Report
ofthe“№4500512612 UNESCO Adaptation Fund project Reducing vulnerabilities of populations in the Central Asia region from glacier lake outburst floods in a changing climate” (GLOFCA) in Kazakhstan.”

Information on moraine lakes in the Talgar River basin

The Talgar River basin, prone to mudflows, is situated in the mountains of the Ile Alatau Range and features a complex, dissected mountainous terrain. The basin's general northern slope comprises several purs of the main ridge, serving as water sheds for Mountain Rivers. Covering a total catchment area of 444.5 km², the Talgar River basin includes the Left Talgar River (273 km²), the Middle Talgar River (103 km²), and the Right Talgar River (68.5 km²). The average slope of the Talgar River is 0.121%. In the upper reaches of these gorges, there are significant glaciations with 129 glaciers spanning a total area of 98.063 km². Over recent years, these glaciers have lost more than 45% of their total mass. The primaryriversinthebasin – Right, Middle, and Left Talgar rivers – all originate from the glaciers of the Ile Alatau Range.

The primary catchment area of the Talgar River basin is situated within the significant glaciations center known as the Talgar mountain knot, which distinctly influences the river's feeding characteristics. In the mountainous regions of the Talgar River basin, Kazselezaschitahas documented and created passports for 24 moraine and glacial lakes, including empty lake basins, identifying seven as particularly prone to break throughs.

This researchinvolvedthecollectionofdataonthemoraine-glacial lakes located in the Talgar River basin. Most information was derived from survey reports conducted during aerial and ground surveys, archival materials from the State Agency "Kazselezaschita," satellite images, and cartographic materials from the 1970s and 1980s, among the sources.

Detailedinformationonthemorainelakesispresentedin Table 1.

Table 1. Moraine dammed glacial lakes in the Talgar basin

№	**Lake**	**Coordinates**		m, a.s.l.	**Glaciername**	**GLOF hazard**	**GLOF Event Date**
1	№1	43°8'24.84"	77°16'29.37"	3415	№150		
2	№2	43°5'23.37"	77°17'5.97"	3632	№156		
3	№3	43°1'51.28"	77°6'48.93"	3591	№116 Tourists’ 2	dangerous	
4	№4	43°1'41.60"	77°6'44.49"	3613	№117 Tourists’ 3		

5	№5	43°7'46.30"	77°13'39.04"	3422	№142 Koptau		
6	№6	43°8'7.23"	77°13'50.61"	3347	№142 Koptau		
7	№7	43°9'46.53"	77°19'25.17"	3223	№167 Sportivnyi		
8	№8	43°0'32.58"	77°10'33.40"	3479	№127 Left Toguzak	dangerous	26.07.1961
9	№8a	43°0'43.07"	77°12'0.07"	3743	№127 Right Toguzak		
10	№8б	43°0'47.57"	77°12'4.63"	3758	№127 Right Toguzak		
11	№9	43°9'23.04"	77°19'57.56"	3391	№167 Sportivnyi		
12	№9a	43°9'37.85"	77°19'42.94"	3326	№167 Sportivnyi		
13	№10	43°0'15.77"	77°6'38.22"	3772	№120 Sov. Climbers	dangerous	
14	№12	43°0'12.83"	77°6'24.49"	3793	№120 Sov. Climbers	dangerous	
15	№13	42°59'37.67"	77°7'49.85"	3597	№121, №122 Dmitriyev 1,2		
16	№14	42°59'56.47"	77° 8'15.56"	3507	№123, №124 Dmitriyev 3,4		
17	№15	43°6'1.64"	77° 6'40.18"	3371	№103 Bogdanovich	dangerous	
18	№16	43°5'51.72"	77°12'51.33"	3466	№138 Jambyl		
	№17	43°6'42.31"	77°15'24.80"	3550	№152 Severnyi		
20	№18	43°7'20.03"	77°17'38.35"	3111	№160 Kroshka		
21	№19	43°2'54.60"	77°11'45.91"	3410	№131 Kalesnik	dangerous	
22	№20	43°3'27.12"	77°12'58.12"	3753	№132 Pioner		
23	№21	43°4'23.30"	77°7'32.32"	3661	Aristov		
24	Unnamed	43°8'30.86"	77°16'31.70"	3400	№150	dangerous	16-24.07.1990, 06.07.1993, 17.07.2014

Bathymetric data of moraine lakes by year

Date	Elevation, m a.s.l.	Length, m	Width, m	Maximun depth, m	Area, m^2	Volume, m^3
Moraine lake №3						
21.08.2019	3591	182	173	9.7	24,084	78,768
08.08.2024				11.3	37,900	143,750
Moraine lake №4						
21.08.2019	3613	110	33	3.7	2,224	3,735
Moraine lake №8						

25.07.2013	3479	560	155	10	52,960	206,000
Moraine lake №8a						
12.07.2019	3743	202	75	6.4	9,682	26,484
Moraine lake №10						
15.09.2021	3772	65.0	50.0	14.0	3,801	14,980
08.08.2024				10.5	19,100	90,400
Morainelake №16						
19.07.2023	3454			7.0	9,300	25,400
Morainelake №19						
29.07.2014	3410	367	143	11.2	29,000	150,000
21.08.2019		340	85	11.5	23,952	113,048
10.07.2024		350	199	17.9	31,300	152,900
Morainelake №20						
29.07.2014	3111	240	78	7.4	13,500	40,000
21.08.2019		210	60.5	5.3	9,805	21,194

Additionally, multiple historical records of mudflow events in theTalgar River basin were reviewed, with efforts made to classify and analyze them based on their formation types. Data on mudflows caused by glacial lake out bursts in the 20th century were collected, although most of these lakes are now empty basins or have completely disappeared. Nevertheless, historical information on these mudflows was archived at the Kazselezaschita State Institution and other sources, and the locations of previously existing and now-emptied lakes were identified and briefly described. Information on past mudflows resulting from glacial lake outbursts (glacial genesis) is summarized in Table 2.

On July 10, 2024, and August 8, 2024 topographic and bathymetric surveys were conducted on moraine lakes №19, №3, and №10 in the Talgar River basin to determine their morphometric characteristics. According to the surveys, Lake №16 has completely drained, leaving the lake basin empty. Lakes №10 and №12 are expected to merge into a single lake in the near future due to thermokarst and thermo-erosional processes. Lake №19 poses a significant breach hazard through its internal moraine drainage channels, indicating a very high degree of mudflow risk.

To reduce the mudflow hazard at moraine Lake №19, preventive measures were undertaken. The conducted works significantly decreased the mudflow risk, preventing the formation of catastrophic mudflow events.

On July 10, 2024, topogeodetic and bathymetric surveys were conducted on moraine lake №19 in the Talgar River basin to determine its morphometric characteristics. The data from these surveys are currently being processed. According to this year's survey data, lake №16 is completely emptied, leaving an empty basin. Due to thermokarst and thermo-erosion processes, lakes №10 and №12 are expected to merge into a single lake in the near future. Additionally, lake

№19 poses a significant threat of break through intra marine run off channels, presenting a very high degree of mudflow hazard.

Table 2. Information on past mudflows resulting from moraine lake outbursts in the Talgar River basin

№	Lake	Coordinates	Date	GLOF	Note
1	Lake №2 in the Left Talgar basin	43° 8'2.82" 77°13'39.77"	-	yes	The lakeemptiedoutcompletely
2	Lake№5 in the Left Talgar basin	43° 2'45.33" 77°11'24.94"	20.06.1970 10.07.1976 16.06.1984	yes	The lake emptied out completely
3	Lake №9 in the Left Talgar basin	43° 3'0.90" 77°11'41.00"	14.07.1970	yes	The lake emptied out completely
4	Lake№6 in the Middle Talgar basin	43°6'44.44" 77°15'6.91"	15.07.1973 15.07.1974 21-22.07.1974 02.08.1974	yes	The lake emptied out completely
5	Lake№6 in the Left Talgar basin	43°1'50.01" 77° 7'24.99"	21.06.1976 24.06.1976	yes	The lake emptied out completely
6	Lake №7 in the Middle Talgar basin (Sportivnyi Glacier)	43° 9'15.39" 77°19'30.69"	21.06.1979	yes	The lake emptied out completely
7	Lake *unnamed* in the Middle Talgar basin	43° 7'8.85"C 77°19'18.51"B	07.07.1990	yes	The lake emptied out completely

Information on past GLOFs

26.07.1961. In the basin of the Left Talgar River, as a result of the breakthrough of glacial lake №8, a sediment-laden flood was formed [Background forecast for glacial mudflows, 1985].

20.06.1970. In the basin of the Left Talgar River, a mud(stone)flow was formed as a result of the breakthrough of Lake №5 under the Kalesnika Glacier through an ice tunnel [Bizhanov et al, 1998’].

14.07.1970. The formation of the debris flow on July 21, 2023, resulted fromthe breakthrough of Lake №9 in the Left Talgar River basin, which occurred through intra-moraine runoff channels penetrating a 200-300 meter ice dam. The outflow volume from the lake was 47,000 m³. The water outflow emerged 0.5 km below the lake, creating an erosion incision that facilitated mudflow formation. The maximum flow rate of the mudflow reached 100-150 m³/s. Solid materials from the mudflow were deposited on the upslope sections of the Ulken Mynzhylky riverbed; however, part of the debris flow continued further, entering the Left Talgar River. On the same day, a small-scale debris flow occurred in the area of Lake №19 (Left Talgar) due to the collapse of moraine ground. [Tokmagambetov et al, 1980; Popov, 1984].

12.07.1971. As a result of Lake №18 (volume 40-50 thousand m3) rupture, mud(stone)flow was formed in the upper reaches of the Left Talgar River. The lake rupture occurred through a 200-300 m ice dam. The maximum flow rate of the mudflow reached 100-150 m3/s [Tokmagambetov et al, 1980].

15.07.1973. In the Left Talgar River basin, a mud(stone)debris flow formed due to the discharge of water from Lake №6, located on the moraine of the TEU-Severny Glacier. According to V.I. Shusharin and I.N. Markov, the lake's basin is situated on the glacier moraine, and its bottom consists of loose clastic material, with buried ice at a depth of 1.0-1.5 meters. On July 15, a grotto formed in the lake's lintel, allowing the lake to discharge a volume of 24,000 m^3 with flow rates sufficient to generate a mudflow. Data from KazHydroMet indicated that the maximum flood flow rate was 20-30 m^3/s. The debris flow had a maximum flow velocity of 8 m/s, a mudflow mass density of 2300 kg/m^3, and a total mudflow volume of 210,000 m^3.Subsequent mudflows with similar formation processes were observed on July 16, 18, and 19, and on August 29 and 30 of the same year. Despite the frequent recurrence of mudflows during the summer of 1973, the lake cofferdam remained intact. With the onset of the warm period in 1974, the lake began to fill again, reaching its maximum level by mid-July. [Shusharin& Popov, 1981; Markov et al, 1983; Shusharin& Markov, 1976].

