IRSTI 36.61.01 https://doi.org/10.26577/EJE.2023.v77.i4.03

L. Akbayeva[1]*, Y. Pangaliyev[1], E. Atasoy[2], N. Mamytova[3], N. Kobetayeva[1], Zh. Bakeshova[1]

[1]Eurasian National University named after L.N. Gumilyov, Kazakhstan, Astana
[2]Bursa Uludag University, Turkey, Bursa
[3]Kazakh University of Technology and Business, Kazakhstan, Astana
*e-mail: akbaeva659@mail.ru

COMPARATIVE CHARACTERISTICS OF THE LAKES OF THE KARAGANDA REGION OVER THE PAST 50 YEARS

The paper gives a general overview of the lakes of the Karaganda region according to the main hydrological characteristics. A comparative analysis of several morphometric indicators of medium and small lakes in the region in 1968 and 2020 was also carried out. Over the past period, the total area of small lakes has not changed, but some of the lakes were dry in 1968, so the total volume of water in this group has increased by 19.7% since 1968. In medium and larger lakes, a significant change in the total area and volume of water is observed: an increase in area by 4.12% and an increase in volume by 12.6%. In the largest lakes of the region (more than 20 km2), with an increase in the area of lakes by 6.5%, the volume of total water increased by 53%. Thus, despite the general increase in the average annual temperature and changes in the precipitation regime in the region, the areas of reservoirs and the volume of the total water mass have increased, while the dynamics of indicators depends on the specific area of the reservoir.

Key words: lakes, hydrology, morphometric indicators, area of lakes, volume of water, Karaganda region.

Л.Х. Акбаева[1], Е.М. Панғалиев[1], Э. Атасой[2],
Н.С. Мамытова[3], Н.К. Кобетаева[1], Ж.У. Бакешова[1]

[1] Л.Н. Гумилев атындағы Еуразия ұлттық университеті, Қазақстан, Астана қ.
[2] Бурса Ұлыдағ университеті, Түркия, Бурса қ.
[3] Қазақ технология және бизнес университеті, Қазақстан, Астана қ.
*e-mail: akbaeva659@mail.ru

Соңғы 50 жылдағы Қарағанды облысындағы көлдердің салыстырмалы сипаттамасы

Мақалада негізгі гидрологиялық сипаттамалары бойынша Қарағанды облысының көлдеріне жалпы шолу жасалған. Сондай-ақ, 1968 және 2020-шы жылдары арасында облыстағы орта және шағын көлдердің бірқатар морфометриялық көрсеткіштеріне салыстырмалы талдау жасалды. Өткен кезеңде шағын көлдердің жалпы ауданы (1-ден 2 км^2-ге дейін) іс жүзінде өзгеріссіз қалды, бірақ 1968 жылы кейбір көлдердің кеуіп кетуіне байланысты осы топтағы көлдердегі судың жалпы көлемі 1968 жылға қарағанда 19,7% өсті. Орта және үлкен көлдерде (ауданы 4-тен 20 км^2-ге дейін) жалпы ауданы мен су көлемінің айтарлықтай өзгеруі байқалады: ауданның 4,12%-ға және көлемі 12,6%-ға ұлғайған. Облыстың ірі көлдерінде (20 км^2-ден астам) көлдер аумағы 6,5%-ға ұлғайса, жалпы су көлемі 53%-ға артты. Осылайша, аймақтағы орташа жылдық температураның өсуіне және жауын-шашын мөлшерінің өзгеруіне қарамастан, көлдердің ауданы мен жалпы су массасының көлемі өсті. Көлдердегі су көлемінің артуының ең ықтимал себебі жауын-шашын мөлшерінің, әсіресе қыс мезгілінде.ұлғаюы.

Түйін сөздер: көлдер, гидрология, морфометриялық көрсеткіштер, көлдер аумағы, су көлемі, Қарағанды облысы.

