ABSTRACT

for the

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«Engineering-geological assessment and conditions of the territory of Almaty city for development of agglomeration» submitted for the degree of Doctor of Philosophy (PhD) in the major 6D075500 – "Hydrogeology and engineering geology"

Relevance of the research: The relevance of the study is determined by the need to investigate dangerous engineering-geological and hydrogeological processes occurring in the city of Almaty, which pose a threat to the population's livelihoods, as well as to industrial and civil construction. Additionally, the relevance of the study is due to the necessity of assessing the impact of human economic activities on the components of the geological environment. The city is actively engaging in new high-rise construction, and the underground space is gradually being developed.

As the level of responsibility for the structures being built increases and the density of construction grows, the priority tasks are ensuring their safety, providing ecological and social comfort for the residents, and achieving maximum economic efficiency in urban planning activities.

The continuous growth in the volume of engineering-geological surveys and, consequently, the increase in engineering-geological data, has emphasized the importance of tasks related to the systematization and analysis of engineering-geological materials from previous years, their use for ongoing work, the construction of forecast maps, and monitoring dangerous geological processes for urban planning purposes.

The object of research is landslides, rockfalls, debris flows, and other geological phenomena occurring in the foothill areas; the impact of the groundwater level and flooding in certain areas in the northern part of the city.

The subject of research includes monitoring hazardous geological processes, forecasting the development of flooding, systematizing and analyzing engineering-geological data, and the anthropogenic impact on geological environment components.

The main purpose of the research is to describe and divide the territory of the Almaty agglomeration based on GHP (geological hazard processes) and conduct detailed studies of these processes in selected experimental areas, characterized by flooding of buildings and structures in the northern part of Almaty and landslide processes on the slope of Mount Kok-Tobe.

To achieve this goal, the following tasks have been solved:

- research and classification of developing hazardous geological processes in the city of Almaty;
- selection of two experimental sites. The first site included the Akbulak microdistrict, located in the northern part of Almaty, and the second site represented the slope of Mount Kok-Tobe;

- creation of a geofiltration model for predictive assessment of the flooding process of buildings and structures in the northern part of Almaty;
- numerical modeling of the flooding process of built-up areas in the northern part of Almaty within the experimental site "Akbulak microdistrict" using the Visual MODFLOW PRO software package;
- calculation of the landslide stability coefficient for the experimental site on the slope of Mount Kok-Tobe in the "GEO5" program, in its natural state and considering possible seismic impact.

Research methods:

- study and classification of developing hazardous geological processes in the city of Almaty, systematization and analysis of the main factors of their occurrence and development in the area based on the results of previously conducted field studies and published works;
- field studies and mapping of selected experimental sites;
- creation of a database that includes climate, geological, hydrological, and hydrogeological data;
- route survey of the site, monitoring the groundwater level in observation wells;
- observation of river runoff and flood phenomena;
- numerical modeling using software complexes: Visual MODFLOW PRO, GEO5, QGIS, Surfer (Golden Software), CorelDRAW, AutoCAD, Google Earth Pro.

The scientific novelty of the work consists of the following:

- based on the results of monitoring hazardous geological processes in the city of Almaty, the necessity of conducting detailed studies in certain areas has been proven.
- a three-layer geofiltering model of groundwater flow in the upper and sub-artesian aquifer horizons, separated by a low-permeability layer, has been created, calibrated, and identified for the experimental site "Akbulak microdistrict" in Almaty, where flooding of built-up areas due to groundwater was observed.
- based on model calculations, the infiltration losses of surface runoff from built-up areas were assessed, concentrating in low-lying areas of the terrain and forming an infiltration mound, leading to the flooding effect.
- long-term changes in the dynamics of groundwater flow in the upper aquifer horizons were assessed from 1967, when natural conditions for groundwater formation on the site were maintained.
- for the first time, the slope stability of Mount Kok-Tobe in Almaty was evaluated, showing that under natural conditions, the north-western slope is unstable, with a stability factor of 1.44.
- the calculation of the stability coefficient of the slopes, considering seismic impact, revealed that both the north-western and north-eastern slopes are unstable, with stability coefficients of 0.99 and 0.41, respectively.