15.07.1974. As a result of the emptying of moraine Lake №6 (with a volume of 26,000 m^3) located under the TEU-Severny Glacier in the basin of the Talgar River, a mudflow of the 2nd-3rd category was formed. Following a brief cooling period on July 13-14, the air temperature began to rise, reaching a maximum of 18°C in the lake on July 15. By 15:20, the lake water began to discharge through the grotto, accompanied by a deafening noise that triggered rockslides on the slopes of the cofferdam and the downstream area. The water flowing from the lake saturated the loose clastic material in the area, causing the mass to reach its fluidity limit and rush downward, gaining speed. As the mudflow passed through an area with gradients reaching 22°C, stones, mud dust, and sparks from the impacts of large boulders were ejected from the stream. Ten minutes after the onset of the mudflow, the channel at the exit from the source deepened by 3 meters. Two additional, less powerful mudflows followed the initial one. Subsequently, a post-mudflow flood with a discharge of up to 5-10 m^3/s was observed. The water level in the lake dropped by 2.5 meters as the cofferdam was eroded. Within 40 minutes of the mudflow's start, the lake had discharged approximately 20,000 m³ of water [Shusharin& Markov, 1976].

21-22.07.1974. The mudflow was formed as a result of a new emptying of Lake №6 under the TEU-Severny glacier (Middle Talgar). After the lake breakthrough on 15.07.1974, landslide processes occurring because of melting of the exposed intramoraine ice led to the formation of temporary cofferdams and, consequently, to its new filling. On 21-22.07.1974 these temporary dams were destroyed. The breakthrough flood rushing into the source formed a mudflow, 2.5 times more powerful than the mudflow on 15 July. The mudflow lasted for 2 hours, its maximum flow rate reached 200-250 m3/s [Tokmagambetov et al, 1980; Markov et al, 1983; Shusharin& Markov, 1976].

02.08.1974. The third mudflow in 1974 was observed in the area of Lake №6 (Middle Talgar River basin). The largest mudflow discharge was estimated at 300 m3/s, although water inflow from Lake №6 into the source did not exceed 30 m3/s. One of the versions of the mudflow formation process is as follows: ‘The front part of the flow, moving along the unprocessed channel and experiencing greater resistance, slows down its movement, the rear part swells up on it. As a result, the power of the shaft is constantly increasing, reaching values tens of times higher than the flow rate of water entering the upper part of the centre’. According to information, on the Middle Talgar River during the summer months of 1973-1974 there were nine mudflow breakthroughs of the glacial lake under the TEU-Severny glacier, the maximum volume of which in all cases did not exceed 25 thousand m3. The outbursts occurred underground through a 20-30 m thick cofferdam. The highest mudflow discharges reached 200-300 m^3/s [Background forecast for glacial mudflows: Methodological Guide, 1985; Markov et al., 1983].

21, 24.06.1976. The breakthrough of Lake №6 under the Turistov Glacier in the basin of the Left Talgar River formed mudflows [Gorbunov,1971]

10.07.1976. During the breakthrough of Lake №5 under the Kalesnika glacier through the ice tunnel in the basin of the Left Talgar River, a mudflow was formed. The volume amounted to 200 thousand m^3[Gorbunov, 1971; Tokmagambetov et al.,1980; Popov,1984].

21.06.1979.A mudflow was formed in the basin of the Left Talgar River, the cause of which was the breakthrough of a moraine lake near the Sporty Glacier through an underground grotto. The maximum flow rate of the breakthrough flood was 5-10 m^3/s. The breakthrough flood, passing through the steps of ancient moraine sediments, formed a system of incisions. Tentatively, the volume of mudflow discharge was estimated at 200.000,0-300.000,0 m^3, and the density of the mudflow mass was more than 2000 kg/m^3. The breakthrough of the moraine lake through the underground grotto is not related to general meteorological conditions (air temperature, precipitation, height of the zero isotherm, etc.). The mudflow destroyed 14 offices and outbuildings of the alpine camp. The average balance estimate of mudflow density at the initial volume of the breakthrough flood of 87 thousand m^3 is 1800 kg/m^3. Apparently, the real density of the mudflow mass could reach 2000 kg/m^3[Background forecast for glacial mudflows: Methodological Guide, 1985; 2. Markov et al., 1983;Shusharin& Markov, 1976].

16.06.1984. In the basin of the Left Talgar River, a small category 3 mudflow was formed due to a large inflow of meltwater from the Kalesnik Glacier into Lake №5 and its subsequent emptying (according to observations byKazselezaschita). According to the data, the emptying took place through an open ice channel. The volume of flood was 200 thousand m^3. [Popov, 1984; Popov,1987].

07.07.1990. In the upper reaches of the Middle Talgar River, as a result of the breakthrough of the moraine lake near glacier №162 (Yubileyny) with a volume of 5-7 thousand m^3, a mud(stone)debris flow of the 3rd category was formed with a maximum flow rate in the area of the breakthrough of 100-120 m^3/s. The debris flow wave spread in the channel of the Middle Talgar River. During the day there were 17 mudflows with flow rates from 15 to 100 m^3/s. In the Talgar River has passed flash flood category 3 with a maximum flow rate of 42 m^3/s. [Shusharin& Markov, 1976].

16-24.07.1990. As a result of impulse discharges of the lake under the Bezymyannyi glacier (Middle Talgar River) from 16 to 24 July, mudflows were registered.

06.07.1993.

Based on the information provided:

1. Bizhanov et al., 1998; Baimoldaev et al., 2007; Kazselezashchita, 1993:

At 9:20 a.m., a mudstone mudflow of the 1st category formed in the Middle Talgar River basin due to the breakthrough of a lake near the Bezymyanny glacier. The event was not linked to specific hydrometeorological conditions like high temperatures, intense snow melting, or heavy rainfall. The lake's breakthrough occurred through intramoraine drainage channels, with 60% of its surface covered by floating snow masses. Mudflow initiation started on the modern moraine ledge, but the primary accumulation of loose clastic material occurred lower, on the steep ledge of an older moraine. The mudflow entered the Middle Talgar riverbed 1.5 km downstream from the Alplager gauging station. During the 7-hour outburst, several large and numerous small surges were observed at the source. Visual estimates by observers indicated peak flow rates near 1000 m^3/s, though the actual maximum flow rate at the channel did not exceed 10-15 m^3/s, still sufficient to generate a mudflow significantly greater than a water flood.

2. Medeu, 2011:

The mud(stone)flow resulted from the lake's breach (100,000 m³ volume) on the Bezymyanny glacier moraine, descending through the lower mudflow incision. It traveled in several large and dozens of small waves along the Middle Talgar and Talgar channels, reaching a maximum flow rate of up to 2000 m³/s. The bulk of the mudflow mass (up to 2 million tons) deposited at a under-construction mudflow retention dam. Continuing downstream, it passed through Talgar city with a maximum flow rate not exceeding 300 m³/s. The mudflow caused damage including the destruction or covering of 3 km of road, drinking water supply pipelines, a bypass canal, and the head structure of the Talgar hydroelectric power station. Additionally, several power line supports were demolished. Due to timely warnings and evacuation efforts, there were no casualties.

These events highlight the destructive potential of mudstone mudflows originating from glacial moraine lakes, underscoring the importance of monitoring and mitigation efforts in vulnerable regions.

21.06.1995. In the left tributary of the Middle Talgar River, at an altitude of 3700-3300 meters, a 2nd category mudstone debris flow occurred. The absence of apparent hydrometeorological triggers suggested that the primary mudflow-forming factor was the traditional collapse of the sides of the source area. Additionally, the hypothesis of small seismic shocks, recorded with an epicenter in the area, influencing the activation of mudflow forming processes, was considered. This hypothesis remained accepted even after an aerial survey of the Talgar River basin. However, ground surveys later suggested that the main cause was the breakthrough of the upstream moraine lake №9.

According to A.F. Prodan, a Kazselezaschita specialist who visited the area on June 22, the lake emptied due to the opening of a grotto at its bottom. Approximately 9.6 thousand m³ of water, present in the lake before the mudflow, drained underground. The maximum flow rate of the debris flow was estimated at 150-180 m³/s, with an average velocity of 5-6 m/s. During the mudflow movement, about 50 meters of pipeline were damaged, disrupting the water supply to Talgar town, a pipe bridge was destroyed, and 150 meters of motorway were swept away [Operational information of Kazselezaschita].

17.07.2014. In the river basin Middle Talgar experienced a 2nd category mudflow. The mudflow was formed as a result of the breakthrough of a thermokarst moraine lake located on a young ice-saturated moraine at an altitude of 3420 m above sea level, under the Solnechny glacier. This lake already broke through in 1993, which led to the formation of a mudflow with a volume of 2 million m3 with a maximum flow rate of 1340 m3/s. In 2014, the lake’s outburst was preceded by rains and increased temperatures in the highlands. The flow rate of the mudflow in Middle Talgar and after its confluence with on Talgar was 50-80 m^3/s. The mudflow flowed along the riverbed in waves, rolling boulders and stones. As the flow approached the dam, large fractions of the mudflow mass were deposited. Approximately 300,000 m^3 of mudflow masses have accumulated in the mudflow catcher bow[Operational information of Kazselezaschita].