Л.Х. Акбаева[1]*, Е.М. Панғалиев[1], Э. Атасой[2],
Н.С. Мамытова[3], Н.К. Кобетаева[1], Ж.У. Бакешова[1]
[1]Евразийский национальный университет имени Л.Н. Гумилева, Казахстан, г. Астана
[2]Университет Бурса Улудаг, Турция, г. Бурса
[3]Казахский университет технологии и бизнеса, Казахстан, г. Астана
*e-mail: akbaeva659@mail.ru

Сравнительная характеристика озер Карагандинский области за последние 50 лет

В работе дан общий обзор озер Карагандинской области по главным гидрологическим характеристикам. Также был проведен сравнительный анализ ряда морфометрических показателей средних и малых озер области в 1968 году и 2020 году. За истекший период суммарная площадь малых озер (1 до 2 км2) практически не изменилась, однако часть озер в 1968 году была пересохшая, поэтому общий объем воды, заключенный в этой группе с 1968 года, вырос на 19.7%. В средних и более крупных озерах (площадью от 4 до 20 км^2) наблюдается достоверное изменение суммарной площади и объема воды: увеличение площади на 4.12 % и увеличение объема на 12.6 %. В самых крупных озерах области (более 20 км2) при увеличении площади озер на 6.5% объем общий воды увеличился на 53%. Таким образом, несмотря на общее увеличение среднегодовой температуры и изменения режима осадков в области, площади водоемов и объем суммарной водной массы увеличились, при этом динамика показателей зависит от конкретной площади водоема. Наиболее вероятная причина увеличения воды в озерах - увеличение осадков, особенно в зимний период.

Ключевые слова: озера, гидрология, морфометрические показатели, площадь озер, объем воды, Карагандинская область.

Introduction

In recent decades, the problem of water resources in the Republic of Kazakhstan has become especially acute in the light of the impending water shortage, climate change, geographic location, and anthropogenic impact [1]. The hydrographic network and the number of reservoirs in most of the territory are relatively poor, and therefore considering the total area of surface waters, the dynamics of changes in their morphological indicators is very important. The concern of hydrologists and ecologists so far has mainly been caused by changes in relatively large reservoirs and rivers. However, insufficient attention was paid to the state of medium and small lakes. At the same time, lakes have a great impact on the microclimate, the well-being of adjacent ecosystems, and are of value for recreation and economic importance [2].

Karaganda region occupies the largest area of the territory of Central Kazakhstan. On average, there are about 1910 lakes with a total area of 926 km^2. Of these, with an area of less than 1 km^2 - 1779, making up 14% of the water surface [3]. Medium and small lakes have shorter water cycles, eutrophy faster, dry up, their disappearance is often not recorded in hydrological registers [4, 5].

The purpose of this work was to conduct a comparative analysis of a number of morphometric indicators of medium and small lakes in the Karaganda region over the past half century.

Working hypothesis: It is assumed that over the past decades there have been significant changes in the indicators of surface waters in Central Kazakhstan, particularly the Karaganda region, due to a whole range of environmental factors. This should be reflected primarily in the number of lakes, the total area of water, the total volume of water mass.

Materials and methods

We carried out expeditionary research in the Karaganda region to obtain visual confirmation of the number of existing reservoirs, their hydrometric indicators, such as maximum and average depth, water level.

Considering that the lakes of the region are mostly shallow, measurements were carried out on the water surface with a hand lot (a sounding lead) from a boat at regular intervals of 10–15 m (for shallow lakes) and 100 m (for lakes larger than 5 km^2) [6, 7].

