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Satbayev University

# Х А Б А Р Л А Р Ы

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## ИЗВЕСТИЯ

НАЦИОНАЛЬНОЙ АКАДЕМИИ  
НАУК РЕСПУБЛИКИ  
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## N E W S

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*NAS RK is pleased to announce that News of NAS RK. Series of geology and technical sciences scientific journal has been accepted for indexing in the Emerging Sources Citation Index, a new edition of Web of Science. Content in this index is under consideration by Clarivate Analytics to be accepted in the Science Citation Index Expanded, the Social Sciences Citation Index, and the Arts & Humanities Citation Index. The quality and depth of content Web of Science offers to researchers, authors, publishers, and institutions sets it apart from other research databases. The inclusion of News of NAS RK. Series of geology and technical sciences in the Emerging Sources Citation Index demonstrates our dedication to providing the most relevant and influential content of geology and engineering sciences to our community.*

*Қазақстан Республикасы Ұлттық ғылым академиясы «ҚР ҰҒА Хабарлары. Геология және техникалық ғылымдар сериясы» ғылыми журналының Web of Science-тің жаңаланған нұсқасы Emerging Sources Citation Index-те индекстелуге қабылданғанын хабарлайды. Бұл индекстелу барысында Clarivate Analytics компаниясы журналды одан әрі the Science Citation Index Expanded, the Social Sciences Citation Index және the Arts & Humanities Citation Index-ке қабылдау мәселесін қарастыруда. Web of Science зерттеушілер, авторлар, баспашылар мен мекемелерге контент тереңдігі мен сапасын ұсынады. ҚР ҰҒА Хабарлары. Геология және техникалық ғылымдар сериясы Emerging Sources Citation Index-ке енуі біздің қоғамдастық үшін ең өзекті және беделді геология және техникалық ғылымдар бойынша контентке адалдығымызды білдіреді.*

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**THE IMPORTANCE OF CONDUCTING RESEARCH METHODS  
TO ASSESS THE STATE OF GLACIAL-MORAINE LAKES**

**Abstract.** The article analyzes the importance of ongoing long-term observations and field research in assessing the state of glacial-moraine lakes. Since the second half of the XX century, 87 mudflows of glacial genesis have been recorded in the northern slope of the Ile Alatau. Mudflows of glacial genesis are considered as catastrophic phenomena, preventing or reducing their damage is possible only taking into account the experience of the past 80-90 years or through comprehensive measures, such as continuous survey, monitoring and evaluation of the areas. Long-term observations and field research of lake surveys of the glacial-moraine complex are essential for Almaty city with a population of 2 million people and economically important facilities located at the foot of the Ile Alatau. During the conducting research the comparative assessment of the scale of mudflow activity and mudflow hazard of different mudflow basins is carried out, the mudflow basins with the highest activity or threatening the facilities of techno-, eco-, and socio-sphere. In order to protect this area from social and economic losses, 3 different methods of preventive measures are carried out to prevent the moraine lakes outburst floods. Therefore, timely and prompt assessment of the state of the lakes, obtained on the basis of research methods, is especially important for prevention and warning of catastrophic mudflows, mudflow hazard forecasting and mudflow risk management.

**Key words:** glacial-moraine complex, moraine lake, mudflow, long-term observations, field research, aerial visual survey.

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## **МҰЗДЫҚТЫҚ-МОРЕНАЛЫҚ КӨЛДЕРДІҢ ЖАЙ-КҮЙІН БАҒАЛАУДА ЖҮЗЕГЕ АСЫРЫЛАТЫН ЗЕРТТЕУ ЖҰМЫСТАРЫНЫҢ МАҢЫЗДЫЛЫҒЫН БАҒАЛАУ**

