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Optimization of the drainage system of overburden dumps using geofiltration modeling

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ABSTRACT

The article describes the assessment of the predicted water flows at the site of the projected rock dumps, which was carried out using geofiltration modeling. When developing the model, we used actual data on capacities, filtration coefficients and water capacity, roof and sole marks of the selected aquifers, precipitation infiltration, as well as the projected dumps are located on the slope surface. We schematized hydrogeological filtration conditions in relation to existing natural conditions, taking into account the planned construction and operation of dumps, and also determined the maximum water inflow of underground and surface water into the drainage system. Based on the obtained data, the most effective version of the drainage system for the removal of underground and surface water from the territory of dumps has been developed, which will allow to perform the maximum possible interception of the flow of underground water and flood water, to form depression surfaces in the near-slope mass of the body of dumps, to prevent filtration deformations of the ledges and to ensure the normative bearing capacity of rocks. The provided drainage devices will ensure the overall stability of the ledges of the dumps, both during their long standing and during their constant formation.

Keywords: geofiltration model, filtration coefficient, aquifer, groundwater level, quarry, dump, conductivity coefficient, GMS.
Article type: Research Article.

INTRODUCTION

The presented researches relate to the problem of ensuring the safety of open-pit mining operations during the formation of waste rock dumps and their operation in the mountain ranges of ore deposit development areas. One of these areas is the Almalyk ore field, located on the north-western slope of the Kuramin ridge of the Tien Shan to the south-east of Tashkent (Republic of Uzbekistan). The field is composed mainly of intrusive rocks: syenite-diorites; diorites and their erupting granodiorite-porphyry of medium Carboniferous age. Host rocks sand-carbonate deposits, effusive quartz porphyry and andesite-dacite porphyry are less widespread. The development of the field takes place in complex geological and hydrogeological conditions (multi-layered structure of the water-bearing rock strata, lithological and facies variability of aquiferous and poorly permeable sediments in the plan and section, between which there is a hydraulic relationship to a greater or lesser extent, their local distribution). Hydrogeological calculations in such complex conditions can be reliably carried out, obviously, only with the use of numerical modeling methods. Modeling of the geofiltration process allows you to understand the essence of the object more deeply than analytical methods of calculation, to identify its new properties or patterns. This is due to the fact that modeling requires a more detailed analysis of the source information within the entire study area, establishing all the external and internal relationships inherent in the object under study. This makes it possible to better take into account the spatial heterogeneity of the filtration properties and composition of rocks, the complex nature and diversity of boundary conditions, infiltration, overflow, and other factors that are actually inherent in complex hydrogeological objects (Lukner & Shestakov 1976; Khaustov & Ustiugov 2017).

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MATERIALS AND METHODS

The creation of a numerical geofiltration model of the open-pit mining site and the area where the dumps are located is based on the integrated Groundwater Modeling System (GMS) program, which is the most popular for solving a wide range of filtration problems in the United States, Western Europe and Russia (Kinzelbach 1984; Agarkov & Ryazhskikh 2019). The development of the numerical geofiltration model was carried out in two stages:

1. Processing of primary geological, hydrogeological, geological and structural information, as well as new mining and geological and hydrogeological data obtained during further development of the field.
2. Creation of a geofiltration model of the area of the site of the location of overburden dumps.

At the first stage of the model development, the analysis and processing of archival and stock initial hydrogeological and geological information of the studied area was carried out. As the source of information used in reports, databases, cartographic materials, which dumps the plans of the surface and the mining plans of a career.

The hydrogeological model is built taking into account field hydrogeological works, engineering-geological and engineering-hydrogeological surveys, as well as general ideas about the hydrogeological parameters of the territory.

The area of the model constructed in the 2D Grid module was divided into a uniform two-dimensional grid. Using the Map module, the initial topography of the area, maps of the actual material, hydrogeological and other information are directly entered into the model, which eliminates possible distortions when specifying technogenic and natural objects-surfaces.

The geofiltration model of the work area is developed on the basis of the GMS program, which allows to realize stationary and non-stationary three-dimensional filtration of underground water in inhomogeneous aquifers. The flow balance of the model is calculated both as a whole for the entire simulated filtration area, and for its individual zone, which allows us to estimate the total balance of underground water for the simulated area and its required sections.

RESULTS AND DISCUSSION

The calculated vertical schematization was performed by evaluating the filtration mode, the flow dimension, and the inhomogeneity of the host rock massifs. Based on the propagation conditions, the nature of the occurrence, the filtration properties of rocks and the General pattern of decreasing their filtration properties with depth, a design scheme is made up of 7 layers (top to bottom): 1 layer schematized at the dump arrays; 2 layer schematized in square aquifer of Quaternary deposits; 3 layer schematized by the average power of the weathered crystalline rocks (thickness 70 m); Layers 4-7 of crystalline rocks are schematized based on the regularity of reducing the filtration properties of rocks with a depth (thickness from 150 to 250 m). The total capacity of the modeled section is about 920 m. Table 1 shows the filtering coefficients of the modeled layers based on the results of the model calibration.

Table 1. Filter coefficient of the modeled layers.