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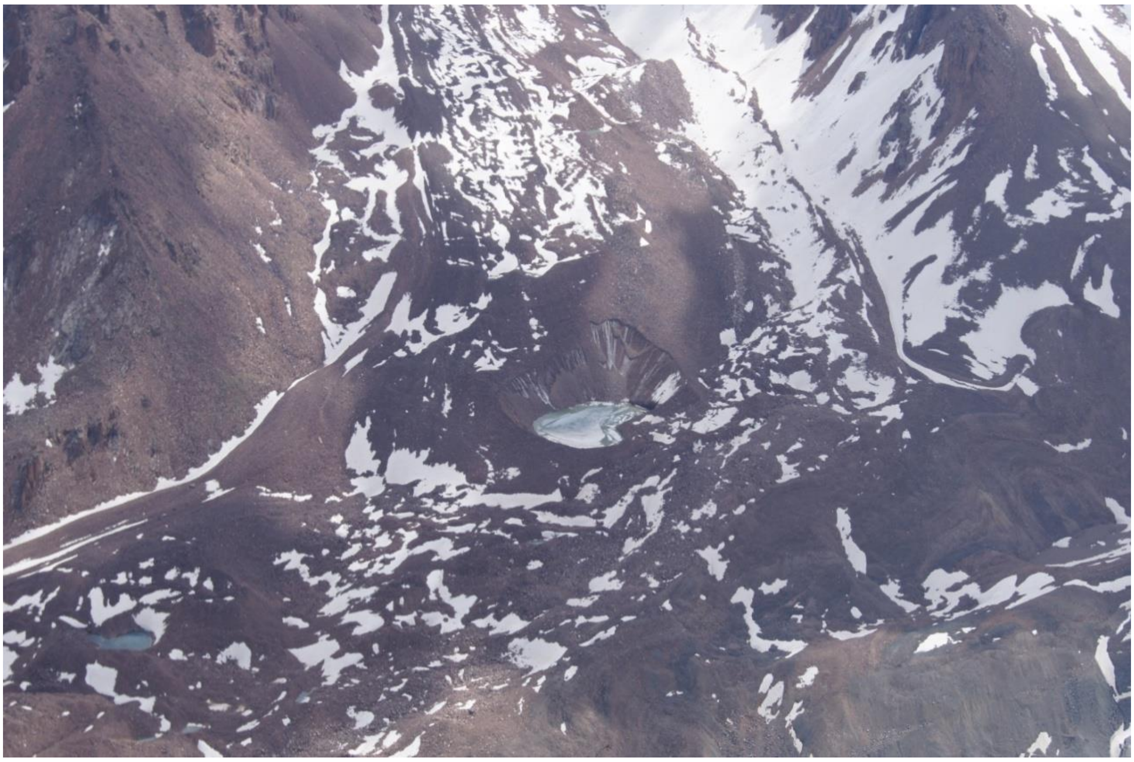
Observation materials from Kazselezaschita

AssiyaBostayeva

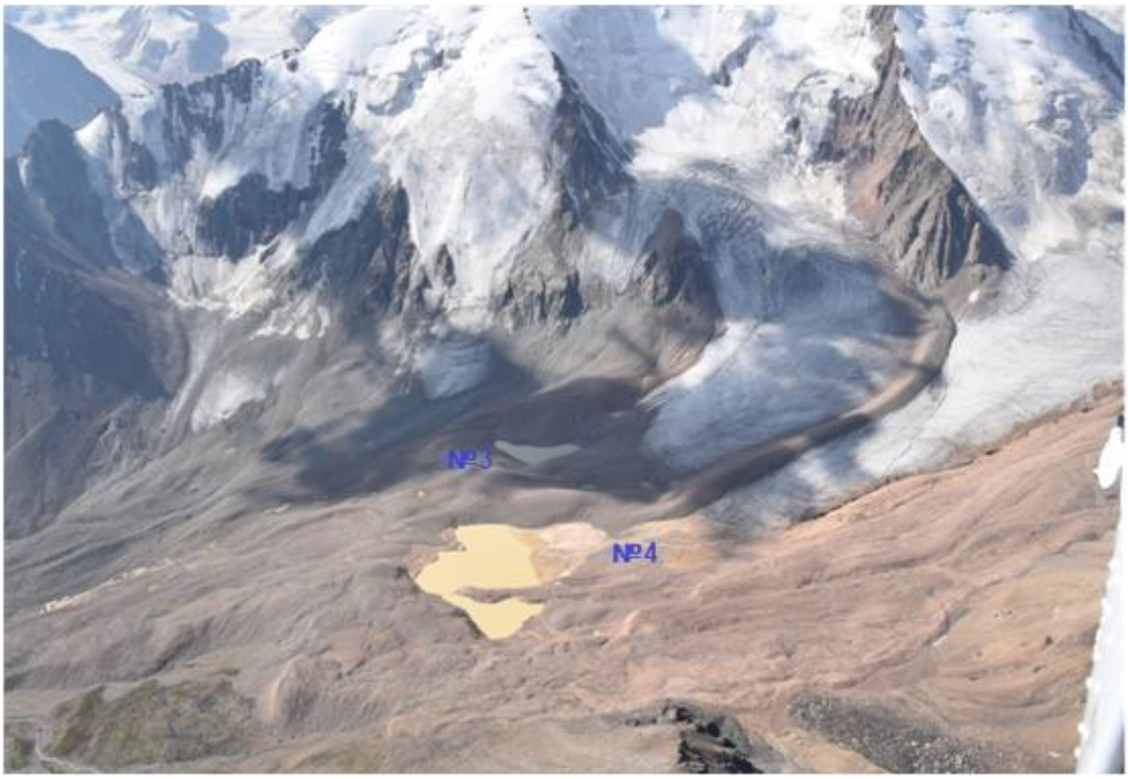
PHOTOGRAPHIC MATERIALS OF MORAINE LAKES

Moraine lake №1

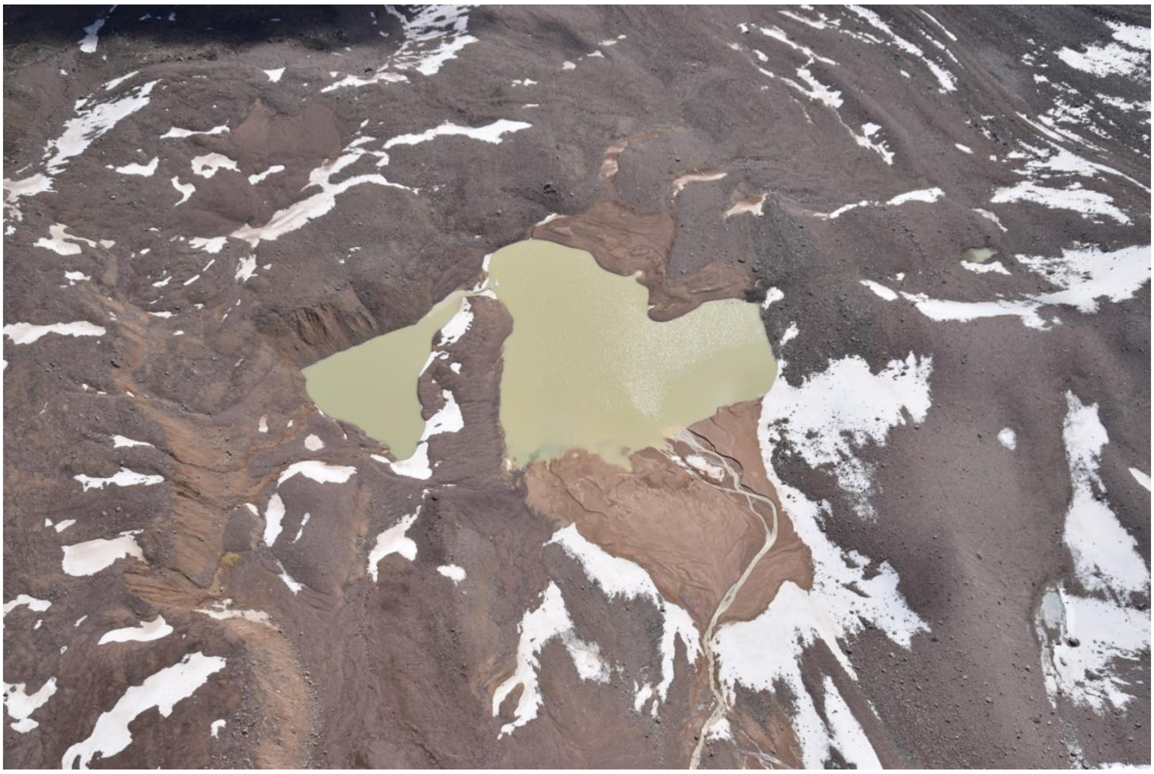
(26.06.2018, photo by Bostayeva)



Moraine lake №2

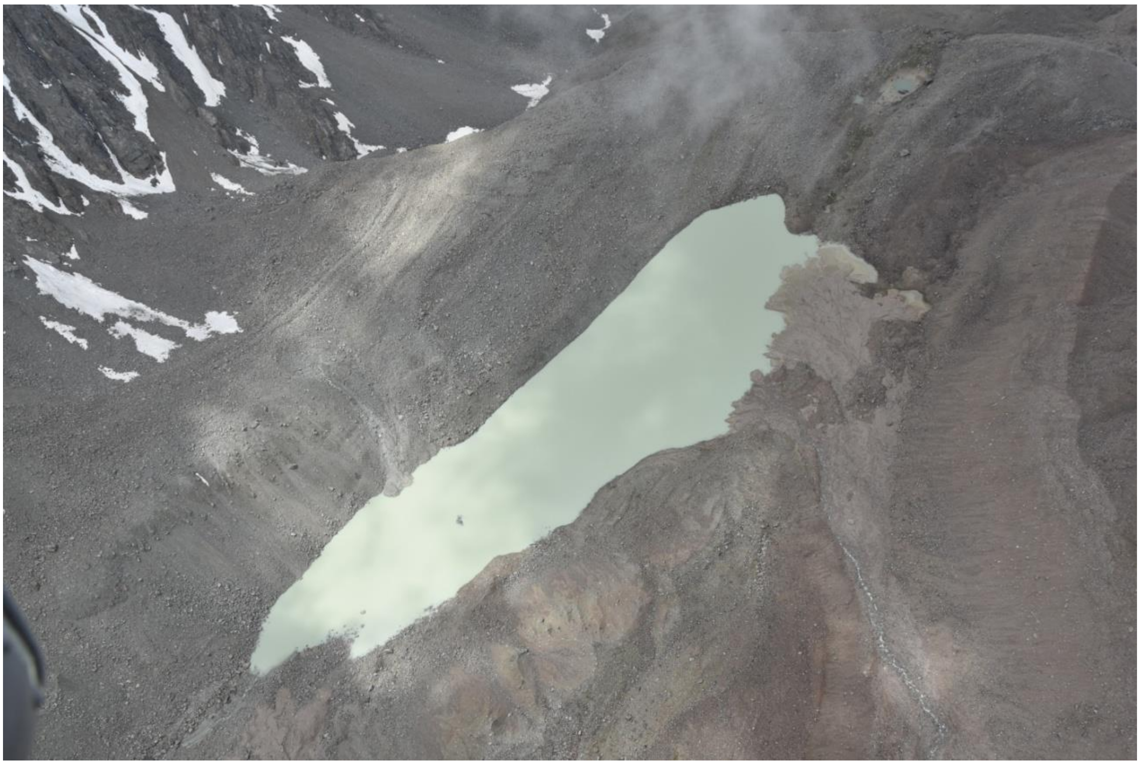


Moraine lakes №4and №3
(18.08.2022, photo by Bostayeva)