To calculate the area of lakes and the catchment area, we used data from the Sentinel-2 series satellites processed using the SNAP software belonging to the European Space Agency and available after basic processing on the specialized Internet portal Copernicus Open Access Hub. Water surface area calculations were carried out using SNAP v7.0 software. For this, the MNDWI index was applied, using data from the green range of the visible

spectrum (for Sentinel-2 it is designated as B3) and the mid-wave MI range (Middle Infrared - MIF, for Sentinel-2 it is designated as B12). The Modified Normalized Difference Water Index (MNDWI) was described by Hanqiu Xu in 2006 [8]. The index is calculated using the formula

MNDWI = (Green – MIR) / (Green + MIR), where Green and MIR are the pixel values of the raster (reflectivity) of the green range and the mid-wave infrared range, respectively.

Index values can range from minus 1 to plus 1, where minus 1 with the maximum probability corresponds to the land, and plus 1 to the water surface. Further, based on the raster with the values of the MNDWI index, water bodies were detected. Detection was carried out using raster binarization according to the criterion of exceeding the threshold value of the index.

The volume of water in the lakes was calculated from the depth and area of the lakes.

In addition, for the purpose of comparison, we used stock materials for the last century on research of lakes in the Karaganda region, as well as literary sources [9, 10, 11].

Characteristics of the object of study

Karaganda region is less rich in lakes than other northern regions of Kazakhstan, while the lakes are very unevenly distributed (Figure 1). The numbers of the lakes correspond to the numbers in Table 1. Over 68% of the lakes are concentrated in the northern part of the region. The number of lakes naturally decreases with an increase in the dryness of the climate and an increase in the infiltration capacity of soils. There are also fewer lakes in the eastern and central highlands, where local runoff accumulation conditions are less favorable. With the exception of the Karkaraly Mountains, where there are several deep natural reservoirs [3, 12].

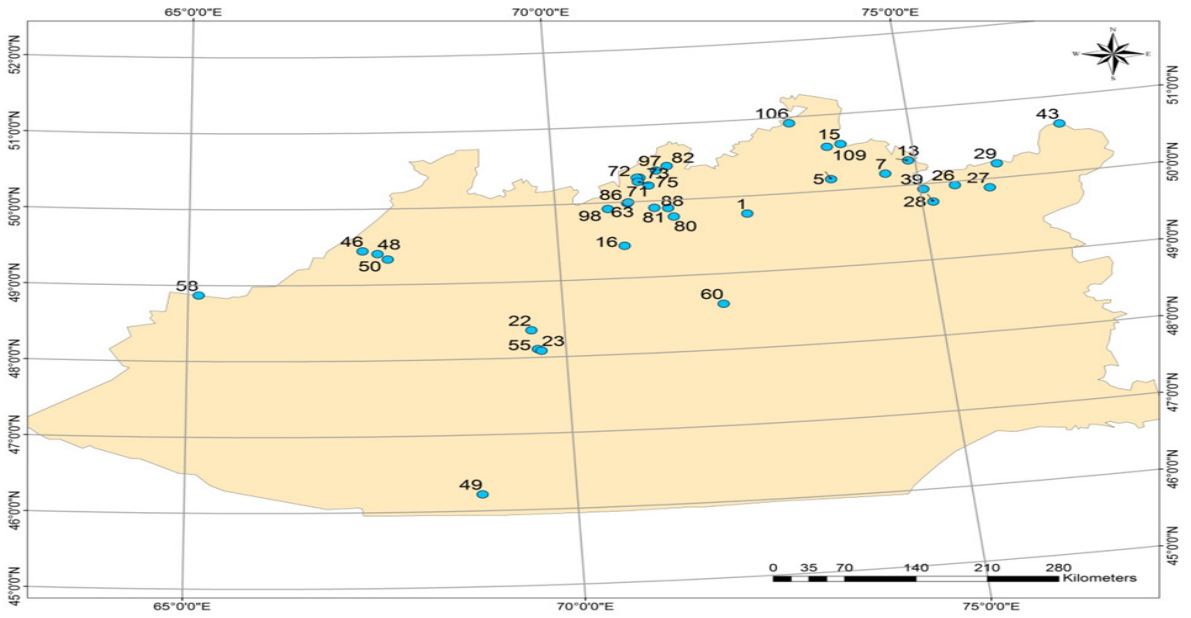

Figure 1 – Distribution of lakes (more than 5 km^2 in area) of the Karaganda region

Small lakes are grouped along rivers, streams and channels, large ones are confined to lowland areas. A significant number (75%) of small lakes are located in the northern regions of the territory, in the basins of the Nura, Kulanutpes, Kon rivers and the drainless basin of lake Karasor. Some of them are located in the floodplains of large rivers, mainly the Nura River (Figure 2) [3].

