SATBAYEV UNIVERSITY
Engineering Journal of Satbayev University
Volume 144 (2022), Issue 4, 46-51

https://doi.org/10.51301/ejsu.2022.i4.07

Dangerous geological processes on Lake Kolsai and the impact of Anthropogenic load on the DGP

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Abstract. This article shows research the risks of landslide processes on the territory of Lake Kolsai, as well as the influence of anthropogenic factors on dangerous geological processes. Examples of data processing from LandSat-7,8 satellites using the Google Earth Pro program and images of the territory of Lake Kolsai using unmanned aerial vehicles are shown. The main purpose of this article is to use the analysis of data from previously carried out works to assess the conditions of zones with potentially dangerous development of landslide processes, as well as to give predictive assessments of the risks of DGP in this area. The area of research is the left side of Lake Kolsai in the northern Tien Shan, in the Kolsai Gorge, in the bridge connecting the Kungei and Zailiysky Alatau ridges. At the end of the nineteenth century, a number of major earthquakes occurred in the above-mentioned area, which caused enormous damage to the environment and to the people of the coastal areas. Subsequently, after these earthquakes, dangerous zones with a potential risk of landslide processes were formed in the study area. This article deals mainly with the left side of Lake Kolsai, which changes year after year due to the strong anthropogenic load. For this article, the collected satellite images and photographs from the UAV have been processed, interpreted and the necessary data extracted. The analysis of previously carried out works is made.

Keywords: *UCP, monitoring, LandSat,Google Earth pro, satellite images, fault, landslide processes, earthquake, seismology.*

1. Introduction

The Shelek river basin occupies the southeastern part of the Ile Alatau ridge and the northeastern part of the Kungei Alatau ridge. The river has a length of 245 km, the basin area is 4980 km^2. The climate here is sharply continental with large daily and annual air temperature amplitudes.

The Shelek River originates from the Zhangaryk glacier at an altitude of 4300 abs.m. It receives a number of tributaries. The river bed is moderately winding, composed of boulders, pebbles and sand, with a large amount of loose clastic material [1].

Here, the most significant dangerous geological processes are observed in comparison with the nearby river basins. The catastrophic earthquakes of 1887, July 1, 1889 (10 points, Chilik) and 1911 left their grandiose traces in the form of huge landslides and landslides. Which created the most beautiful dammed lakes, blocking mountain rivers.

The Kolsai River is the right tributary of the Shelek River. The river has three unnamed tributaries, two of which are left-bank. There is no glaciation in the river basin. In the upper part of the basin (2000-3400 abs.m) the relief is smoothed, although in some places there are rocky outcrops and scree. At altitudes of 3000-2800 abs.m, erosion processes are weakly expressed, however, when the continuity of the turf is disturbed, potholes form on the slopes. In the lower zone (1600-2800 abs.m), the relief is characterized by sharp shapes and steep slopes, which contributes to active erosion processes [2].

There are three large dammed lakes in the river basin, located directly in the bed of the Kolsay River. The cascade of lakes on the Kolsai river is more than 1000 years old.

The first (Upper Kolsai), at an altitude of 2660 m is the first lake. Its length is 580 m, average width is 190 m, maximum depth is 23,5 m. The runoff is carried out by filtering through the body of the cofferdam, composed of fine and medium detrital material with a large amount of gravel-fine earth filler. The length of the cofferdam is 790 m, the width is 200 m, the slope of the surface is 30°. The lake belongs to the high category of mudflow hazard.

The second lake (Middle Kolsai) has a water level mark of 2250 m. Its length is 1150 m, average width is 298 m, maximum depth is 57 m. Flowing lake with 3 incoming tributaries and 1 outflow. The dam consists of large debris with little aggregate content.

