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The Application Of Spatial Analysis And GIS Modeling At The Stage Of Solving The Reverse Problem In Mathematical Modeling Of Geofiltration

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SUMMARY

In order to effectively manage the water resources, the qualitative and quantitative indicators are estimated using the mathematical models. At the same time the application of these models on the local areas becomes more complex due to the lack of detailed information about the groundwater. For this purpose, the authors studied the functionality of GIS application in the process of mathematical modeling of geofiltration.

To provide the reliable approximation of the discrete entrance data, necessary for building the geofiltration model at the stage of solving the reverse problem in mathematical modeling of geofiltration, in particular, the coefficients of transmissibility, porosity and hydrodynamic pressures, the authors propose to apply the following modules «Darcy Flow» and «Darcy Velocity» with the modules «Particle Track» and«Porous Puff» ArcGis software. These modules are intended for elementary mathematical modeling of groundwater movemnets based on the total water balance. Their application allows reasonbly to accomplish the approximation of discrete entrance hydrogeological data and obtain the relevant and constant raster models of geological and physical fields. This approach reduces the time of solving the reverse problem, comparing to the traditional method, when the result is obtained by successive substitution method and the rialability is based upon the general hydrogeological concerns.

Introduction

The basic method for a prognostic change of groundwater level (a hydrodynamic pressure) as a result of technogenic influence, is the method of mathematical modeling of geofiltraion (Koshliakov et al., 2010). At such modeling, the geofiltration equations are solved in relation to unknown dynamic function (a hydrodynamic pressure and expenditures of groundwater flow), using the approximate numerical methods and finite difference method in particular. This method is realized in Processing Modflow (PMWIN) software.

Method and/or Theory

There are four types of problems, which are solved at mathematical modeling of geofiltraion: direct, reverse, inverse and inductive problems.

The direct problems are aimed at determination of unknown dynamic function at the investigated area with the given size of a modeling object, geofiltrating parameters of the environment and known area conditions. In general, these are prognostic problems. In geological science, the reverse, inverse and inductive problems are considered as one term - "the reverse problem". It is related to the fact that all the similar problems are often solved successively for the one and the same territory, gradually improving and specifying the model of geofiltration (Chomko et al., 2019). The reverse problem precedes the direct one.

The solving of the reverse problem reduces to finding such distribution of geofiltration parameters and value of groundwater nutrition and discharge (including those, which characterize the interactions between groundwater and surface water), where the difference between the model value and location value of hydrodynamic pressures, and pressure gradients between the water flow horizons and slopes at single horizons being modelled, will be minimal (Koshliakov et al., 2019). This procedure is called the model identification. Identification here means the justification of model relevance to the natural or technogenic conditions.

The basis of natural hydrogeological model is information, which is obtained after analysis of available reserves and, mainly, after special hydrogeological fieldworks. In general, this information deals with the geological structure of the area, the conditions of location and spreading of aquifer and non-easily penetrable watertable, the location of tectonic disturbances and their hydrogeological impact, the main sources of groundwater formation, the conditions of groundwater nutrition and discharge, the main hydrogeological parameters of aquifer and non-easily penetrable watertable and the patterns of their change in plan and section, the surface water objects and conditions of groundwater and surface water interactions, the structure of aeration zone and conditions of precipitation's infiltration, anthropogenic sources of groundwater nutrition and discharge. Furthermore, this information is sufficient for describing the functioning of hydrodynamic pressures and flow expenditures, conditions and value of groundwater nutrition and discharge under the influence of natural and anthropogenic factors as well (Drobnokhod, 2008). In fact, the hydrogeological model is the complex of maps, sections and graphics.

Subsequently, the natural model is transferred into geofiltration model, in which the natural hydrodynamic conditions are formalized by the determining of the main factors forming the groundwater (aquifer and non-easily penetrable watertable, their borders, sources of nutrition, distribution of geofiltrating parameters etc.). It is the geofiltration model which is transferred into mathematical calculation model, which counts the filtration regime, the necessary amount of layers in section, the planned layout of filtration area into calculation blocks. But also the boundaries of filtration area are fixed, the area conditions and calculation value of geofiltration parameters.

In determined mathematical modeling of geofiltration it is counted that the groundwater flows are the determined systems and can be characterized by the complex of geological and physical fields and their boundaries conditions (Drobnokhod, 2008). These fields characterize the filtrating and volume parameters of aquifer and non-easily penetrable watertable and hydrodynamic pressures of groundwater. The complex of these fields determines the structure of hydrofiltration flows and conditions of groundwater motion. Thus, the reliability of sketching of hydrofiltration conditions is determined by the objective mapping of these fields.

Since the mentioned fields interact between each other and have the interrelated structure, their one and the same changes can be caused by different reasons. This convergence of fields, when one and the same structure and change can be determined by the influence of different factors, is the result of polyfactorial conditions of their formation.

In difficult hydrogeological conditions, emerged in the result of the technogenic impact, the information characteristics of proportions between the geological and physical fields cannot be often provided by the sufficient volume of reference values at observation points. It arises the question of reliable approximation of discrete entrance data, which are used at subsequent transfer from the discrete (at observation points) to the constant (at the maps, models, sections, schemes) information while solving the reverse problem.