**Аннотация.** Мақалада мұздықтық-мореналық көлдердің жай-күйін бағалауда жүзеге асырылатын стационарлық және экспедициялық зерттеу жұмыстарының маңыздылығы зерттелді. XX ғасырдың екінші жартысынан бастап зерттеліп отырған ауданда гляциалды генезистегі 87 сел тасқыны тіркелген. Гляциалды генезистегі сел тасқындары апатты құбылыстар ретінде қарастырылады, оның келтіретін залалын тек өткен 80-90 жылдардың тәжірибесін ескере отырып немесе жүргізіліп жатқан зерттеулер, аумақтарды бақылау және бағалау сияқты кешенді шаралар арқылы алдын алуға немесе азайтуға болады. Мұздықтық-мореналық кешендегі көлдерге жүргізілетін стационарлық және экспедициялық зерттеу әдістері – Іле Алатауының етегінде орналасқан 2 млн халқы және экономикалық маңыздылығы жоғары кәсіпорындары бар Алматы қаласы үшін аса маңызды. Зерттеу жұмыстарын жүргізу барысында сел қызметінің ауқымына және әртүрлі сел алаптарының сел қауіптілігіне салыстырмалы бағалау жүзеге асырылады, белсенділігі неғұрлым жоғары немесе техно-, эко-, социосфера объектілеріне қауіп төндіретін сел алаптары анықталады. Осы қаланы әлеуметтік және экономикалық шығындардан қорғау мақсатында, мұздықтық-мореналық көлдердің ақтарылу қауіптілігінің алдын алу үшін превентивті шаралар 3 түрлі әдісте жүзеге асырылады. Сол себепті, Іле Алатауының солтүстік беткейінің орталық бөлігінде орналасқан көлдердің жай-күйін бағалаудағы зерттеу жұмыстарының маңыздылығын анықтау, апатты сел тасқындарының алдын-алу мәселелерін шешу, олардың болашақтағы қауіптілігін бағалау, қауіпін басқаруда аса маңызды.

**Түйін сөздер:** мұздықтық-мореналық кешен, мореналық көл, сел тасқыны, стационарлық зерттеулер, экспедициялық зерттеулер, аэровизуалды барлау.

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## ОЦЕНКА ЗНАЧИМОСТИ ОСУЩЕСТВЛЯЕМЫХ ИССЛЕДОВАТЕЛЬСКИХ РАБОТ В ОЦЕНКЕ СОСТОЯНИЯ МОРЕННО- ЛЕДНИКОВЫХ ОЗЕР

**Аннотация.** В статье дан анализ важности проводимых стационарных и экспедиционных исследовательских работ при оценке состояния моренно-ледниковых озер. Со второй половины XX века в северном склоне Илейского Алатау зафиксировано 87 селевых потоков гляциального генезиса. Сели гляциального генезиса рассматриваются как катастрофические явления, предотвратить или уменьшить ущерб от которых можно лишь учитывая опыт прошлых 80-90 лет или путем комплексных мероприятий, таких как проведение постоянного обследования, мониторинг и оценка территорий. Стационарные и экспедиционные методы обследования озер моренно-ледникового комплекса являются наиболее важными для города Алматы с населением 2 млн человек и с экономически важными объектами, расположенными у подножия Илейского Алатау. В целях защиты данной территории от социальных и экономических потерь принимаются превентивные меры 3-мя различными способами для предотвращения прорывоопасности моренных озер. В ходе проведения исследовательских работ осуществляется сравнительная оценка масштабов селевой деятельности и селевой опасности различных селевых бассейнов, выявляются селеопасные районы, представляющие наибольшую активность или угрозу объектам техно -, эко -, социосферы. Поэтому своевременная и оперативная оценка состояния озер, полученная на основе научно-исследовательских методов, особенно важна для предотвращения и предупреждения катастрофических селевых потоков, прогноза селевой опасности и управления селевыми рисками.

**Ключевые слова:** моренно-ледниковый комплекс, моренное озеро, селевой поток, стационарные исследования, экспедиционные исследования, аэрофотозондирование.

**Introduction.** Numerous glacial-moraine lakes are an integral element of the landscape of the highlands of Ile Alatau, as well as other mountainous regions of Central Asia. These mountain areas are characterized by catastrophic mudflows, which are often formed as a result of the glacial-moraine lakes outburst floods (Kapitsa et al., 2018).