The third lake (Lower Kolsai) is located at an altitude of 1800 m. Before the breakthrough with partial emptying in 1984, its length was 1520 m, average width – 222 m, maximum depth - 38.6 m. Lintel width – 50 m, length – 830 m. The right part of the cofferdam slope is coarse-grained (scree with fragments up to 0.5 m in diameter), the left part is made of fine-grained equipment. All three dams of the Kolsai lakes have at the base of the rocky cut rocks, then blocked by landslide and landslide masses, with a volume on the lower and middle lake of 300-500 thousand m^3, on the upper - 150-200 thousand m^3 [1].

Recently, the Kolsai Lakes are a popular holiday destination not only for residents of Almaty, but also for tourists of near and far abroad.

On weekends, the number of tourists is about 2000 people, while the number of passenger vehicles on average exceeds 200 units, the number of buses is more than 40 units.

For reference:

On June 2, 1984, on Lake Nizhny Kolsai, as a result of increased flow, which led to undermining and collapse of the left part of the cofferdam body, composed of loams and subsequent breakthrough of the blockage, 509 thousand m^3 of water was drawn from the lake with a maximum flow rate of 19.4 m^3 / s. At the same time, the height of the lake cofferdam decreased by 1.59 m. A mudflow with a flow rate of 25.5 m^3 / s was formed in the mudflow incision.

On June 2, 1987, a partial emptying of the lake occurred again, which led to the formation of a debris flow cofferdam in the mudflow incision with a flow rate of 56 m^3 / s. After the collapse of the mudflow mass at the first kilometer below the incision, the flow was transformed into a nanowater flood. 217 thousand m^3 of water was drawn from the lake, the lake level dropped by 0.7 m.

At the end of the 19th century, a number of large earthquakes occurred on the territory of the study area, after which dangerous zones appeared on this territory with a potential risk of developing landslide processes.

The main parameters of the earthquake: the epicentral zone of the earthquake covers the eastern parts of the Ile and Kungei Alatau ranges and extends from the Ili River to the north-eastern coast of the lake Issyk-Kul. After the earthquake, cracks formed, many huge screes and landslides in the mountains and gorges. On June 21, 1938, at the mouth of the Bolshoy Kemin River, the Kemino-Chuy catastrophic earthquake occurred in the southwestern regions, it manifested itself with a force of 7-8 points (in Almaty 6 points). In the period until 1970, after this earthquake, a seismic lull occurred in the Almaty observation zone, and since 1970 the Almaty zone became active again: Sarykamysh on June 5, 1970 (in the Kegen region - up to 6 points), Toraigyr on February 12, 1975 (in Chilik region - up to 6 points) and a number of other tangible tremors. On March 25, 1978, the Zhalanash earthquake occurred with the epicenter in the area of the eastern immersion of the Kungei Alatau. After the Kemin disaster of 1911, it is the largest in this zone. The strength of the concussion in the Kegen region reached 8 points, which brought huge material damage [2].

On November 12, 1990, another strong earthquake was recorded in the Almaty zone - the Baysorun earthquake. His strength in Kegen district reached 8 points. This earthquake ended the next stage of the activation of seismic activity in the territory of the Almaty zone. The zones of distribution of the earthquake are shown in Figure 1, on the specified map it can be seen that during the period of the above time the seismic activity near Lake Kolsai was 8-9 points. In this regard, landslides and potential areas of landslides and landslide processes were formed [3].

The parameters of the erosion source of Lake Nizhny Kolsai are: length - 1.6 km, average width of the cut at the base - 50 meters, average width of the cut at the top - 200 meters, the height of the sides of the cut in the upper part of the 50-70 meters.