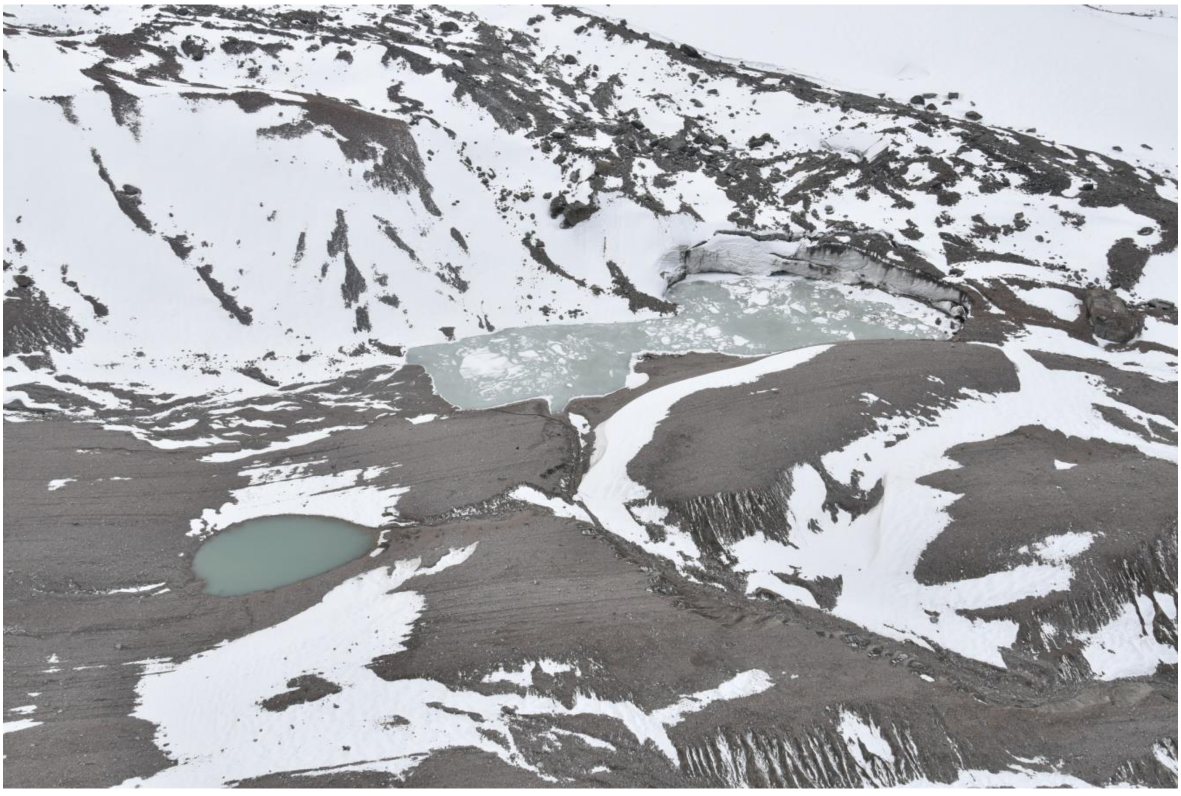
Moraine lake №3

Moraine lakes №7 and 9a
(18.07.2019, photo by Bostayeva)

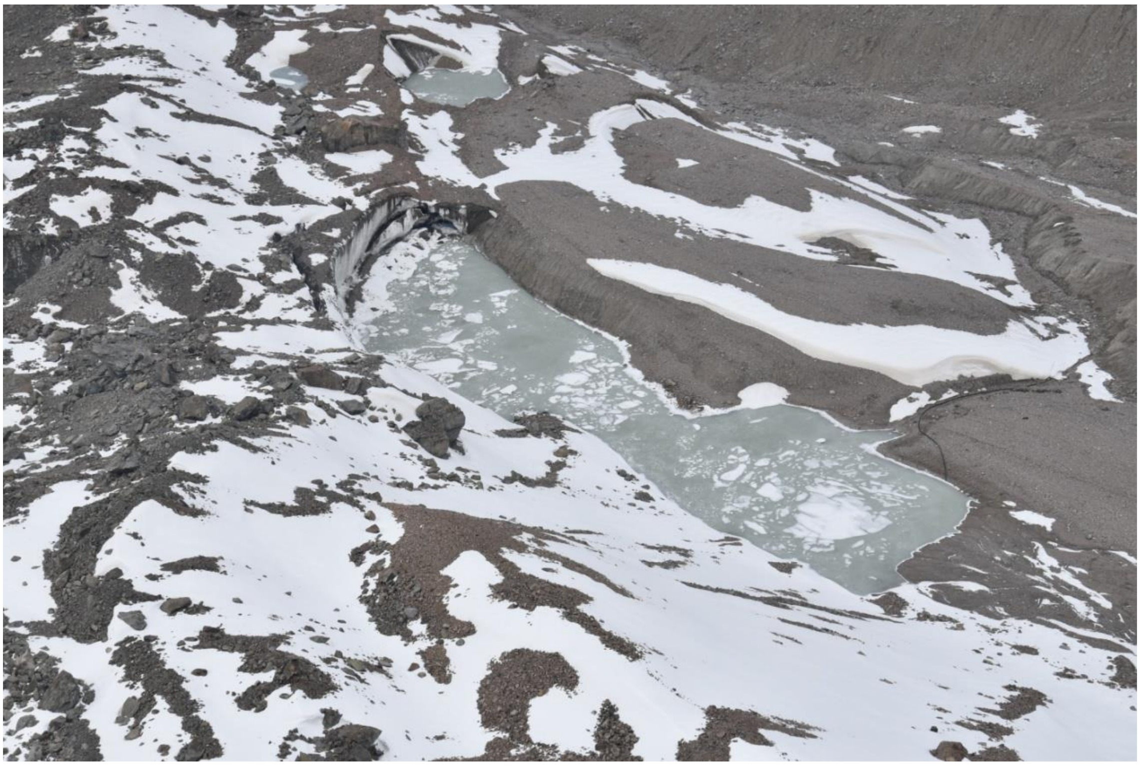


Moraine lake №8
(05.07.2024, photo by Bostayeva)

Moraine lake №8
(photo by Bostayeva)



Moraine lakes №8a and №8b



Moraine lake №8a
(04.06.2024, photo by Bostayeva)

Moraine lake №8b
(04.06.2024, photo by Bostayeva)

Moraine lakes №9 and 9a
(18.08.2022, photo by Bostayeva)

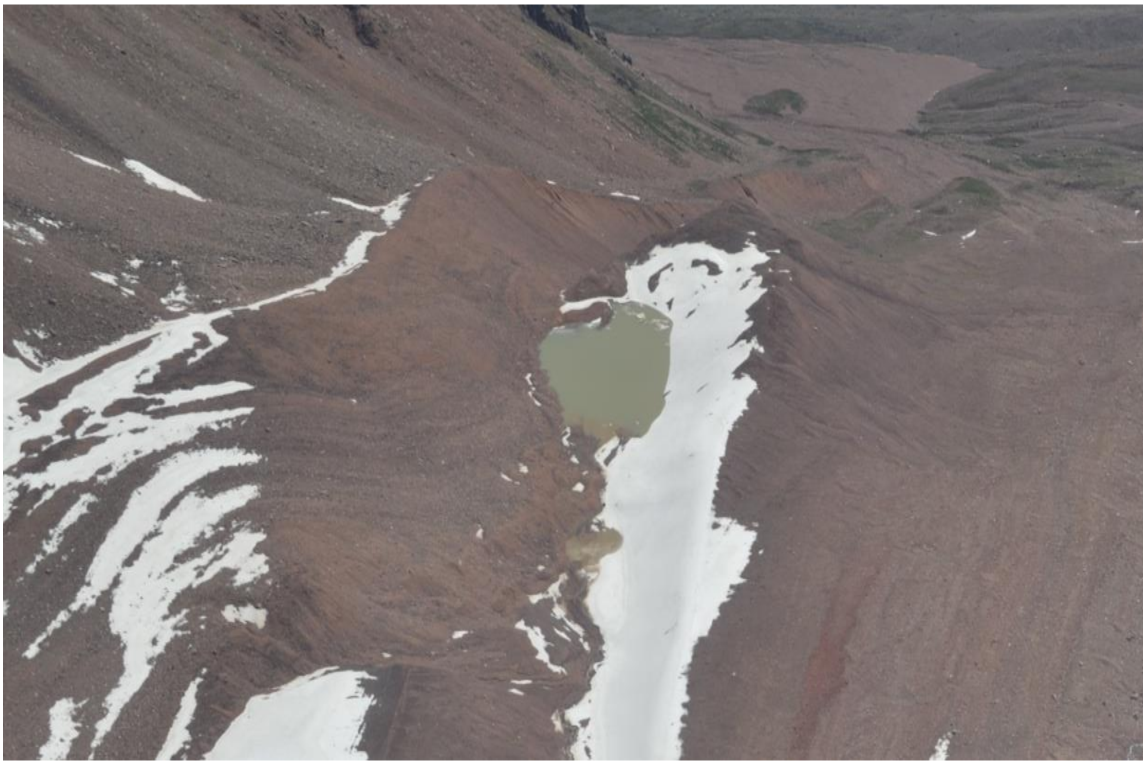
Moraine lakes №12 and №10
(05.07.2024, photo by Bostayeva)

Moraine lake №13
(04.06.2024, photo by Bostayeva)