№ layer	Title	Thickness, м	Filter coefficient Kx=Ky, m/day
1	Technogenic aquifer	-	0.5
2	The alluvial aquifer of the valleys of rivers and streams	5-25	40-70
2	Deluvial-proluvial deposits of slopes	5-50	0.5
3	Zone of weathering of crystalline rocks	70	0.02-0.1
4	Fractured crystalline rocks	150	0.001
5	The upper part of weakly fractured crystalline rocks	200	0.0001
6	The middle part of weakly fractured crystalline rocks	250	0.00001
7	The lower part of weakly fractured crystalline rocks	250	0.000005

All natural hydrogeological environment on the field site and adjacent territory is schematized in the form of a hydraulically interconnected system consisting of non-pressure and low-pressure aquifers. The studied filtration area (14.2 km × 12.0 km) is divided by a rectangular grid. In the section, as noted above, there are 7 calculated layers. The dimensions of the prisms on the x and y axes are 25 m, on the z axis-corresponds to the thickness of the layer under consideration. The diagram of the hydrodynamic model is shown in Fig. 1.

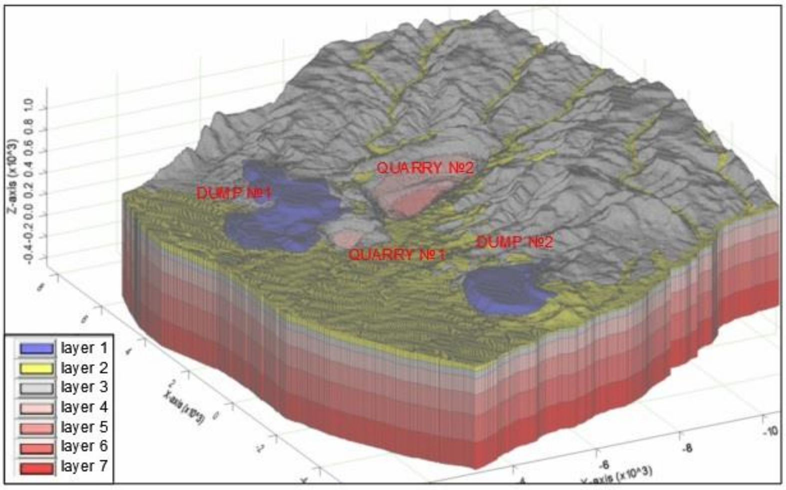

Fig. 1. Diagram of the hydrodynamic model.

The upper outer boundary of the modeling area in the plan is the surface of the aquifer, on which the infiltration feed with a constant flow rate (Q = const) is set in the area of the formation of the groundwater flow. The task of internal boundary conditions for watercourses was performed using the Drain package, which corresponds to the boundary conditions of the third sort [Q = f (H, A)].

Surface reservoirs were defined using the General Head package with boundary conditions of the third sort (Q=f where: H - the water level in the surface reservoir, and A - the characteristic of the integral conductivity of subsurface sediments (m^2/day). The lower bound of the model is set to be impenetrable and is implemented by boundary conditions of the second sort (Q = 0). The lower boundary of the model is the variable mark of almost water-resistant rocks, which corresponds to a depth of about 920 m from the day surface.

Adaptive techniques were used to comply with the condition of continuity of the flow in the areas of wedging of the calculated layers. Fig. 2 shows a diagram of the boundary conditions (Lomakin *et al.* 1988; Surinaidu *et al.* 2014).

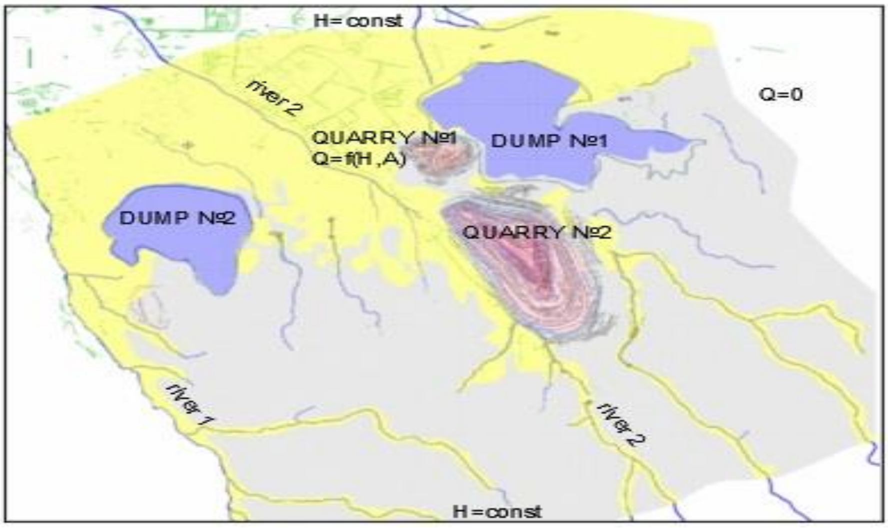

Fig. 2. Diagram of boundary conditions.