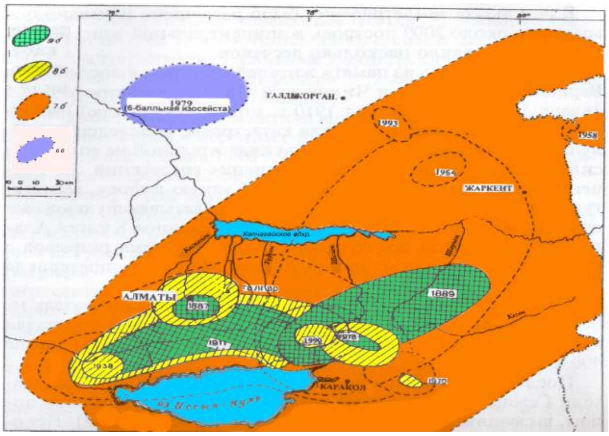

Figure 1. Schematic map of strong earthquakes in the Almaty region

The left side is steep, consists mainly of gravelly gravel deposits forming a plume of scree almost throughout the incision, which will be worked out to the natural angle of slope. Soil layer about 30 cm. The shedding process will continue until the formation of a natural slope of the soil. Depending on the intensity and amount of precipitation, the melting of snow will take about 3-7 years. Presumably, the edge of the erosion cut will move another 30-40 meters. Also, on the port side on the body there are wedgings of groundwater with insignificant expenses due to precipitation. On the slope of the cut there are landslides with volumes of up to a thousand cubic meters.

Lake lintel in satisfactory condition. No traces of wedging out of filtration waters were revealed. It is necessary to carry out repair and restoration work and reconstruction of the structure.

On the body of the landslide and in the erosion focus there is a large anthropogenic load which is expressed in the construction of houses and buildings, the lack of a unified sewerage system, the construction of swimming pools, the lack of supply and discharge structures, sealed containers for wastewater, toilets, etc. (Figure 2, a,b).

As a result of catastrophic displacement, the original rocks are divided into separate blocks and crumpled into complex folds and lenses. Some of the largest blocks retained their structure and were found in outcrops along the escarpments of the dam's body. The bulk of the rock is represented by difficult contact blocky, gravel and gruss soils with traces of the external structure. Dark gray clays and loams, both formed during the friction of displacement and involved in this process, red-brown neogene cohesive soils act as fillers.

The steepness of the sides in the upper part, composed of soils of the blockage itself (composition see above) is 70…90°, while in some areas the surface of the slopes has a reverse slope of up to 5°. The height of such slopes varies within 5...20 m.

Below (i.e., almost the entire) surface of the sides of the valley Kolsai river is formed by a plume of talus, represented mainly by crushed stone and woody soils with sandy-loamy aggregate. The steepness of the scree surface varies within 37...52°, i.e. the bodies of scree are in an unstable state, the detrital material is constantly shifting down especially actively during the period of snowmelt and heavy rains.

a)

b)

Figure 2. Structure on the erosion focus (picture from UAV)

In addition, the surface of the sides is disturbed by numerous water-erosion incisions, along which temporary watercourses actively displace the soil masses of the blockage and scree to the riverbed, forming alluvial fans of various sizes. At the same time, the largest of them reach the riverbed and partially block the water flow. It can be assumed that thicker fans with complete blocking of the riverbed can also form in these areas.

Along the edge of the left-bank slope at a distance of 0.2...0.3 m, the presence of shallow separation cracks 1...3 cm wide was revealed.

The crumbling process will continue until the formation of a natural slope of the soils that form the plumes of talus. Depending on the intensity and amount of precipitation, melting snow, this process can take about 3-7 years. Presumably, the edge of the erosion incision will move towards the technogenically loaded territory by another 30-40 meters. Also, on the port side on the body there are wedgings of groundwater with insignificant expenses due to precipitation. (Figure 3, a-d).

At the time of writing this article, using the Google Earth Pro program, space images were taken from the LandSat-7, 8 satellites, taken in 2010 and 2021. An analysis was carried out for changes in the dimensions of the port side, comparisons were made at 3 identical points, graphical examples of these analyzes are given in the appendices (Figure 4, a-f). According to the data obtained, it can be noted that during the taken period of time the following details are noted:

• Significantly increased anthropogenic and technogenic pressure on the left side of Lake Kolsai.

