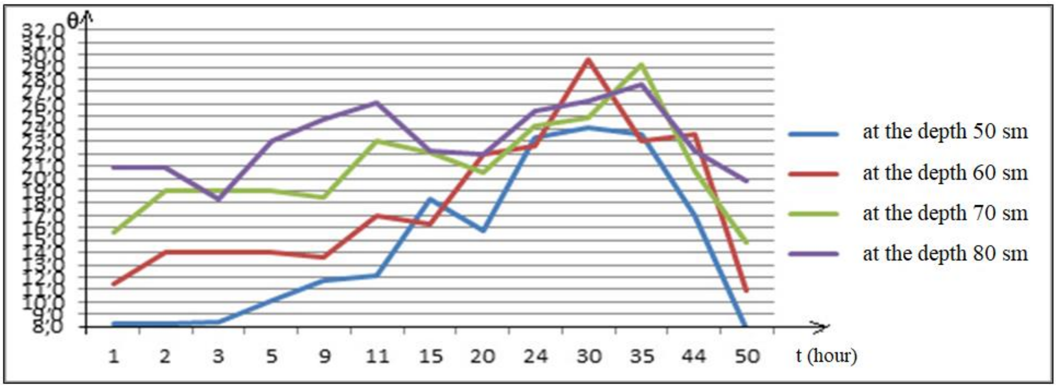

Fig 4. - Graph of the function $\theta(\tau, z)$ at a depth of up to 80 cm.

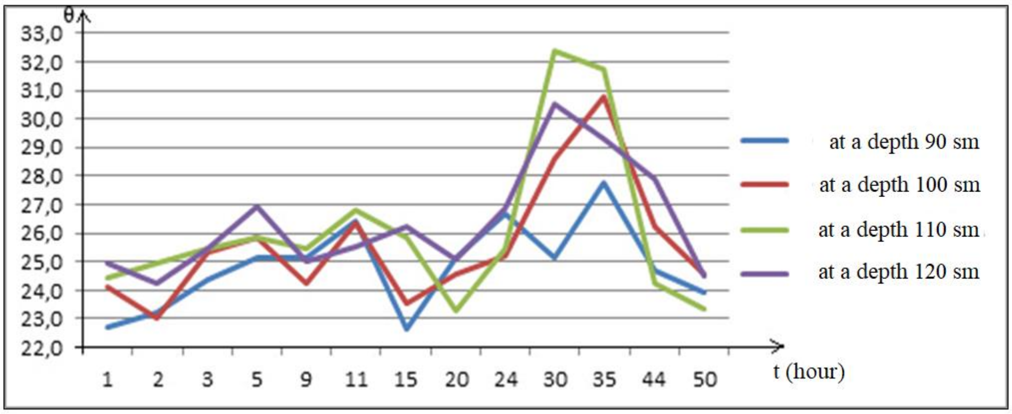

Fig 5. - Graph of the function $\theta(\tau, z)$ at a depth of up to 120 cm.

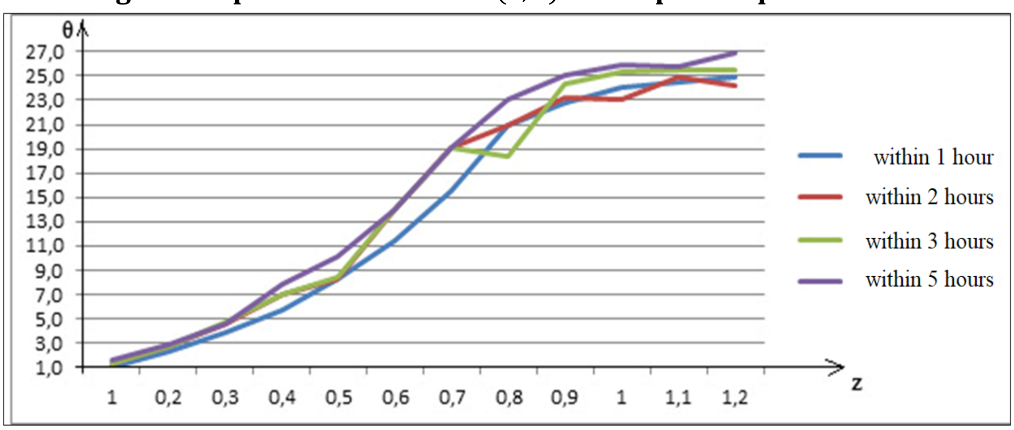

Fig 6. - Graph of the function $\theta(\tau, z)$ for 5 hours.

