Underground Water Resources Management for Flooding Prevention

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Olena Sierikova
Applied Mechanics and Environmental Technologies Deptartment
National University of Civil Defence of Ukraine
Kharkiv, Ukraine
sierikova_olena@ukr.net

Elena Strelnikova
A. Pidhornyi Institute of Mechanical Engineering Problems NAS of Ukraine
Kharkiv, Ukraine
elena15@gmx.com

Kyryl Degtyariov
A. Pidhornyi Institute for Mechanical Engineering Problems NAS of Ukraine
Kharkiv, Ukraine
kdegt89@gmail.com

Abstract—**Technogenic factors that affect urban area flooding development, forecasts of improving groundwater level changes, and comprehensive management of urban groundwater must be taken into account and controlled. A three-dimensional mathematical model of groundwater level changes in cities has been developed, which takes into account atmospheric water infiltration, additional groundwater replenishment, transpiration, evaporation, evapotranspiration, and groundwater intake.**

Keywords—flooding; grounwater level; environmental safety; flooding prediction; additional infiltration

I. Introduction and Literature Review

Flooding is one of the most widespread modern exogenous geological processes that develops both under natural conditions and under the influence of technogenic factors. Technogenic factors are often decisive. The essence of this process is an increase in the groundwater level due to a violation of the territory water balance, which reaches critical values and requires the use of protective measures. This process is classified as one of the most dangerous for human life [1,2].

It is known that the flooding process causes and activates a number of dangerous geological processes. Therefore, the flooding intensification, which has been taking place within certain regions of Ukraine in recent years, is a real threat to the safety of the population and the functioning of numerous economic facilities. In this regard, the issue of studying the conditions of development and distribution of flooded areas within the entire territory of the state, as well as the organization of monitoring thereof, becomes a priority and urgent. Under the growing influence of technogenic factors, there is a tendency to expand the areas of flooding and the negative impact on the environment [3,4].

Underground water regime violation and the flooded territories development and expansion are the result of water losses from water supply communications, lack of stewardship towards the territories being developed, non-compliance with the legislation requirements in the design and construction of new facilities, non-implementation of state plans and programs due to insufficient funding, timely investigations, absence of retrospective analysis of the engineering and geological conditions of the built-up areas, the absence of high-quality long-term forecasts [5].

It is necessary to take into account technogenic factors that affect the flooding development of the urban area, improve forecasts of groundwater level changes, and comprehensive management of urban groundwater. [6].

In papers [4,7], a system for managing the flooding of urban areas has been proposed, which includes management and engineering measures to prevent and eliminate the flooding consequences, as well as an algorithm of actions during the monitoring of the groundwater level on flooded and potentially flooded areas.

The issue of groundwater flow has been discussed by many scientists from different aspects, for example, Klute [8] reduced the diffusion equation to an ordinary differential equation and applied the method of direct integration and iteration of the resulting equation, Verma [9] has obtained a solution to the equation describing the one-dimensional supply of groundwater for constant diffusion and linear conductivity using the Laplace transform. Prasad et al. [10] has created a numerical model for simulating moisture flow through unsaturated zones using the finite element method. Desai [11] has obtained a composite solution for the expansion of groundwater in the vertical direction. Shah K. and Kunjan T. [12] have obtained the solution of the Burger equation for the description of a one-dimensional reserve of groundwater by diffusion in a porous medium. Joshi and others [13] have gained the solution of the equation for one-dimensional vertical groundwater recharge using a group theoretical approach. Nasseri et al. [14] have investigated the solution of the advection-diffusion equation based on the simplified Brooks-Corey model for soil conductivity and diffusion.

Koohestani N. has treated only natural factors affected on groundwater and based on this data made a prediction of changes in the groundwater balance [15].

II. METODOLOGY

A. *Problem Statement*

In contrast to the authors' previous studies [1-7], this paper considers the issue of forecasting changes in the groundwater level in a three-dimensional setting.

The filtration pressure equation in the follow form has been considered

$$\gamma^2 \frac{\partial^2 h}{\partial y^2} + \frac{\partial^2 h}{\partial x^2} + \frac{\partial^2 h}{\partial z^2} = 0. \qquad (1)$$

Where *h* is the groundwater level, *x*, *y*, *z* are coordinates have been shown at Fig. 1, γ is the anisotropy coefficient.