• There are noticeable changes in the shape, steepness and size of the port side.

a)

b)

c)

d)

Figure 3. Photographic materials of landslide-prone areas on the territory of the State National Natural Park "Kolsai Lakes" of Almaty region (September 28-29, 2022): (a) – Portside. Slopes below the water intake 70 m; (b) – Portside. Slopes below the water intake 150 m; (c) – Portside. Water-erosion incision and alluvial fan displacing the water flow of the Kolsai River (≈ 200 m below the intake); (d) – Portside. Separation crack below water intake 60 m.

Given the above changes, it can be noted that various factors, such as weather conditions, anthropogenic load, seismic activity, tourism development and other conditions strongly affect the left side of Lake Kolsay. Such rates of anthropogenic and man-made influence on this site, together with natural phenomena, can lead to landslide shifts on the left side of Lake Kolsay.

For example, in 2012, in the north of India, near the tourist city of Durbuk, a landslide occurred, which isolated the road, as a result, about 500 tourists, 150 cars, in which there were local residents on vacation, were isolated. Also, in a hilly area about 50 km north of Kuala Lumpur, a landslide leveled a campsite while people were sleeping in their tents. Among the dead were seven children.

In order to avoid such cases in the study area, it is necessary to conduct a complex of engineering geological studies, as well as to create a centralized network of sewerage and water supply and other types of work to strengthen the left side of Lake Kolsay.

Conclusions on the stability of the left side of the valley of the river. Kolsai in the investigated area (Figures 5,6.).

1. Slopes are in an unstable state. According to preliminary calculations, the stability coefficient varies within 0.2...0.7 (upper escarpments and scree).

2. The surface of the slopes is undocked. Vegetation was noted only on the surface of the side of the gorge behind the edge of the canyon with a thickness of 30 cm.

3. Numerous water-erosional cuts of temporary action of various scales of manifestation on the surface of slopes are revealed, the development of which deforms the structure of slopes and worsens their bearing capacity as a basis for any structures. In addition, such cuts, as a result of backward erosion, deform even the turfed surface of the blockage itself.

4. There is a constantly changing technogenic load (buildings, structures, vehicles). At the same time, many of them are located almost along the edge of the slopes of the left side of the Kolsai river valley.

5. Uncontrolled saturation of the body of the dam with water of technogenic genesis (water supply, sewage drains) was revealed.