Over the past 70 years, 87 cases of mudflows of glacial genesis were observed in the mountains of the Ile Alatau (Medeu et al., 2020). The most powerful mudflows by energy characteristics were formed in the basins of the Ulken Almaty and Kishi Almaty rivers located in the central part of the northern slope of the Ile Alatau, and the total number of registered mudflows in these basins is 37 cases.



One of the most important regions for the country's economy, the city of Almaty, is located at the foot of the Ile Alatau. The population of Almaty is about 2 million people, and about 25% of all enterprises of the country operate on this territory. Almaty with its current boundaries is the leader in terms of the spread of mudflow centers (Baymoldayev et al., 2018).

Glacial mudflows became an object of research after the passage of earthflows in the basin of the Kishi Almaty river in 1951 and 1956. The Alma-Ata hydrogeological party of the Hydrogeological Administration of the Ministry of Geology of the Kazakh SSR carried out the first engineering-geological and geophysical works to study the structure of modern and ancient moraines in the river valleys of the northern slope of the Ile Alatau in 1964-1968 (Baymoldayev et al., 2007), which allowed identifying the main problems and became the fundamental theoretical basis for preventive measures and works to reduce the mudflow hazard.

In 1974-1978, active work on creation of a network of observation and warning posts in mountain river basins, control centers for receiving and processing information on the state of mudflow hazards, organization and conduct of ground-based field surveys of moraine lakes, mudflow centers and mountain river beds was conducted. Also, aerial visual surveys of mudflow-prone areas for baseline assessment of the situation have been widely used.

The above-mentioned activities are carried out until now and are the main methods of identification and assessment of mudflow hazards in glacial-moraine lakes located in the central part of the northern slope of the Ile Alatau. Also, the methods of identification and assessment of mudflow hazards of lakes are controlled by organizations such as the State Institution "Kazselezashchita" and RSE "Kazhydromet" (Stepanov et al., 2014). In addition, in 1985, on the basis of the results of long-term observations and field research methods, a passport system of moraine lakes was created for the first time. These documents for assessment of the condition of the lakes contain information on location, brief characteristics, relationship with glaciers, type of lake basin, height, length and width of lakes, area, depth, water volume and physical composition of the lake. Also, for estimation of risk of lakes outburst floods, information about volumes of inflows and outflows, the maximum level exceeding the level above the shoreline, the maximum lake level held back by a cofferdam, the potential location of the lake, and the stability of the ground are provided. According to the identified attributes, glacial-moraine lakes are subdivided into mudflow hazard categories: high, medium, and low mudflow hazard (Medeu et al., 2018). Positive outcomes of long-term observations and field studies used for warning the population and prevention of glacial mudflows can be determined by reduction of the number of destructive mudflows in recent years.

According to the Atlas of emergency situations, the study area belongs to an area with a high degree of mudflow hazard. Therefore, the assessment of research methods, which determine outburst hazard criterion of the moraine lakes located in the central part of the northern slope of the Ile Alatau, as well as improving the monitoring of glacier moraine lakes by including remote sensing observations is extremely important in alerting the population and preventing catastrophic mudflows.

**Methods and materials.** The article was written on the basis of literature and historical data, as well as the results of monitoring observations of the State Institution “Kazselezashchita” of the Ministry of Emergency Situations of the Republic of Kazakhstan and RSE “Kazhydromet” of the Ministry of Ecology, Geology and Natural Resources of the Republic of Kazakhstan.

The data on observation posts and control centers in the study area were used to evaluate the conducted stationary studies, the results of which were marked on the map. The mapping of observation posts and control centers was carried out using ArcGIS 10.8 software. The main geographic objects were taken from the OpenStreetMap web-mapping crowdsourcing project.

Materials on the preventive work which is carried out to prevent and warn about the moraine lakes outburst floods are collected and summarized by the results of scientific and technical reports of the State Institution “Kazselezashchita”.