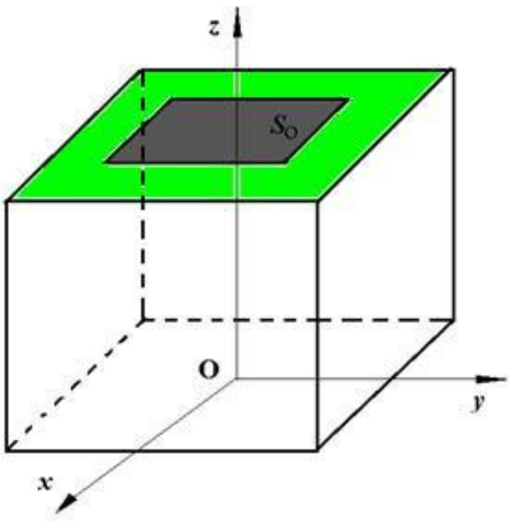

Figure 1. Calculation area to determine the groundwater level

The boundary conditions for equation (1) have been formulated, which include the artificial coverings presence, natural infiltration, evaporation and transpiration, as well as the effect of evapotranspiration. These conditions have been corresponded to the unknown function values, or its normal derivative at the boundaries of the computational domain. The rectangular parallelepiped has been assumed as the computational domain. The lower and upper faces of this parallelepiped are rectangles S with sides $[2a, 2b]$.

III. RESULTS AND DISCUSSION

Mathematical models in 2D and 3D formulation work from any value of initial groundwater level.

Therefore, the groundwater level changes values obtained at 3D simulation are less than ones that have been gained as the calculations result carried out according to the two-dimensional theory. Therefore, data of 2D simulation could be applied as an upper bound for groundwater level changes estimation. Groundwater level changes at other values of the present demonstrated the similar behavior. These data have been shown at Fig. 2.

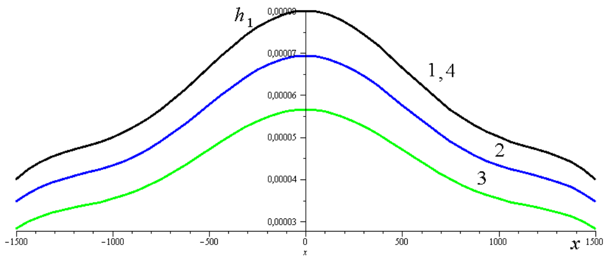

Figure 2. Groundwater level changes at other values of y.

Groundwater level changes at *y*=–2 and different values of z have been presented at Fig. 3.

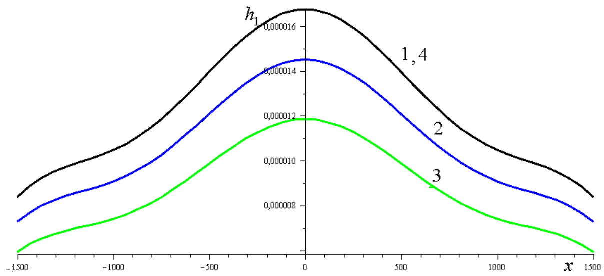

Figure 3. Groundwater level changes at *y*= -2 and different values of z.

Three-dimensional modeling of the groundwater level changes, in contrast to the two-dimensional one, allows to take into account the evapotranspiration dependence on the artificial covers presence on the soil surface, which are unevenly located and have different filtration coefficients and caused corresponding changes in the urban groundwater level.

IV. CONCLUSION AND FURTHER RESEARCH

A three-dimensional mathematical model of groundwater level changes in urban areas has been developed, which takes into account atmospheric water infiltration, additional groundwater replenishment, transpiration, evaporation, evapotranspiration, and groundwater intake. The boundary conditions of the three-dimensional mathematical model have been formulated. The analytical solution of the differential filtration equations has been solved using the Maple computer program to create a model of groundwater level changes.

In three-dimensional modeling of the groundwater level changes processes, outcomes have been gained with a lower rise in the groundwater level than the calculation result has been obtained according to the two-dimensional theory, due to the consideration of changes in parameters in different areas. . Therefore, 2D modeling data could be used as an upper bound to estimate the groundwater level changes and 3D modeling for more accurate estimation.

It is planned to develop more accurate models of groundwater level changes over time, as well as a groundwater level management system that takes into account additional technogenic factors of water level changes.

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