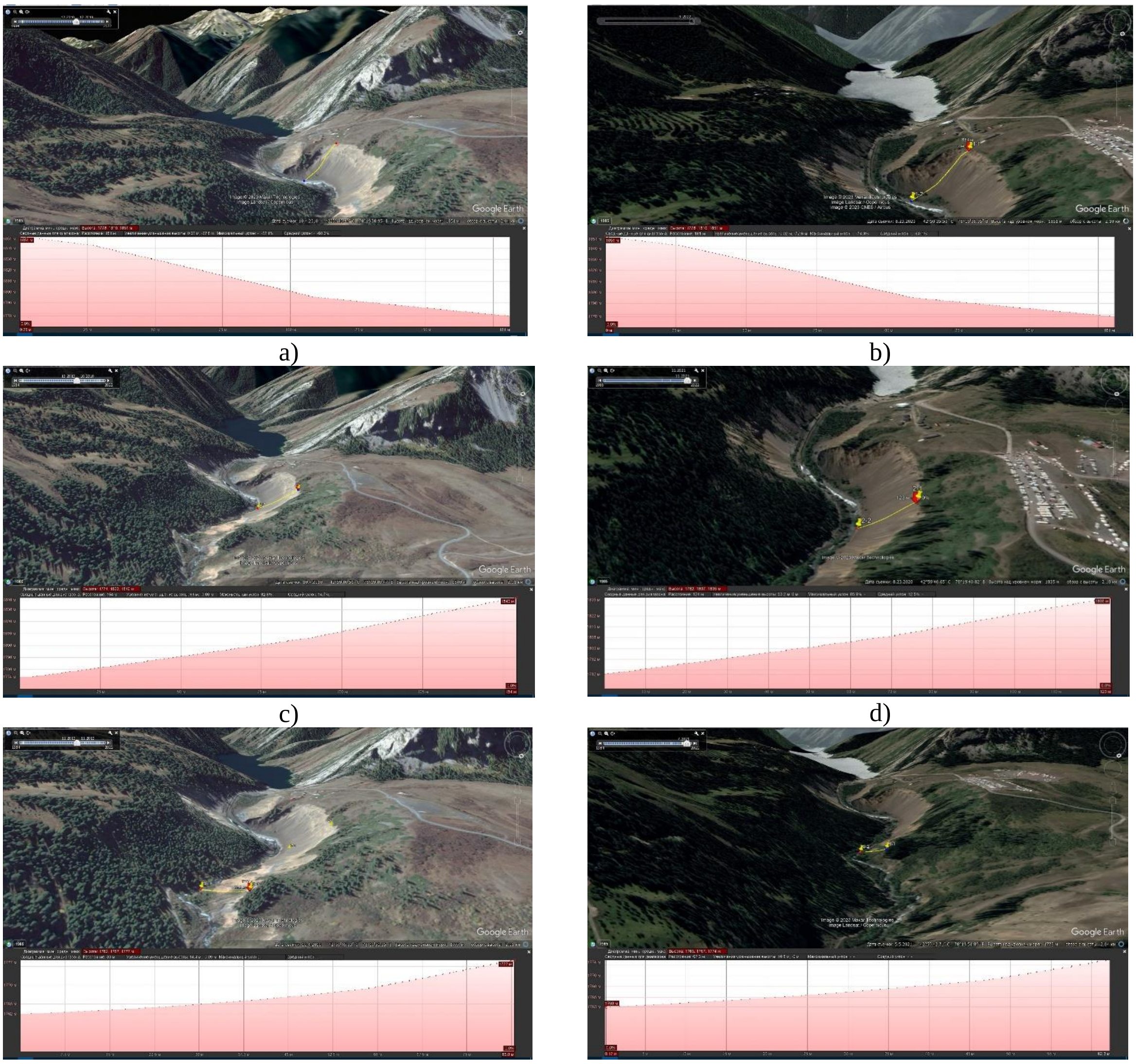

Figure 4. Space images of landslide-prone areas on the territory of the State National Natural Park "Kolsai Lakes" of Almaty region: (a) – the first profile of the relief of the left side of the Kolsai River (space image of 2010); (b) – the first relief profile of the left bank of the Kolsai river (space image 2021); (c) – the second relief profile of the left side of the Kolsai river (space image of 2010); (d) – the second relief profile of the left side of the Kolsai river (space image 2021); (e) – the third relief profile of the left side of the Kolsai river (space image 2010); (f) – the third relief profile of the left side of the Kolsai river (space image 2021)

Figure 5. Portside (picture from UAV)

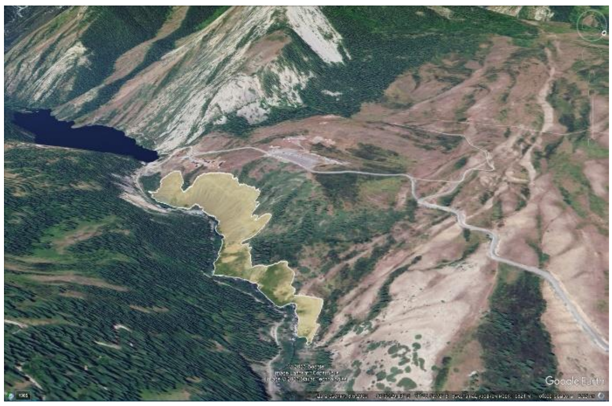

Figure 6. Contours of the left side of the Kolsai River. (contour perimeter ≈ 2.55 km contour area ≈ 7.9 ha)

According to the stock materials (Tunnel spillway from Lake Kolsai. Report on the preliminary assessment of the engineering and geological conditions of the construction area. 1989), the coefficients of filtration of the soils of the body of the blockage vary within 0.12...0.79 m / day, which contributes to the uncontrolled formation of temporary local aquifers in the body of the blockage and, accordingly, reduces the bearing capacity of soils in a variety of areas, without the possibility of their localization within the territory under study [5].