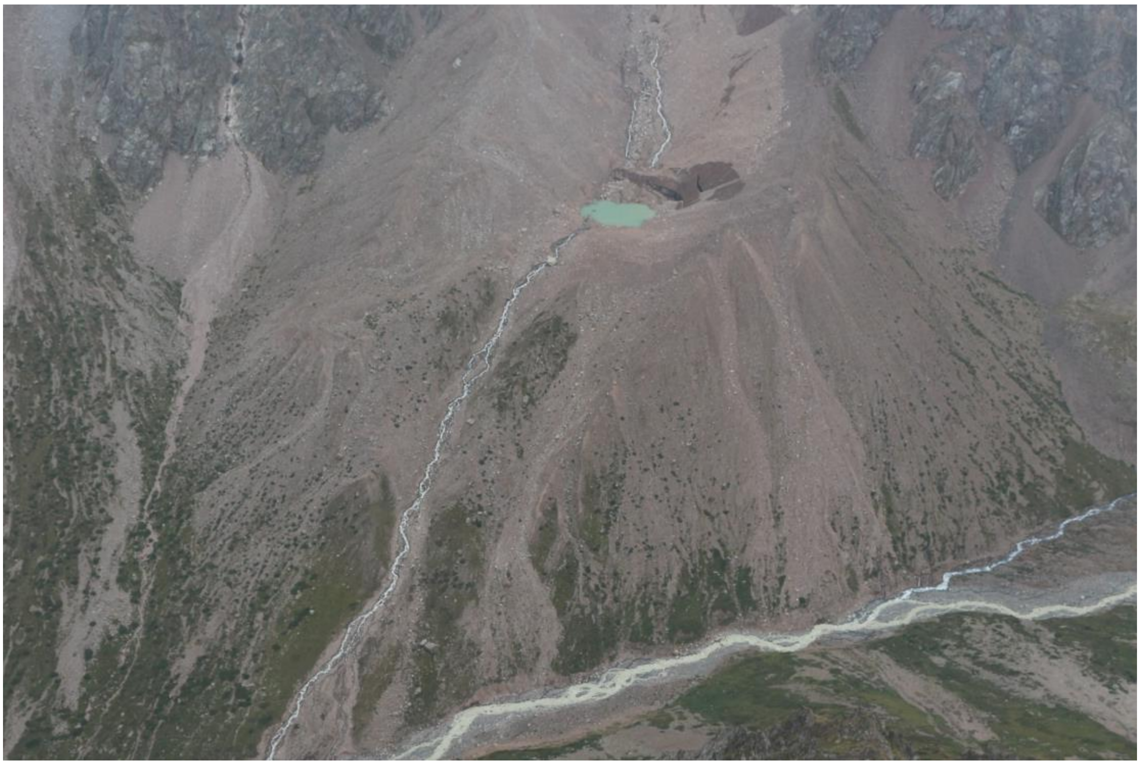
Moraine lake №14
(04.06.2024, photo by Bostayeva)

Moraine lake №15
(14.07.2023, photo by Bostayeva)

Moraine lake №16
(18.08.2022, photo by Bostayeva)



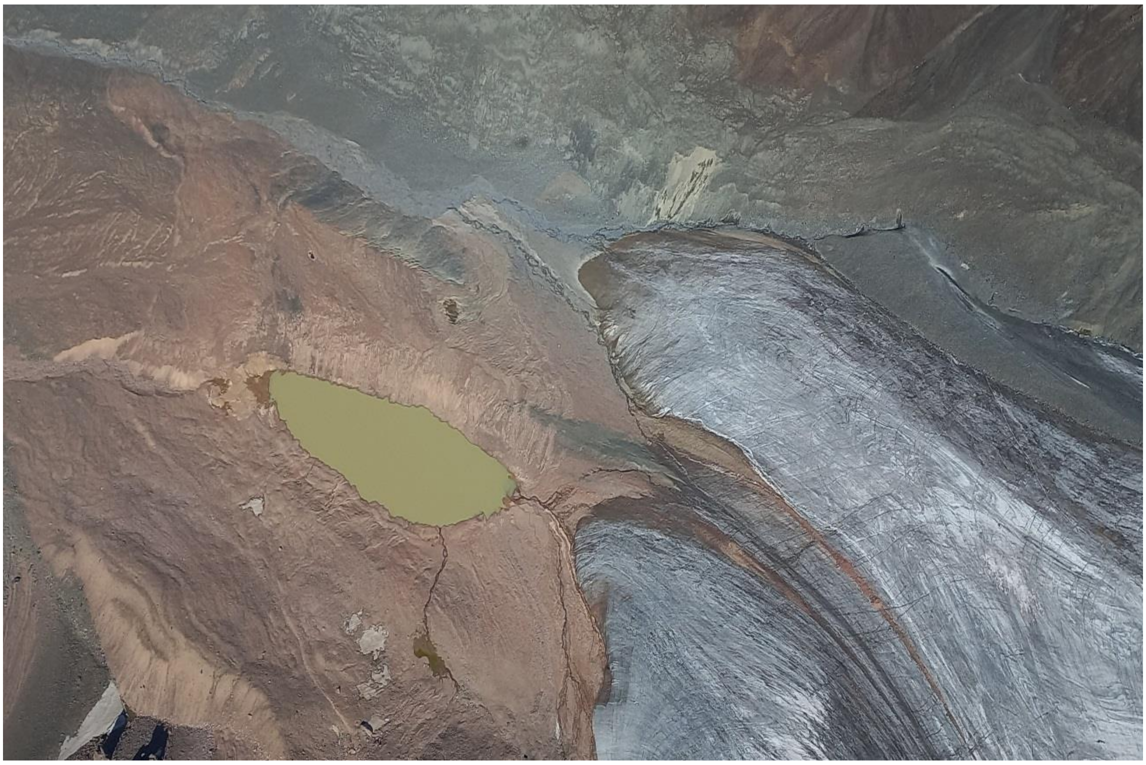
Moraine lake №17
(18.08.2022, photo by Bostayeva)



Moraine lake №18
(18.08.2022, photo by Bostayeva)

Moraine lake №19
(05.07.2024, photo by Bostayeva)

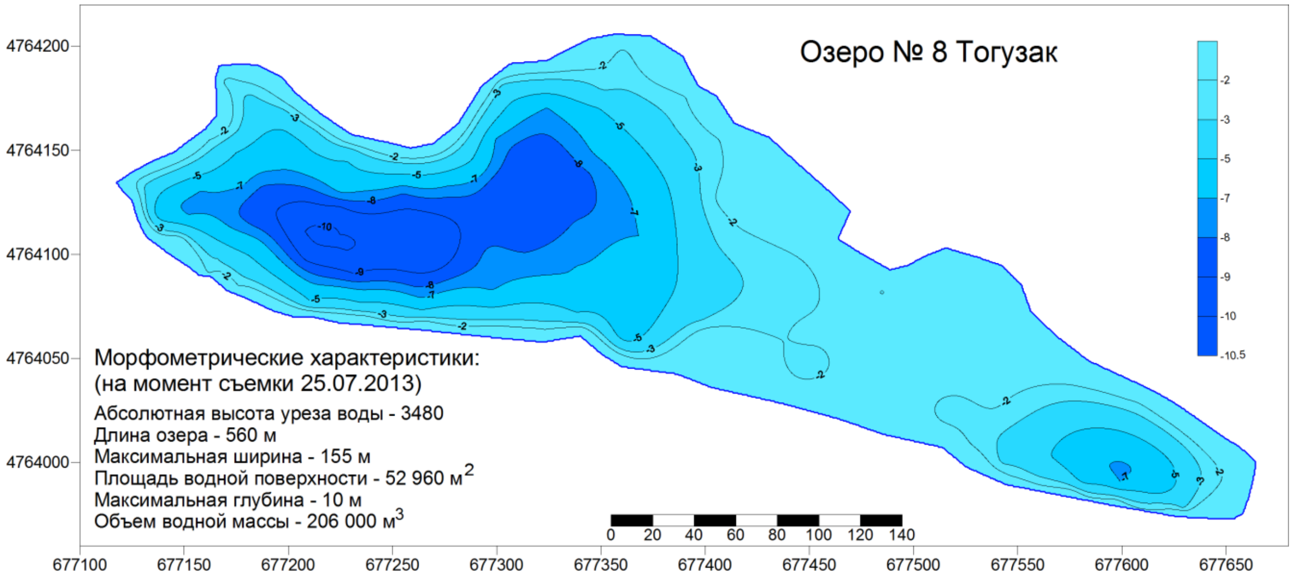
Moraine lake №19
(photo by Bostayeva)


Moraine lake №20
(18.08.2022, photo by Bostayeva)

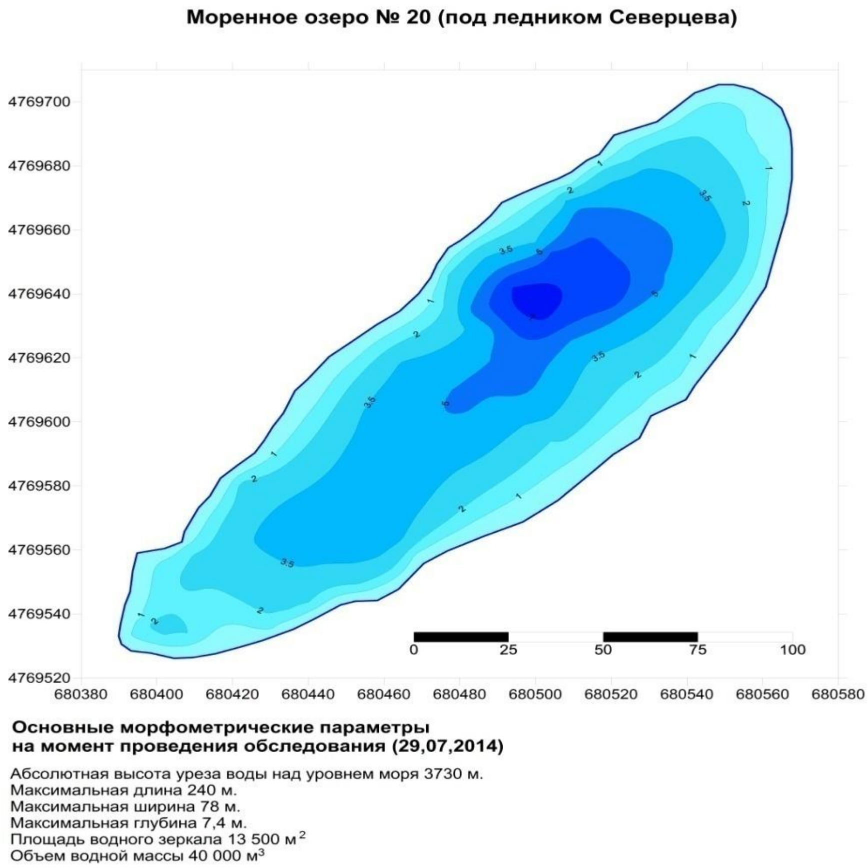

Moraine lake №21

Moraine lake «Unnamed»
(18.08.2022, photo by Bostayeva)