The model was calibrated to clarify the parameters of the permeability (filtration coefficient) of aquifers, their anisotropy, the parameters of the relationship between underground and surface water, and infiltration nutrition.

Based on the results of solving more than 20 technological problems on the model, the maximum inflow of underground and surface water into the drainage system of dump No. 2 was estimated at 1085 m^3/h, and 400 m^3/h, respectively, into the drainage ditches (DD) of dump No. 1. Underground water inflows are relatively stable over time and constitute the so-called normal inflow. Surface water inflows, on the contrary, are characterized by significant variability, both in terms of the time of their formation and in terms of volume.

Taking into account the data obtained from the simulation results, the optimal variant of the drainage system for the drainage of underground and surface water was selected. Further optimization was performed considering the design features of the drains in the mountains, technological facilities extended drains, use of natural fracture zones subject to suitable to the contour of the dump geomorphological elements of the terrain. For every particular variant, the model reproduced different scenarios of their effectiveness and then evaluated the economic indicators. The choice fell on the lowest labor-intensive option. In one of the variants on the territory of the dump No. 1, it was planned to build a single drainage ditch along the contour of the dump. Through the drainage ditch (DD), water must be collected in the sump. The layout of the drainage devices on the territory of the dump No. 1 is shown in Fig. 3.

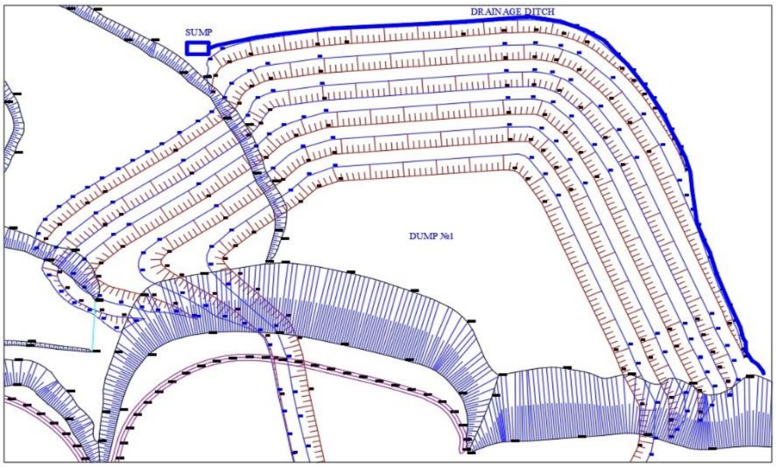

Fig. 3. Layout of the projected dump No. 1 and the drainage system.

On the territory of the dump No. 2, it is proposed to protect it from flooding with the help of eight drainage ditches (DD on the scheme). The layout of the drainage ditches and zumpfs is shown in Fig. 4. Water from the drainage ditches DD-1 – DD-8 is collected in zumpfs, and then from them is diverted outside the mining zone.

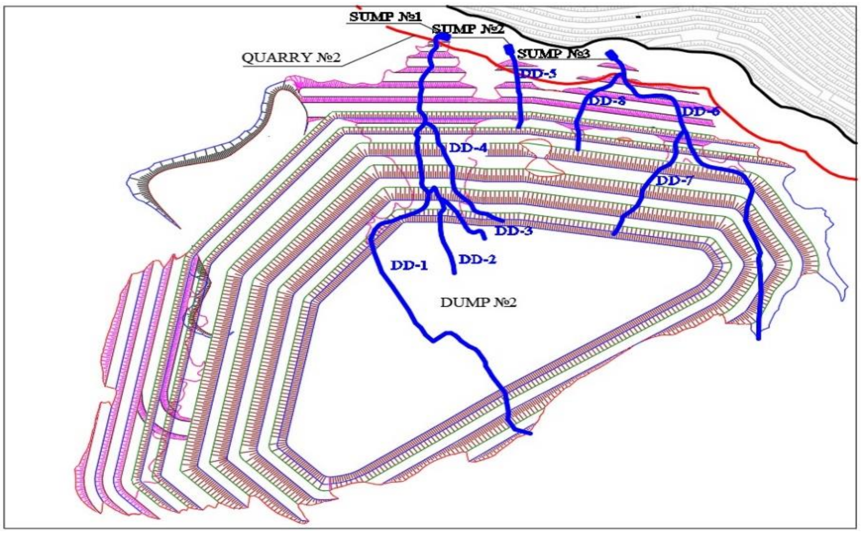

Fig. 4. Layout of the projected dump No. 2 and the drainage system.

CONCLUSION

The researches performed with the help of computer modeling of geofiltration make it possible to make a deeper calculation in comparison with analytical methods, to know the essence of the object, to identify its new features and related patterns, often intangible before the implementation of numerical geofiltration modeling. In our case, the forecast of filtration of underground and surface water in the study area was made according to several decision-making options (more than 20 technological tasks). The obtained results of geofiltration modeling allowed us to develop an optimal drainage system from the point of view of economic feasibility and technological feasibility. Such a drainage scheme will effectively divert drainage water outside the territory of storage of rock waste. Drainage of overburden rock dumps will ensure the production safety of the processes of further storage of soils and their stability in general.

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