On average, there is 0.27 km^2 of water surface per 100 km2. The northern Nura region is the richest in lakes, but even in it their water surface is 1.3 km^2 per 100 km^2 of land [13].

In general, clayey soils are widespread in the territory of the region and significant silting of lakes is observed, therefore, water exchange between the water mass of the lake and the soil of its bed is usually difficult. Filtration and groundwater inflow here usually do not exceed 5–20% of evaporation [14].

The studied lakes are located in different structural and lithological conditions: they are

laid both in loose sedimentary formations of the Mesozoic-Cenozoic and in rigid igneous rocks of the Precambrian and Paleozoic. Back in the 1960s and 1970s, it was established that four types of lakes occur in this area in the formation of basins: hydrogenous, suffusion-karst, eolian, and tectonic [15, 16, 17].

According to the chemical composition of the water, 66 lakes belong to the chloride type (77.7%), 16 to the hydrocarbonate type (18.8%), and 3 to the sulfate type (3.5%) [18]. The total number of fresh and conditionally fresh lakes (with the sum of ions in the summer low water up to 2.5-3 g/l) was 32%, weakly brackish (up to 9-10 g/l) - 22% and strongly brackish (up to 25 g/l) - 13%, the remaining 32% are O.A. Alekin to the hydrochloric group (over 25 g/l). When hydrometeorological conditions change, some lakes move from one group to another [19].

The depth of the lakes ranges from a few centimeters (drying water bodies) to 3-4 m, rarely more.