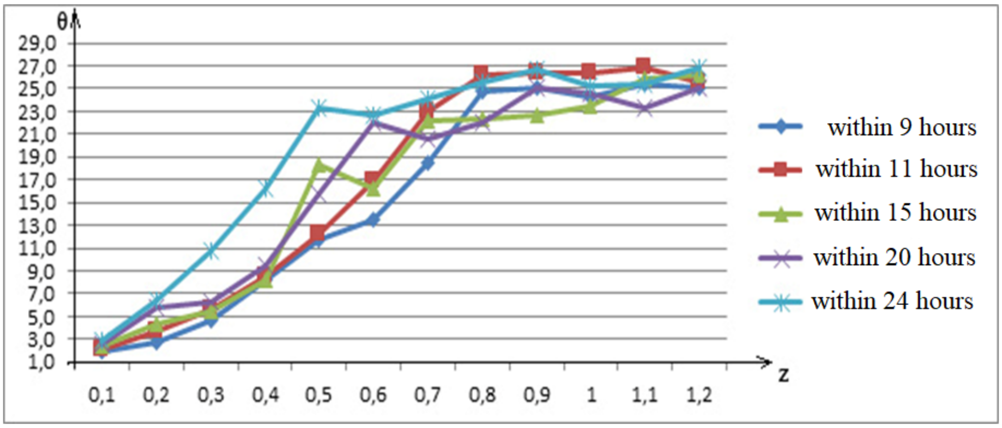

Fig 7. - Graph of the function $\theta(\tau, z)$ for 24 hours.

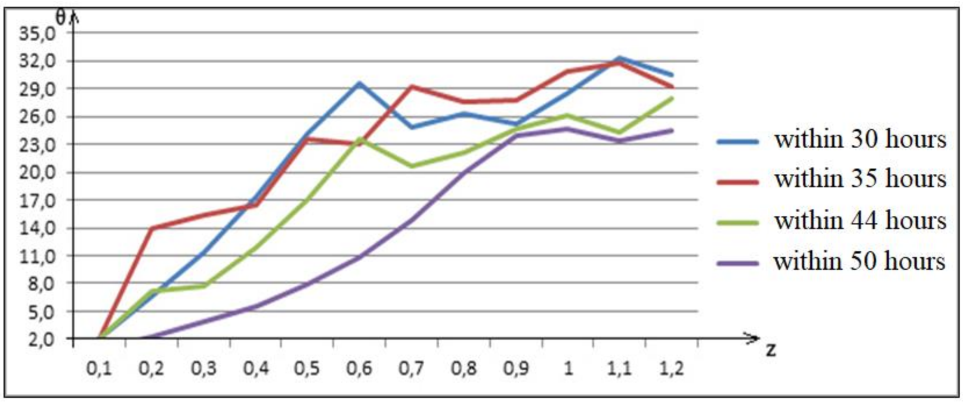

Fig 8. - Graph of the function $\theta(\tau, z)$ for 50 hours.

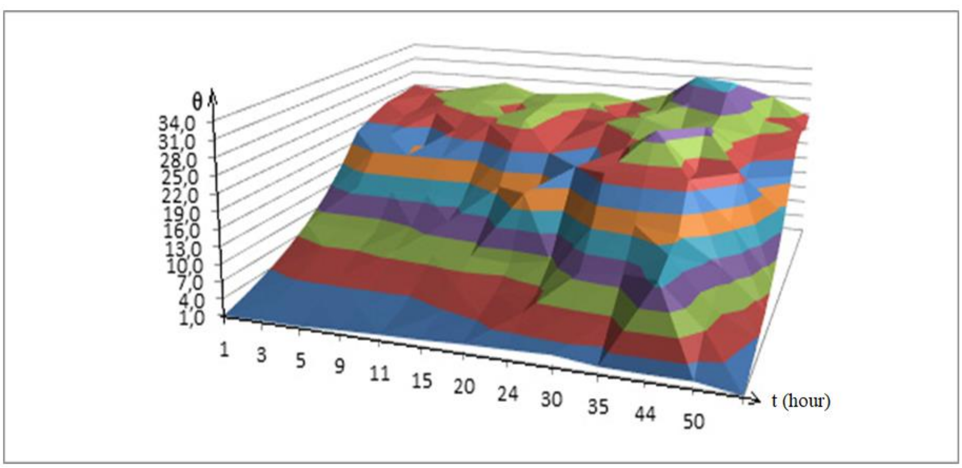

Fig 9. - Graph of the function $\theta(\tau, z)$

CONCLUSION

A numerical experiment of a hydraulic model for controlling the moisture transfer regime using the full-scale parameters of the object of study is performed, the dynamics of moisture changes in hydromorphic media for an arbitrary moment of time due to changes in the groundwater level is considered

The obtained patterns of changes in soil moisture allowed us to establish the nature of changes in moisture transfer at various depths of the soil cover.

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