BATHYMETRIC SURVEY DATA

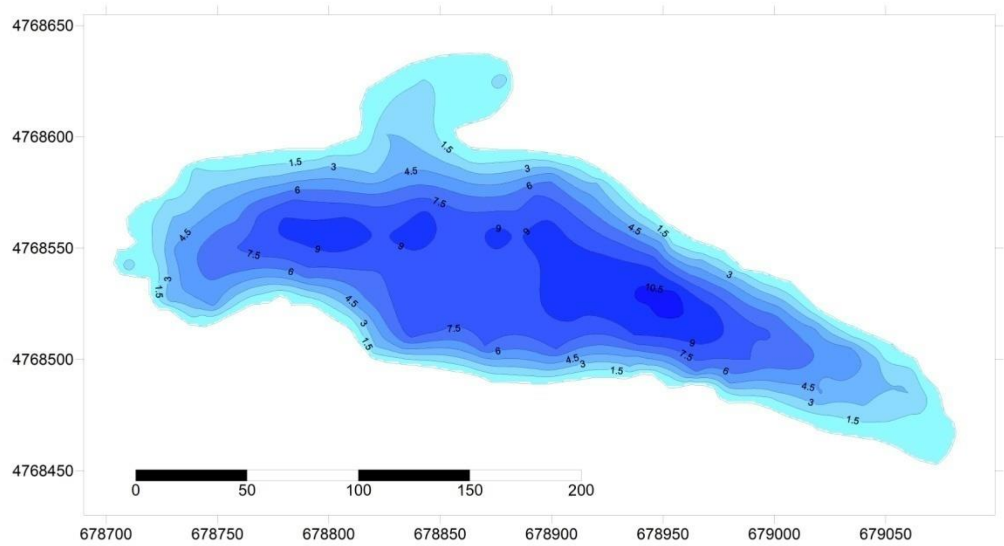


Lake № 8 under Toguzak Glacier (July 25, 2013)



Lake № 20 under Severtsev Glacier (July 29, 2014)

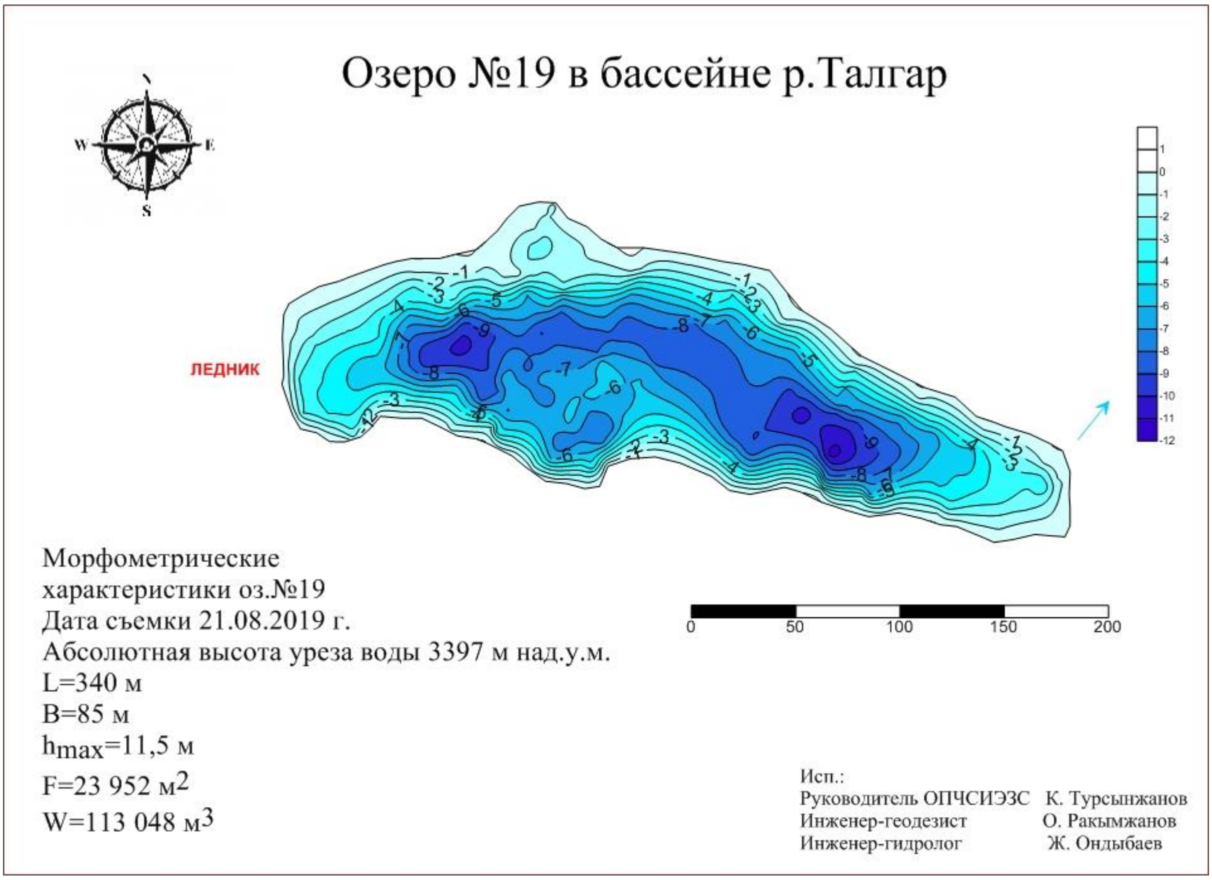
Моренное озеро № 19 (под ледником Калесника)



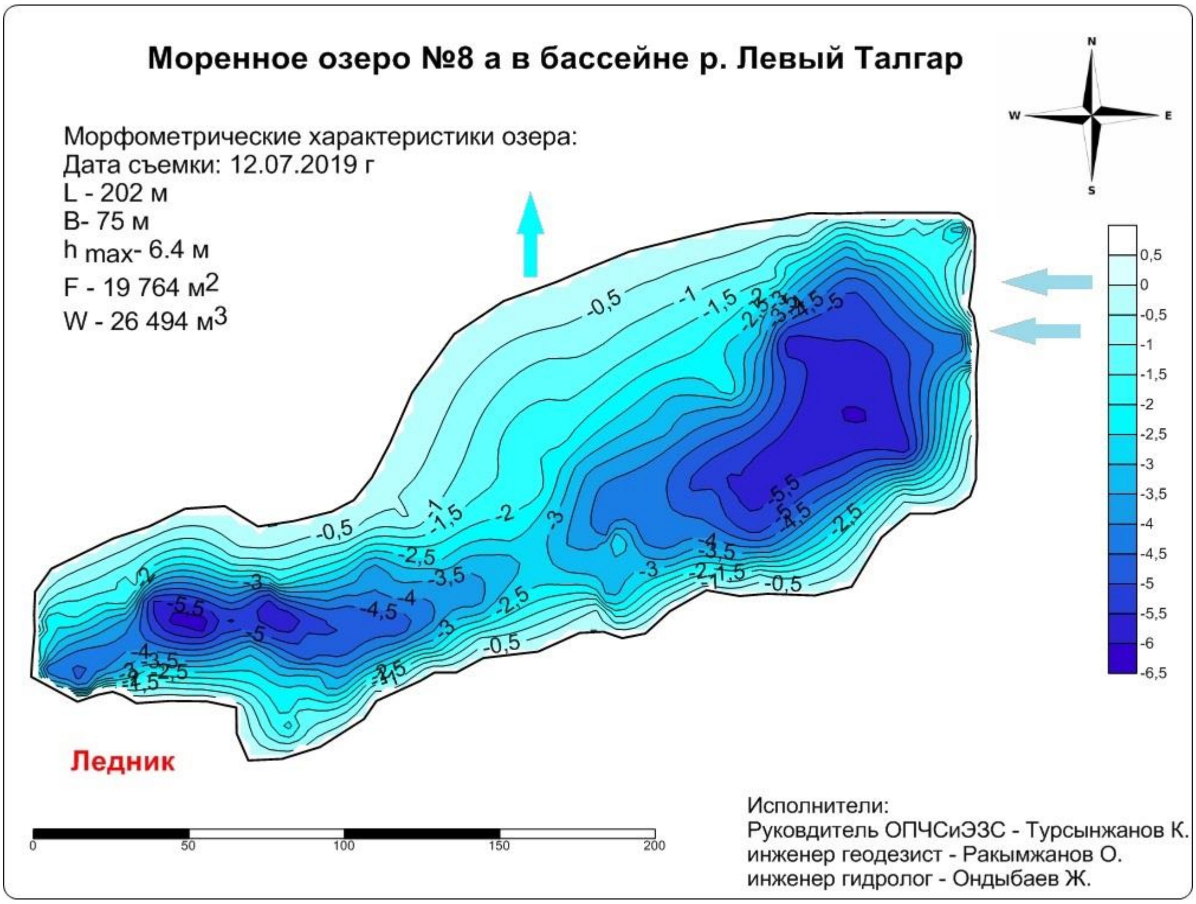
Основные морфометрические параметры
на момент проведения обследования (29,07,2014):

Абсолютная высота уреза воды над уровнем моря 3400 м.
Максимальная длина 367 м.
Максимальная ширина 143 м.
Максимальная глубина 11,2 м.
Площадь водного зеркала 29 000 м^2
Объем водной массы 150 000 м^3

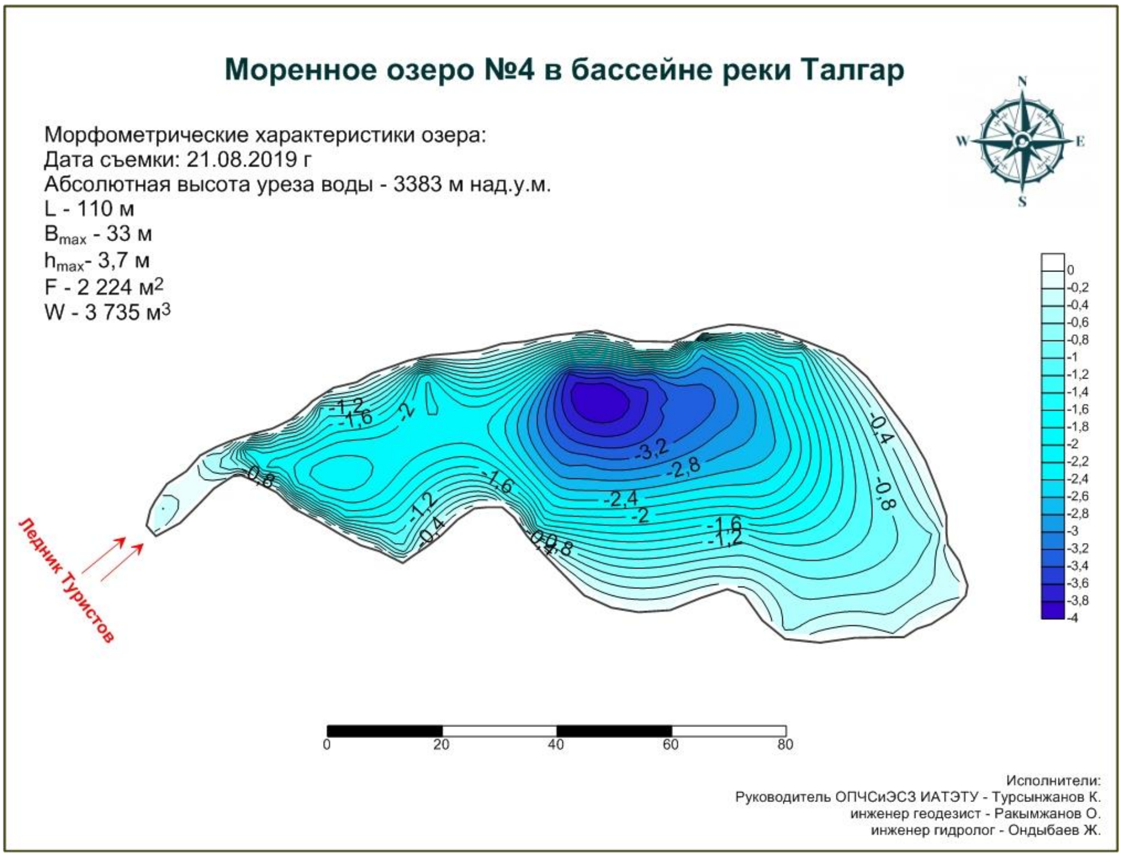
Lake №19 under Kalesnik Glacier (July 29, 2014)