The starboard side is made of gruss, pebbles, and several kurums are formed from boulders of various sizes with a maximum size of up to 2 meters. At the sole of the kurumniks there are wedgings of groundwater in the form of descending springs: the water flow rate in the upper spring is 2 liters per second, in the lower spring the flow rate is about 4 liters per second. Springs due to the lack of a stormwater net flow along the operational road. The upper part of the weathering zone consists of different age eluvial deposits. Landslide events were not detected. Possible collapses with volumes of up to 10 cubic meters and falls of single large blocks, which poses a real threat to passing tourists and vacationers.

For reference: Kurums are local, limited in three-dimensional space, accumulations of stone acute-angled boulders, formed in a natural way, having the appearance of a closed undivided cover on the surface of the earth.

4. Conclusions

The landslide body on Lake Nizhny Kolsai belongs to the landslides of an incomplete cycle. The Kolsai river basin belongs to the 9-point seismic zone.

The entire territory of the erosion mudflow incision is subject to dangerous geological processes. The danger of soil sliding along the entire length of the erosion focus remains.

After the absorption of critical weight and with a dynamic effect on the landslide body in the erosion focus, the probability of breakage and slippage of the port side is very high, and it is also possible to activate landslide phenomena under the influence of natural factors (exposure to rains).

A high anthropogenic load is observed on the body of the landslide and on the body of the lake cofferdam, including in the mudflow incision.

As a result of the chaotic construction of buildings, structures, swimming pools, the absence of storm drains, as well as the complete absence of a sewerage system, the lack of sealed containers for wastewater and toilets increased the processes of soaking soils, the installation of additional asphalt pavements and observation platforms also does not contribute to the natural aeration of moisture in the soils. The device of such artificial structures leads to hidden flooding of territories, because. the surface for evaporation of moisture decreases and the surface for artificial accumulation of moisture in the soil increases.

The organization of the tourist cluster is carried out without considering the landslide hazard and the risk of landslides and landslides, with trimming of the slopes, and also without considering the significant load and overload of the slopes.

The lake is a point tourist site of a very vulnerable nature for which a calculated and metered load is necessary.

Currently, there is a chaotic uncontrolled development of the territories of the lakes in connection with the growing interests in these objects among tourists.

The territory is built up randomly, the influx of tourists is huge, especially in the summer, hundreds of yurts and tents are being built here, not counting the already erected capital structures, which negatively affects the ecological state of the objects.

For the proper environmentally safe functioning of the Kolsai Lakes facility, it is necessary to develop a detailed program for the functioning of these facilities with the involvement of a wide range of specialists in geology, hydrogeology, ecology, biology, climatology, etc.

After the development of a detailed program, it is necessary to offer a rational schedule for visiting the sites by tourist groups and individual tourists in an environmentally dosed format.

Delivery to the lakes by special transport for the excursion the recommended daily load for visiting the lakes should not exceed 250-300 people per day.

Recommendations:

1. It is necessary to carry out engineering-geological surveys using georadar to determine the stability of the lake cofferdam and the landslide-landslide body in general for all three lakes;

2. Conduct regular surveys of the state of the lake cofferdam, landslide-landslide body, including commission. It is necessary to organize instrumental control with the installation of benchmarks and markers for the dynamics of the movement of the landslide body and erosion processes in the mudflow incision;

- on the organization of the sewerage system, pipeline lines on the principle of "pipe in a pipe" with control wells;
- on the prohibition of the construction of pools or other reservoirs on the body of a landslide;
- on the organization of storm-discharge networks.