Examples (Optional)

To provide the reliable approximation of discrete entrance data which are necessary for building the geofiltration model at the stage of solving the reverse problem, in particular, the coefficients of transmissibility, porosity and hydrodynamic pressures (the layers of ground water), the authors propose to apply the following modules «Darcy Flow» and «Darcy Velocity» with the modules «Particle Track» and «Porous Puff» ArcGis software. These modules are intended for elementary mathematical modeling of groundwater movements based on the total water balance. Their application allows reasonably (from the hydrodynamic point of view) to accomplish the approximation of discrete entrance data and obtain the relevant and constant raster models of geological and physical fields.

This approach reduces the time of solving the reverse problem, comparing to the traditional method, when the result is obtained by successive substitution method and the reliability of data is based upon the general hydrogeological concerns.

Below, it is illustrated the results, obtained by the authors while realization of the mentioned approach, in modeling the groundwater flow motion at one of the built-up areas in Kyiv.

Figure 1 demonstrates the raster map of the field of hydrodynamic pressures (layers of groundwater). The picture was obtained by the discrete number of the observation points. The approximate method of inverse distance weighting was applied. This field is basic one for solving the reverse problem.

The fields of hydrogeological parameters were corrected in a way to provide a map of the water balance on the particular territory, which is relevant to the conditions of the laminar flow taking into consideration the conditions of waterground flow nutrition and discharge. The map of the water balance was checked by module Darcy Flow and given on the figure 2.

While checking the model balance by the module Darcy Flow it was taken into account the geological and lithological structure of the area, the conditions of location and spreading of aquifer and non-easily penetrable watertable, the patterns of their change in space.

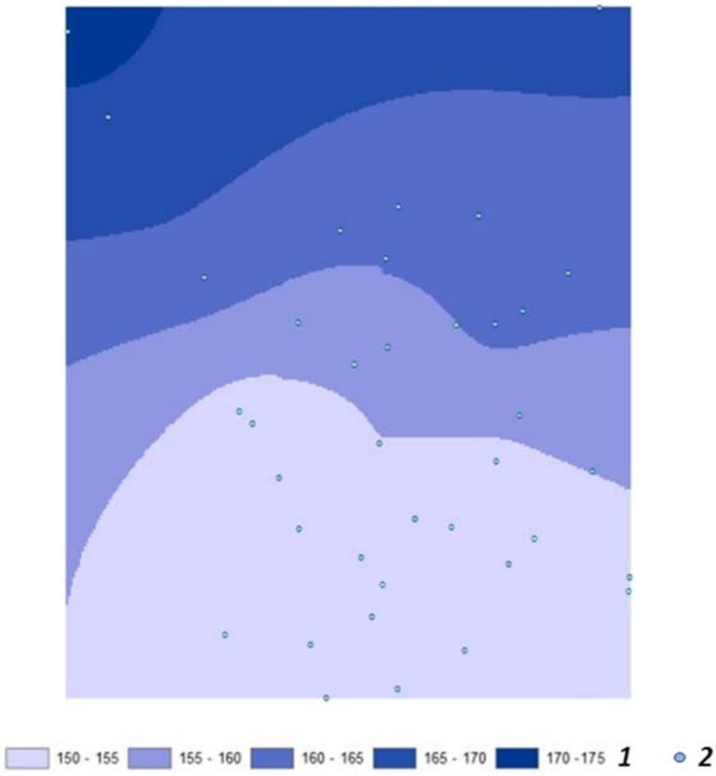

Figure 1 *The raster map of the field of layers of groundwater. 1 – layers of groundwater; 2 - wells*

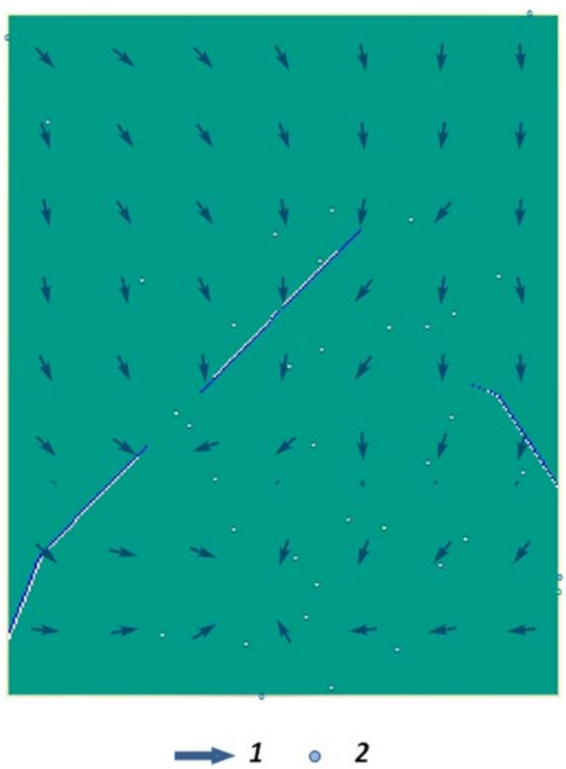

Figure 2 *The map of the water balance was checked by module Darcy Flow.*
1 – vector of Darcyr; 2 - wells

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