The long-term observations method is used to study the dynamics of mudflow objects and to identify mudflow hazards in the study area. The results of long-term observations are of great theoretical and practical importance. Thus, observation networks of posts were created for the purpose of timely detection of changes in the state of mudflow hazardous objects and transfer of information for prompt warning of the possible occurrence of mudflow. The main tasks of the observation posts are to provide data on the level, volume, water and air temperature, precipitation, snow height in the glacier-moraine complex (Chigrinets et al., 2020). The data are transmitted and processed by 24-hour control centers, which provide reception and transmission of information. Also, they are used to implement preventive measures of destructive mudflows .

Many years of experience in organizing the observation network has allowed us to develop a certain methodology of placing stations in basins, from moraine lakes to settlements and on critical engineering structures of protection (Baymoldayev et al., 2007).

At present, according to the data of the State Institution “Kazselezashchita”, there are 4 permanent and 4 seasonal stations which operate in the basin of the Ulken Almaty river and 3 permanent and 2 seasonal stations in the basin of the Kishi Almaty river (Figure 1 (a)). The seasonal stations carry out observations in the mudflow hazardous period. Also, according to RSE “Kazhydromet”, the number of active stations in the basin of the Ulken Almaty river is 5 and the number of closed stations is 5. In the Kishi Almaty river basin, there are 5 stationary stations and 7 closed stations, as well as one site where water discharge is measured (Figure 1 (b)).

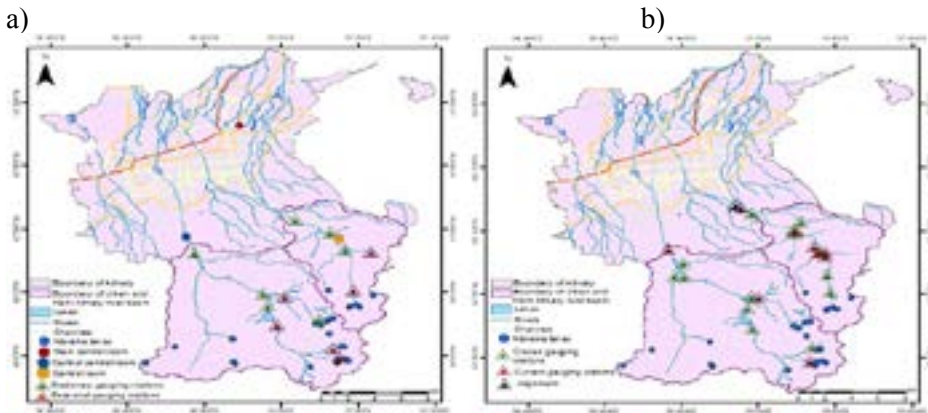


Figure 1. Location map of hydrological gauging stations in the basins of the Ulken and Kishi Almaty rivers a) observation network of the State Institution “Kazselezashchita”; b) observation network of RSE “Kazhydromet”

The number and density of observation posts and their location are determined by the degree of the moraine lakes outburst floods (Bolch et al., 2011), the presence of economic facilities located in hazardous areas, and the control centers can monitor the situation using a group of nearby basins. Data are received and analyzed by the Main Control Center in the State Institution “Kazselezashchita”.

In addition, the significance of field research works, which are carried out to assess the hydrometeorological characteristics of the glacial-moraine complex, was studied. Field research works are carried out in the following areas :

- reconnaissance survey;
- specialized survey of the glacial-moraine complex.

Reconnaissance surveys of the glacier-moraine complex are divided into aerial visual and ground-based survey methods. During the reconnaissance survey the comparative assessment of the scale of mudflow activity and mudflow hazard of different mudflow basins is carried out, the mudflow basins with the highest activity or threatening the facilities of techno-, eco-, and socio-sphere are determined in order to carry out specialized detailed surveys in them (Medeu et al., 2018).

Aerial visual surveys are carried out from helicopters by the staff of the State Institution “Kazselezashchita”. The use of a helicopter is more practical, as its flight speed is lower and it has more opportunities for maneuvering. Surveys are conducted along a pre-planned route, which is mapped.