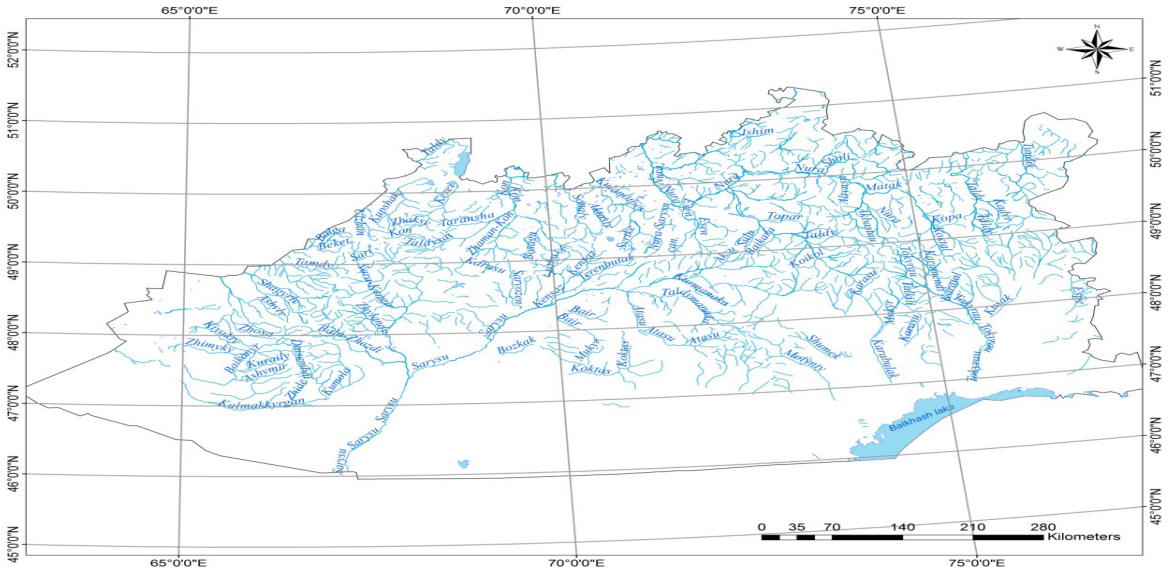

Figure 2 – Hydrographic network of river basins in Karaganda region

At the same time, fresh and slightly brackish water bodies are in most cases deeper than saline (mineral) ones. Salt lakes (Karasor, Karakoin, etc.) predominate on the territory. Fresh lakes are located mainly in the north, in the Nura river basin and in the Karkaraly mountains [3].

On all lakes, the rise in the level from the influx of water during the period of spring snowmelt begins at the end of March and ends mainly in 10-15 days. The height of the spring rise in the level varies from year to year and can exceed 2 meters. The lowest water level in the lakes is set in October. The annual amplitude of water level fluctuations averages 0.6-0.8 meters [20].

The lakes of the region, with rare exceptions, are endorheic and stagnant. Only some floodplain lakes in the basins of the Nura and Kulanutpes rivers, as well as the lakes of the Karkaraly Mountains (Pashino, Ulkenkol, Ashchykol), are flowing.

Results and Discussion

We collected data on the number and morphometric parameters of lakes in the Karaganda region according to available scientific sources for 1938, 1968 and 1973. And compared them with the data of our research. The results are collected in table 1.

In general, out of 109 lakes studied by us, 34 water bodies have an area of 1 to 2 km^2, 32 (29%) lakes with an area of 2.0 to 4.0 km^2, 15 (13.5%) lakes with an area of 4.0–6.0 km^2, 21 (19.2%) lakes with an area of 6.0 to 18.6 km^2 and 7 (6.4%) lakes larger than 20 km^2.

If we do not consider numerous small lakes with an area of less than 1 km^2, then because of the study of everything, we described 109 lakes, information on which has also been preserved since 1968. In earlier periods, such systematic work was not carried out.