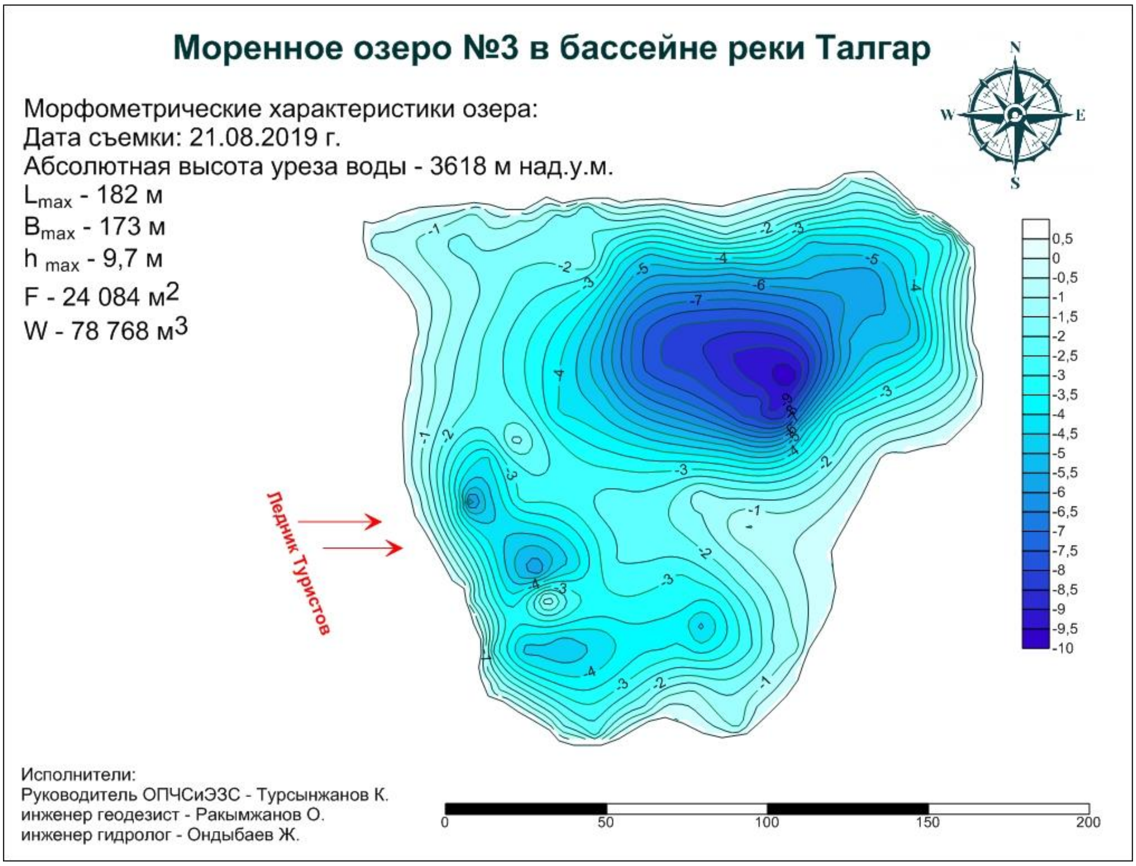
Lake № 19 (August 21, 2019)



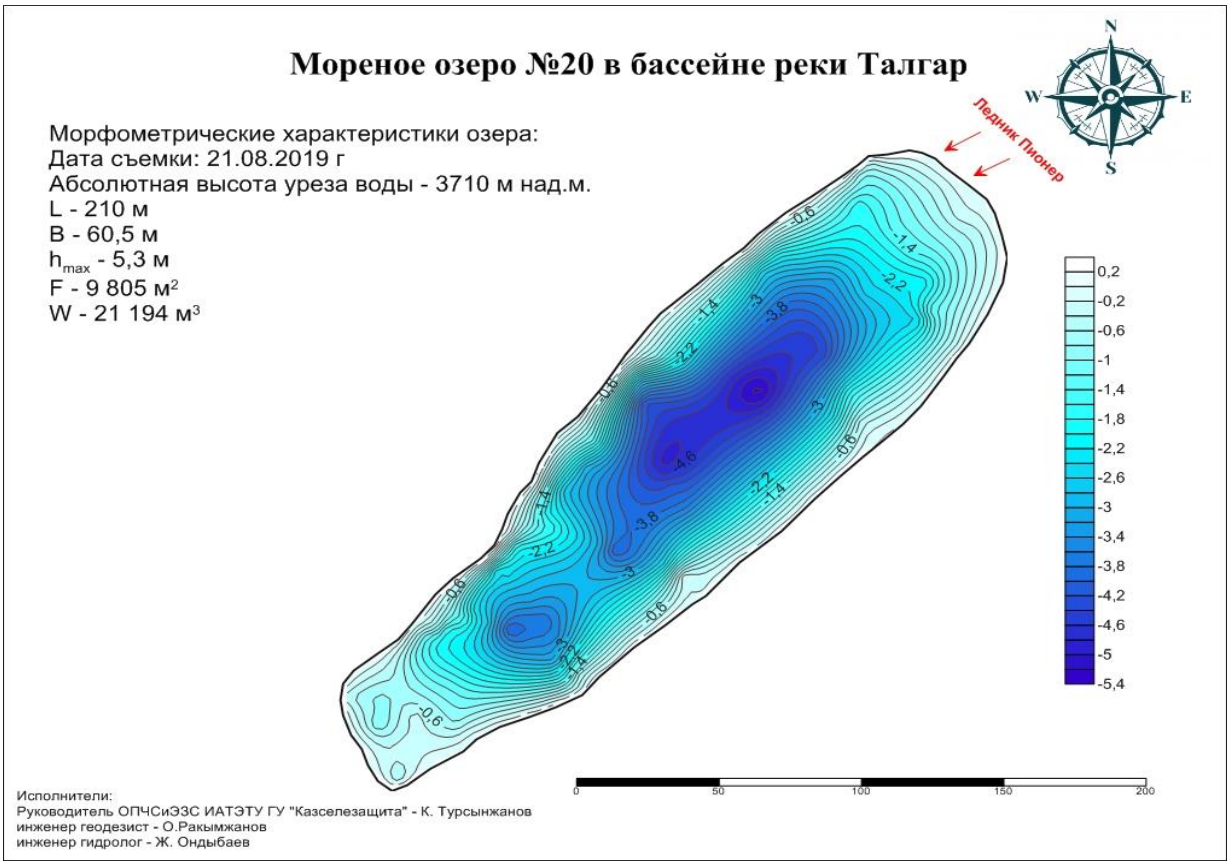
Lake № 8ain the Left Talgar basin (July 12, 2019)



Lake № 4 (August 21, 2019)

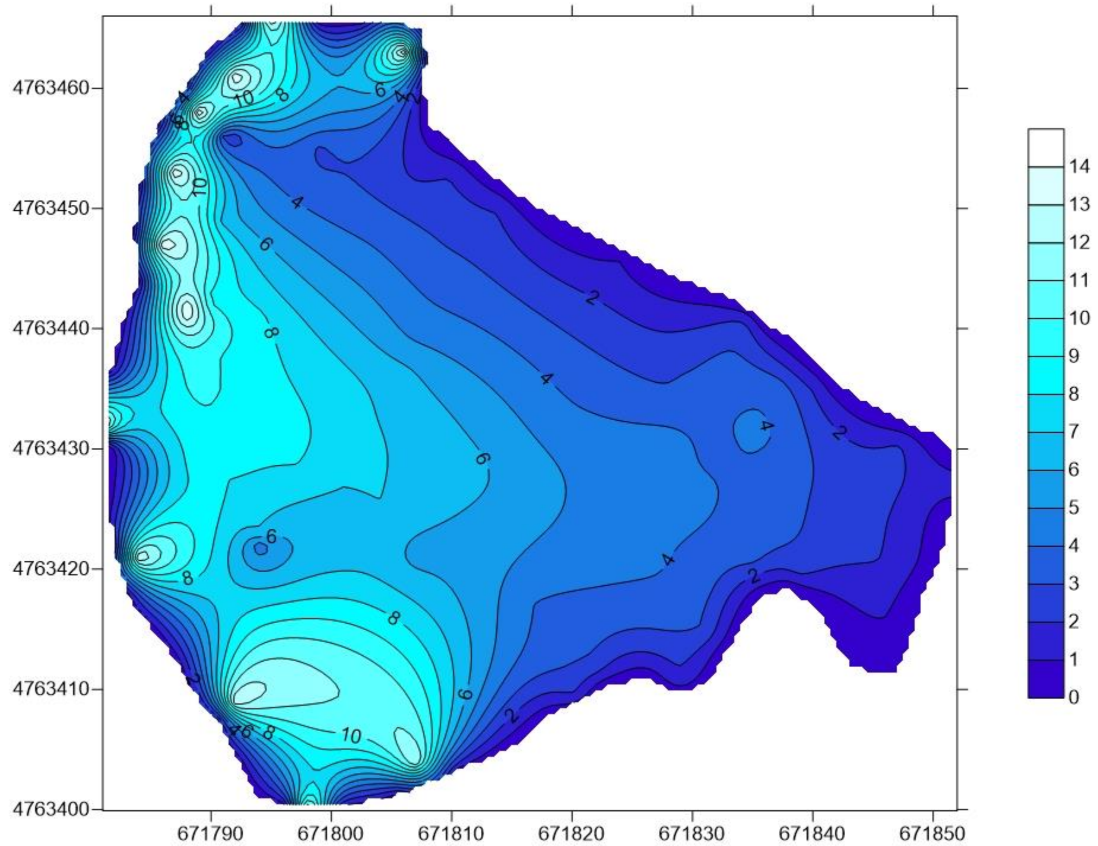


Lake № 3 (August 21, 2019)