The main provisions submitted for protection:

1. Quantitative assessment of the flooding process of the developed area of the experimental site "Akbulak Microdistrict" in Almaty, based on the geofiltration model of groundwater flow in the upper confined and unconfined aquifers.

2. Characterization of the changed conditions of the interaction between surface and groundwater, recharge and discharge areas in undisturbed conditions, during the absence of development on the site in 1967, and during the highest groundwater levels in the period of building flooding in 2020.

3. In areas flooded by groundwater, there is a sharp increase in infiltration losses, which in areas of surface runoff concentration can exceed the annual atmospheric precipitation by up to 8 times. Meanwhile, the total flow of groundwater through the modeled aquifers has decreased nearly fourfold since 1967 due to increased water extraction within the city and the expansion of built-up areas that hinder the infiltration of atmospheric precipitation.

4. Evaluation of the stability of the landslide slope on the experimental site in Kok-Tobe, based on the results of the calculation of the stability coefficient, showing that the north-western slope is unstable in its natural state, and, taking into account horizontal and vertical seismic accelerations, the north-eastern slope also becomes unstable.

The field of application – hydrogeology, engineering geology.

Scientific and practical significance of the research. In the study of hazardous engineering-geological and hydrogeological processes occurring in the Almaty city agglomeration, priority was given for the first time to the quantitative assessment of these processes using hydrofiltration and geomechanical mathematical models. Field and laboratory work, along with the analysis of previous researchers' work, provided the primary characterization of the fundamental parameters of landslide formation and the physical activity of landslide processes in the foothills, as well as groundwater-induced flooding processes in the northern part of the urban development. This made it possible to:

- for the first time, quantitatively assess the main components of the groundwater flooding process, such as: infiltration losses from surface runoff in built-up areas, which accumulate in lower terrain areas and form an infiltration mound, as well as the dynamics of its formation over time and in space, leading to flooding effects.
- identify the key factors contributing to the development of the flooding process in the northern part of Almaty's urban development.
- assess the stability of the Kok-Tobe slope in its natural state and under seismic impact.

The practical significance of the work, along with the specific results of the assessment of the studied HGP, lies in the following:

- the created model can further be used as a continuously operating model, serving as a tool for carrying out both operational and long-term forecasts of flooding processes in the Akbulak microdistrict, located in the northern part of Almaty.

- the simulation of the flooding process by groundwater has revealed a number of issues that will clearly require additional field experimental work, which could become the subject of subsequent scientific-theoretical and scientific-practical research.
- the stability assessments of the landslide slope indicate the instability of the northwestern slope of Mount Kok-Tobe, which requires additional engineering measures to strengthen this section of the slope, in accordance with the recommendations proposed in the work.
- based on global experience, a methodology has been proposed for conducting research on this type of landslide and using the appropriate software to solve the given task.

The author's personal contribution includes setting the goals and objectives of the dissertation; collecting and summarizing research materials; conducting field surveys; creating thematic maps; mastering software complexes; interpreting the obtained results; formulating conclusions and key points to be defended; writing scientific articles and reports on the dissertation topic.

Publication. The main results of the dissertation have been published in 5 articles, including 2 articles in international journals indexed in the Scopus database ("Journal of Flood Risk Management" and "Bulletin of Tomsk Polytechnic University. Engineering of Geo-Resources"); 2 articles in a national specialized publication recommended by the Committee for Quality Assurance in Science and Higher Education of the Ministry of Education and Science of the Republic of Kazakhstan ("Vestnik KazNITU" and "Vestnik KazNU. Geography Series"); 1 article published in the proceedings of an international scientific-practical conference ("Satpaev Readings").

Structure and volume of the dissertation. The dissertation consists of an introduction, five chapters, a conclusion, and a list of references. The work is presented on 98 pages of typed text, contains 11 tables, 42 figures, a list of 26 references, and 4 appendices.

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