During the ground-based surveys, all the data obtained as a result of the aerial visual survey are verified on the terrain, the selection of observation points for specialized surveys or work on the study of the conditions of mudflow formation is made. Materials of reconnaissance surveys are the basis for drafting the program of specialized surveys. Specialized survey of the moraine complex is carried out to identify the conditions of mudflow formation; to establish the characteristics of past mudflows; to obtain morphometric characteristics of mudflow centers, channels, fields and cones, mudflow-

prone lakes; physical and mechanical characteristics of soils and grounds of mudflow deposits .

The collection of available information on the past mudflows from literature and other sources and the study of cartographic and aerial survey materials in order to identify the main mudflow sites in advance should be done before the conduct of field surveys (Krylenko et al., 2008).

**Results and Discussion.** With this study we were able to include remote sensing into state-of-the-art glacier-moraine lake monitoring. As a result of the field survey of mudflow-prone lakes, the morphometric characteristics of basins, structure and condition of lake cofferdams, ways of water outflow channels from lake, level of maximum filling of lakes, mechanisms of lake emptying, characteristics of earlier outburst floods are determined. Based on the analysis of these characteristics, the degree of mudflow hazard of the lakes in the study area is determined.

Preventive measures are taken to prevent the moraine lake outburst floods (Baymoldayev et al., 2018). Preventive measures are a set of long-term measures aimed at mitigating the situation by reducing the risk of glacial mudflows. Different methods of controlled emptying of mudflow-risky water bodies are applied depending on morphometric characteristics of lakes, structure of lake cofferdams, destruction of which may naturally lead to formation of catastrophic mudflows (Stepanov et al., 2001). Three methods can be distinguished, which are widely used in our country (Figure 2):

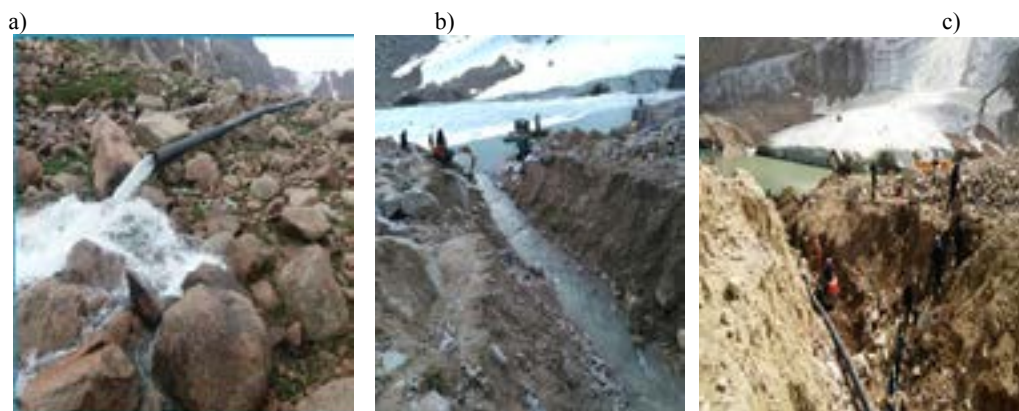


Figure 2. Methods of preventive measures for emptying of glacial-moraine lakes - a) siphon method; b) trench channel method; c) comprehensive method

Economic and ecological efficiency of preventive measures is rather high. The experience of the State Institution “Kazselezashchita” shows that the time spent on emptying a moraine lake outburst flooding in a non-critical situation is determined to a crucial extent by geological conditions, the quality of preliminary scientific and technical preparation for the work, and the degree of preparedness of persons. So far, 11 moraine lakes have been emptied in the study area (Figure 3).