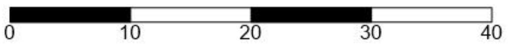


Lake № 20 (August 21, 2019)

Озеро №10 в бассейне реки Талгар



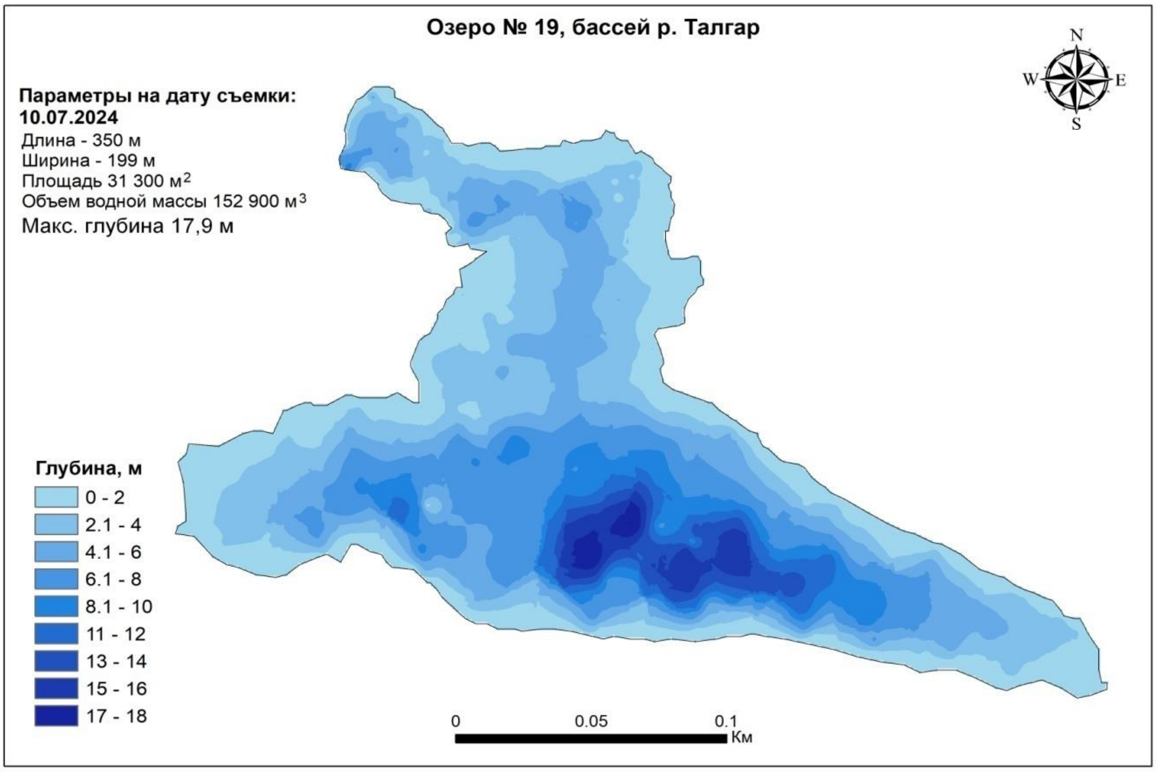
Морфометрические
характеристики:



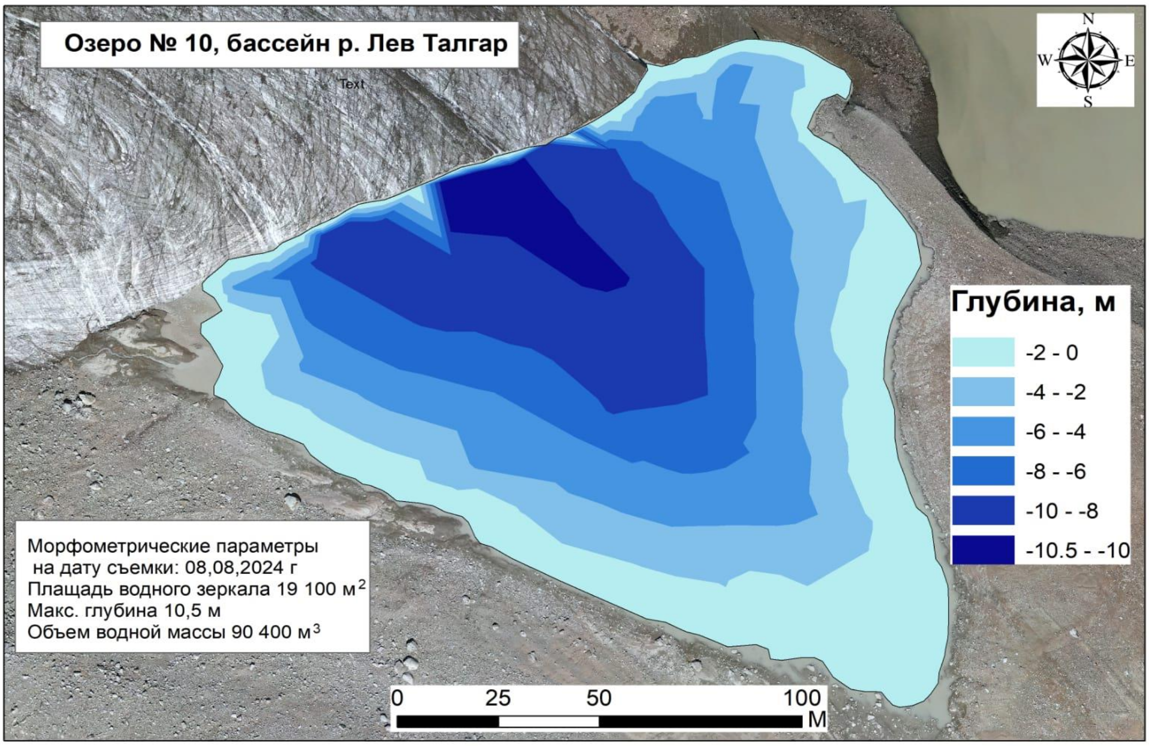
L=65 м
B=50 м
h_{max}=14 м
F=3801 $м^2$
W=14980 $м^3$

Дата съемки 15.09.2021г.
Съемку произвели:
Руководитель ОПЧСиЭЗС: Турсынжанов К.Т.
Руководитель ОДСМиО: Копжасаров А.А.

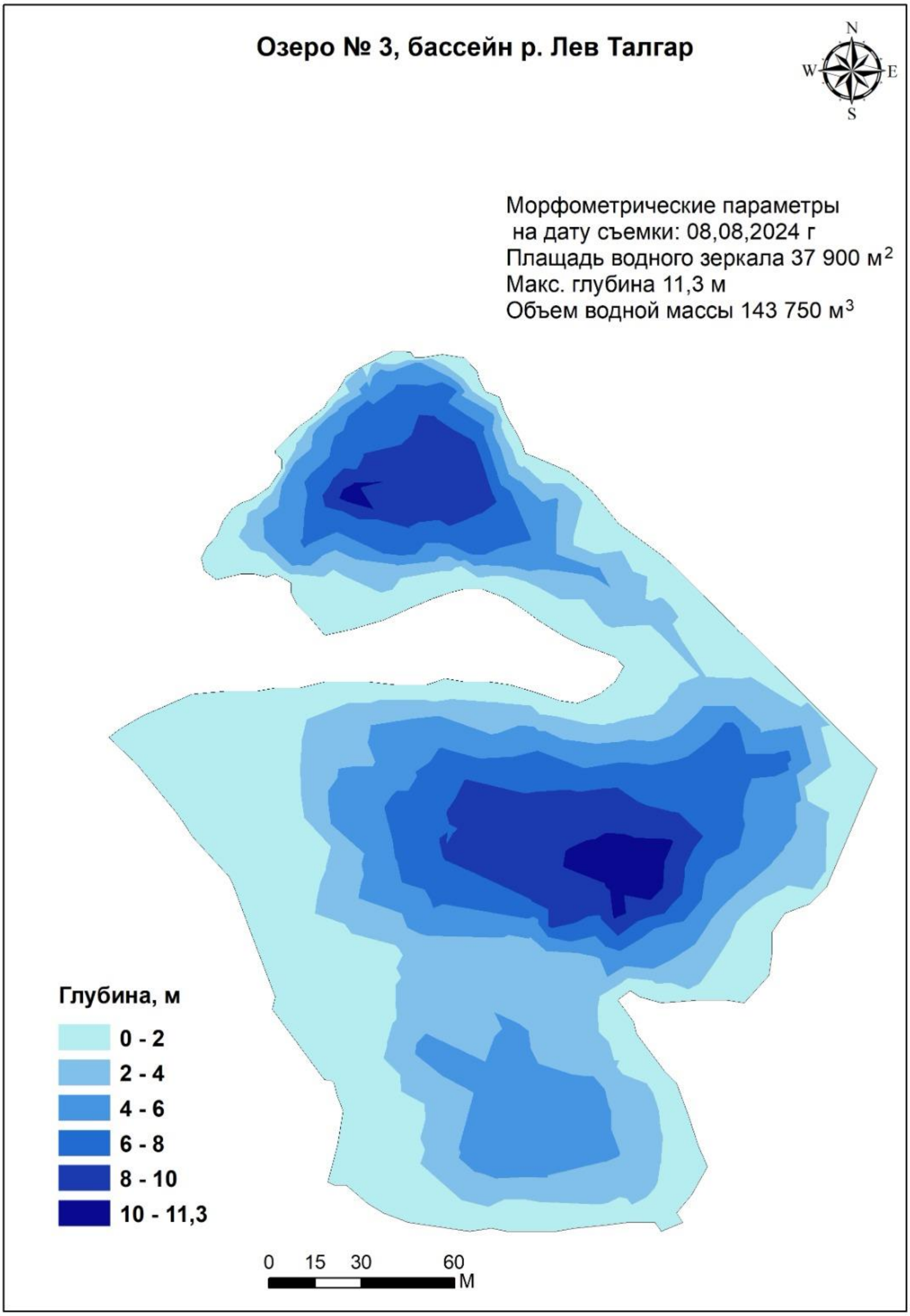
Lake № 10 (September15, 2021)



Lake № 19 (July 10, 2024)



Lake № 10 (August 8, 2024)



Lake № 3 (August 8, 2024)