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Көлсай көліндегі қауіпті геологиялық процестер және олардың антропогендік жүктеменің әсері

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Аңдатпа. Бұл мақалада Көлсай көлінің аумағындағы жүргізілген зерттеу беткейлік сырғыма процестерінің қаупі, сондай-ақ қауіпті геологиялық процестерге антропогендік факторлардың әсері көрсетілген. Google Earth Pro бағдарламасын қолдана отырып, Landsat-7,8 спутниктерінен деректерді өңдеу мысалдары және ұшқышсыз ұшу аппараттарын қолдана отырып, Көлсай көлінің аумағының суреттері көрсетілген. Бұл мақаланың негізгі мақсаты – бұрын жүргізілген жұмыстардың деректерін талдау, беткейлік сырғыма процестерінің болуы мүмкін қауіпті аймақтардың жағдайын бағалау, сондай-ақ осы учаскедегі қауіпті геологиялық процестердің болуын болжау және баға беру. Зерттеу учаскесі ретінде – Солтүстік Тянь-Шаньдағы Көлсай көлінің сол жақ беткей жағалауы, Көлсай шатқалында, Күнгей мен Іле Алатауын байланыстыратын аумақ қарастырылады. Жоғарыда аталған аумақта XIX ғасырдың аяғында бірқатар ірі жер сілкінісі болған, бұл қоршаған ортаға және жақын маңдағы адамдарға үлкен зиян келтірген. Зерттеу барысында осы жер сілкінісінен кейін зерттеу учаскесінде беткейлік сырғыма процестерінің болу қаупі бар қауіпті аймақтар пайда болды. Бұл мақалада Көлсай көлінің аумағындағы туристік аймақтың дамуына байланысты сол жағалаудың антропогендік жүктемеге байланысты жылдан жылға өзгеруі қарастырылады. Бұл мақалада дрон ұшу аппараттарынан жиналған және жерді қашықтықтан зондтау ғарыштық суреттер мен фотосуреттер өңделіп, түсіндіріліп, қажетті мәліметтер алынды. Сонымен қоса бұрын жүргізілген жұмыстарға талдау жасалды.

Негізгі сөздер: *ОГП, мониторинг, LandSat, Google Earth pro, ғарыштық суреттер, ақаулар, сырғыма процестері, жер сілкінісі, сейсмология.*

Опасные геологические процессы на озере Колсай и влияние антропогенной нагрузки на ОГП

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Аннотация. В данной статье показаны результаты исследование на территории озера Кольсай, а так же влияние антропогенных факторов возможные риски оползневых процессов и опасные геологические процессы. Показаны примеры обработки данных со спутников LandSat-7,8, с использованием программы Google Earth Pro, и снимки территории озера Кольсай с использованием беспилотных летательных аппаратов. Основная цель данной статьи – с помощью анализа данных обследовании с ранее проведенных работ, оценить состояния зон с потенциально опасным развитием склоновых процессов, а также дать прогнозные оценки рисков ОГП на данном участке. Областью исследований является левый борт озера Кольсай в северном Тянь-Шане, в ущелье Кольсай, в перемычке, соединяющей хребты Кунгей и Заилийский Алатау. В вышеуказанном участке в конце XIX века произошли ряд крупных землетрясении, которые причинили колосальный вред, для окружающей среды и для людей приблежных районов. В следствии после данных землетярсении на исследуемом участке оброзовались опасные зоны с потенциальным риском развития оползневых процессов. В данной статье рассматривается преимущественно левый борт озера Кольсай, который год за годом меняется, в связи с развитием туристичикии зоны и сильной антропогенной нагрузкой. Для данной статьи собранные космоснимки и фотоснимки с БПЛА обработаны, проинтерпретированы и извлечены необходимые данные. Сделан анализ ранее проведенных работ.

Ключевые слова: *ОГП, мониторинг, LandSat,Google Earth pro, космоснимки, разлом, оползневые процессы, землетрясение, сейсмология.*