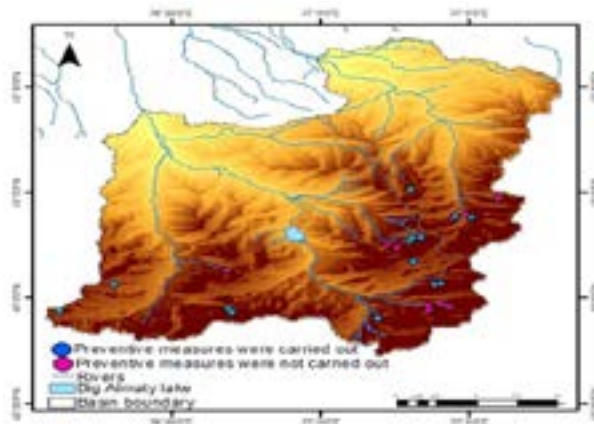


Figure 3. Preventive measures carried out in glacial-moraine lakes in the basins of the Ulken and Kishi Almaty rivers

As a result of preventive works, the danger of glacial-moraine lakes outburst floods with subsequent formation of catastrophic mudflows was eliminated, and in others it was significantly reduced. Examples are preventive works on moraine lakes: No.6 near the M. Mametova glacier in the basin of the Kishi Almaty river, No.13-bis near the Sovetov glacier in the basin of the Ulken Almaty river (Petraikov et al., 2004). The works allowed achieving the main things: to eliminate the real threat of catastrophic mudflows, to protect the population, business facilities and territories from this extremely dangerous natural phenomenon.

Comprehensive use of research to assess the state of moraine lakes of the central part of the northern slope of the Ile Alatau plays an important role in prevention of glacial mudflows and reduction of social and economic losses. The result of the effectiveness of the conducted long-term observations and field studies is a timely warning about the hazard of moraine lakes outburst floods (Romang et al., 2010).

At present, Earth remote sensing data are widely used in foreign countries to study the moraine complex, its condition and prospects (Mussina et al., 2016). Therefore, the application of Earth remote sensing data and GIS-technologies should become an alternative to the traditional aerial photography for large-scale mapping of the study area (Krylenko et al., 2008). The Earth remote sensing data and GIS-technologies can improve the quality of large-scale mudflow maps, which provide a detailed description of the glacial-moraine complex in certain mountain areas and watersheds (Fisher et al., 2016). With the help of space images it is possible to identify the litho-genetic composition of the complex of bedrock and sedimentary covers taking into account the age and anti-denudation properties, zones of separated fractures and tectonic faults, mudflow centers classified according to the origin of mudflow forming processes, mudflow channels of permanent and temporary streams. Also, when processing space images we can get morphological characteristics of mudflow centers and other objects, such as: slope, area, volume, length, width, height. The use of LULC (Land Use and Land Cover) images is also noteworthy and gives an idea of the economic development

of the area, which may be in the zone of mudflow impact or occurrence (Salerno et al., 2012).

The use of space images is especially important in cases where aerial visual and ground-based methods of research are not possible, for example, in the study of hard-to-reach, hazardous, remote moraine lakes. Today, multispectral images are used to identify water bodies and to clarify morphometric characteristics using the NDWI index method (Junli et al., 2012). A set of images on the concerned territory, gives a complex characteristic of the terrain and allows obtaining reliable information on the state of the territory. On some satellites of Landsat, Terra (Aster), EO-1 (Hyperion, ALI), the range of spatial resolution varies from 15 m to 1000 m.

**Conclusion.** The modern foundations of the organization and conduct of research works on moraine lakes were formed in stages. The aforementioned research works have led to the accumulation of certain experience in understanding the process of formation of glacial mudflows.

Along with this, the stages of research development in Kazakhstan are associated with the passage of catastrophic mudflows in the region, which stimulated the intensification of research work (Mussina et al., 2019). However, conducting the above-mentioned studies requires a long time and economic costs.

Nowadays, remote sensing data and GIS technologies are widely used in assess and calculation maximum discharge characteristics of hydrological hazards in Kazakhstan (Duskayev et al., 2021). Therefore, we provide a cost-efficient way using the application of Earth remote sensing and GIS technologies to monitor glacier-moraine lakes. This most effectively affect the quality of informed and timely decision-making in the management of mudflow risks and the identification of hazards in the glacial-moraine complex, prevention and protection of socio-, techno- and ecosphere facilities from the negative effects of mudflow phenomena.

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