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ASSESSMENT AND MAPPING OF LANDSLIDE RISK IN THE TERRITORY OF ALMATY CITY

Abstract. The problem of assessing landslide risk is very urgent for the city of Almaty and its environs. Many landslide areas are built up by residential buildings or are actively used in economic activities. The landslide hazard and the territory development maps were used to assess landslide risk. The landslide hazard map was compiled based on the results of surveys of landslides' traces and the data on seismogenic landslides of 1887. In Almaty region, landslide risk is largely due to a seismogenic factor. Three degrees of hazard were distinguished on the map of landslide hazard: a significant one, a moderate one and a low one. The criteria for identifying a degree of hazard were the data on volumes of landslides and the proportion of landslide areas. The map of the territory dacha development was divided into territories with urban development, with dacha development, territories adjacent to built-up areas, uninhabited territories used for recreation, and uninhabited territories rarely visited by people. Assessment of landslide risk, meaning a possibility of landslides causing damage of a certain severity, was done by combining the maps of landslide hazard and the territory development. There were identified areas with a significant, a moderate and a low risk on the landslide risk map. Territories with a significant risk include all landslide areas with a permanent population and territories with a high degree of landslide hazard, adjacent to populated areas. A significant damage from landslides is quite possible in these territories. It is necessary to carry out engineering anti-landslide measures here. Areas with a moderate and a low landslide hazards that adjoin to populated areas or are used for recreation are characterized by a moderate risk. Probability of damage from landslides is small here. In such territories, it is sufficient to create a warning system. A low risk is observed in areas rarely visited by people, and in areas with a low landslide hazard, used for recreation. In such areas, anti-landslide measures are not applied.

Key words: landslides, rock falls, landslide risk, assessment and mapping.

Introduction. The largest megalopolis of Kazakhstan, the city of Almaty, with a population of more than 1.7 million people is located at the foot of the Ile Alatau Ridge. The southern part of the city occupies a low-mountain zone where loess-like loams are widespread. The low-mountain zone, adjacent to the city's territory, is used for dachas and as a recreation area. In recent years, cottages are being actively built here.

The territories formed by loess-like loams are characterized by a significant degree of landslide hazard. Typically, landslides are formed in spring and early summer, when an annual maximum of precipitation is recorded in the Ile Alatau [1]. Recently, landslide activity has increased as a result of human activities like cutting and overloading of slopes during construction of roads and houses, wetting of slopes by domestic sewage and as a result of water pipe breaks.

The Ile Alatau Ridge is distinguished by its high seismic activity. Here earthquakes of up to 9-10 points are possible. Such earthquakes occurred here in 1887 and 1911 [2]. There is a very high probability of mass formation of seismogenic landslides, as it occurred on May 28, 1887.

Therefore, the task of assessing and mapping of landslide risk is very urgent for the city of Almaty and its environs. As it is known, risk is a product of damage from any dangerous phenomenon by probability of such a phenomenon [3]. In our case, we are considering the risk caused by landslides that is landslide risk. In conditions of a great uncertainty of the components of landslide risk, when it is impossible to accurately calculate a level of the risk in quantitative indicators, we must resort to risk assessment by qualitative categories [4, 5]. In this paper, we used three grades of risk level: an unacceptable, acceptable and negligible. A level of risk is considered unacceptable when a possibility of landslides is high and they are likely to cause significant damage and human casualties. In this case, engineering protection measures are necessary. An acceptable level of risk means that there is a significant possibility of landslides, which can cause an insignificant damage. In such conditions it is enough to organize proper land use and establish a warning system. The risk is considered negligible when both a probability of landslides and damage from them are insignificant. In this case, no protective measures are taken.

To assess landslide risk in Almaty, the data on volume and distribution of landslides obtained in the course of field surveys and on literary data were used. A potential damage was determined by presence of a permanent or temporary population, facilities and infrastructure in the given territory.

Seismogenic landslides in Almaty regions. A very valuable material on landslides and rock falls is stated in a book by I. Mushketov, published in 1890 [6, 7]. An earthquake with a magnitude of 7.3 occurred early in the morning on May 28, 1887. The maximum force in the epicenter was more than 9-10 points [2]. In total, 332 people became victims of the earthquake. 154 people of those died in the mountains under rock falls and landslides.

Large and continuous destructions begin from the Belbulak and Koturbulak Valleys, stretching almost an uninterrupted path to the west of the Kaskelen Valley. The length of the greatest damage path is 35 km. In the transverse direction it is 20 km. The lower boundary passes at the foot of the Ridge at an altitude of 900-1 200 m above sea level, the upper boundary is at 2 400-2700 m above sea level. The largest and almost continuous damages can be traced to an altitude of 1 500-1800 m. The entire area of damage occupies 2 000 km^2, but the area of continuous damage is 175 km^2. The total volume of displaced rocks on the northern slope of the Ile Alatau is 440 million m^3.

The eyewitnesses testify that all the landslides and rock falls occurred simultaneously, as they were from one blow. At the same time, the earth "was exploding and throwing up large blocks", and "liquid mud was flying out" from some cracks. Mud slides immediately flowed from all the ravines. At first, they were flowing swiftly, but then very slowly, so that the largest ones passed not more than 300 m per a day. Motion of some of the mud slides continued for several days.

In the course of their advancing from the slopes to the valley, the mud slides dammed stream channels and formed temporary lakes. Breakthrough of these lakes, which took place in 1-3 days, was rather rough in some places. The largest landslides and rock falls occurred on the site from the Shirokaya Shchel to the Aksai. At present, this territory is a part of Almaty.

In the Pryamaya Shchel the mud slides begin at an altitude of more than 1800 m, and stretch almost continuously for 10 km. The main mud slide occupies almost the entire valley of the Pryamaya Shchel. There are only 2 km left to reach the foot of the mountains. The main mud slide length is about 7 km, the width is from 100 to 500 m, the thickness is from 30 to 60 m, in some places it is even 70 m, and the volume is 84 million m^3. The total volume of landslides in the Pryamaya Shchel Valley is 126 million m^3.

In the Shirokaya Shchel, the total volume of landslides is 1.5 million m^3. In the Kishi Almaty Valley, the volume of displaced rocks is 12 million m^3. The volume of all the displacements between the Ulken and Kishi Almaty Gorges is 6 million m^3.

Destructions in the Ulken Almaty Valley begin at an altitude of 850 m. Opposite to the Teresbutak outfall on the left side of the Ulken Almaty, there is a granite rock fall in the side gorge of the Koksheka. It differs from other rock falls with its white color. The length of the rock fall is 4 km, the width is 200 m, the thickness is 30 m, and the volume is 24 million m^3.

A huge rock fall that is above the Teresbutak amazes with its size. It emerged from the left inflow that is the Prokhodnaya Shchel. This rock fall overwhelmed a house of a forester with his entire family, as well as several yurts with 39 shepherds and many cattle. The thickness of the rock fall sediments is 60 m. It filled the Ulken Almaty Valley with 300 m in width and 3 km in length. Its volume is 54 million m^3.

Between the Ulken Almaty and Jamanbulak, mud slides are numerous, but they do not reach the bottom of the mountains. Their volume is 6 million m^3.

There is a mud slide in the Jamanbulak that filled not only the entire valley, but also went beyond the mountains. The stream of thick mud was moving very slowly, and after leaving the mountains, continued to crawl for 4 days. It spread widely along the foothill plain along the both banks of the outfall, filled the