Table 1 – Morphometric indicators of the lakes of the Karaganda region

№	Titles	Year of study	Area of lakes, km^2	Length, km	Maximum width, km	Average depth (maximum depth), m	Water volume million m^3	Coastline length, km	Lake catchment area, km^2	Coordinates
1	Sasykkol	1968	16.16	8	3.9	1.8 (5.5)	25	23.8	208	49°37’54.6”N 72°28’50.6”E
		2020	22.3	8.3	5.0	2.0 (5.5)	31	27.3		
2	Sopaksor	1968	4.7	3.7	2.0	(0.5)	1.02	11	111	49°38’26.9”N 71°42’54.2”E
		2020	4.5	3.4	1.8	0.3 (0.5)	0.8	8.9		
3	Shubar	1968	2.0	4.5	0.5	(0.5)	P	12.9	51	49°35’22.7”N 71°45’21.2”E
		2020	2.2	4.3	0.7	0.2 (0.4)	0.4	13.2		
4	Kok-Dombak	1968	3.42	4.0	1.3	(0.1)	P	8.9	82	47°00’28.9”N 74°24’40.4”E
		2020	3.3	3.57	1.52	0.1 (0.2)	0.3	8.54		
5	Botakara	1968	7.3	4.2	2.5	2.0 (5.0)	15.0	10.8	495	50°06’18.4”N 73°43’35.0”E
		2020	21.1	7.6	4.1	2.0 (5.0)	42.2	25.9		
6	Kaiyndykol	1968	2.0	1.8	1.4	0.8 (1.3)	1.6	4.9	40	50°15’05.5”N 74°45’30.1”E
		2020	2.1	2.1	1.4	1.0 (1.3)	2.1	5.9		
7	Ashchykol	1968	4.5	2.8	2.2	1.7 (3.5)	7.5	10.0	98	50°01’55.9”N 74°33’05.5”E
		2020	5.0	3.1	2.1	2.0 (4.0)	10.0	9.0		
8	Bolshoy Sarykol	1968	1.1	1.5	1	2.0 (3.6)	2.2	4.0	12	49°28’41.6”N 73°41’51.8”E
		2020	1.2	1.7	1.2	2.0 (3.6)	2.4	5.4		
9	Manten	1968	2.3	2.4	1.5	(0.15)	P	6.9	34	50°10’51.5”N 73°30’39.8”E
		2020	2.4	2.3	1.53	0.1 (0.2)	0.2	8.29		
10	Kurgankol	1968	2.9	2.3	1.8	2.0 (3.0)	5.0	6.8	69	50°18’42.3”N 73°46’44.3”E
		2020	4.3	3.1	2.3	2.0 (3.0)	8.6	9.8		
11	Kumdykol	1968	2.16	1.9	1.3	(2.2)	5.0	5.2	51	50°27’54.0”N 73°58’29.6”E
		2020	2.1	2.07	1.4	2.2 (3.5)	4.6	5.5		
12	Aryktykol	1968	1.6	1.7	1.4	2.0 (4.5)	3.2	4.8	80	50°06’34.8”N 72°26’37.9”E
		2020	1.96	1.8	1.4	2.0 (4.5)	3.9	5.2		
13	Rudnichnoye	1968	6.56	4.2	2.0	4.3 (8.5)	35.8	15.0	30	50°13’38.1”N 74°52’15.1”E
		2020	7.4	4.39	2.0	4.3 (8.5)	31.8	18.7		
14	Shalkarkol	1968	3.09	2.1	1.9	1.4 (3.5)	4.4	10.5	33	50°14’21.1”N 74°54’13.7”E
		2020	2.7	2.4	1.9	1.4 (3.5)	3.78	7.07		
15	Batpakkol	1968	7.0	3.6	2.5	1.2 (2.2)	8.0	9.4	84	50°36’20.3”N 74°01’18.5”E
		2020	6.3	3.6	2.3	1.0 (2.2)	6.3	9.7		
16	Shoshkakol	1968	32.0	8.5	6.7	(1.0)	P	28.3	360	49°16’57.2”N 70°49’29.5”E
		2020	26.7	6.7	5.9	0.2 (1.0)	5.3	27.2		
17	Sorkol	1968	2.1	3.5	1.2	(1.2)	0.92	8.4	230	48°33’34.7”N 70°16’47.9”E
		2020	1.9	2.09	1.2	0.4 (1.0)	0.76	5.4		
18	Botagankol	1968	2.0	1.7	1.6	(0.7)	0.7	7.5	92	48°30’14.0”N 70°37’22.8”E
		2020	1.3	1.7	1.34	0.35 (0.7)	0.45	8.9		
19	Shagyrlykol	1968	1.3	1.9	1.1	(0.35)	P	4.9	38	48°28’55.0”N 70°31’21.5”E
		2020	1.01	1.08	0.9	0.1 (0.3)	P	4.6		
20	Zhyngyrlykol	1968	1.65	3.4	0.7	-	P	9.4	49	48°18’38.7”N 70°16’13.1”E
		2020	1.44	3.3	0.8	0.1 (0.5)	0.05	9.34		

Table continuation

№	Titles	Year of study	Area of lakes, km^2	Length, km	Maximum width, km	Average depth (maximum depth), m	Water volume million m^3	Coastline length, km	Lake catchment area, km^2	Coordinates
21	Bozkol	1968	1.9	2.7	1.1	-	P	7.7	323	48°10’23.6”N 70°01’20.1”E
		2020	1.95	2.6	1.09	-	P	7.56		
22	Kabyrshakty	1968	5.8	4.0	2.0	0.9 (1.3)	5.0	14.3	916	48°20’08.8”N 69°31’15.4”E
		2020	5.8	3.8	2.02	0.8 (1.3)	4.62	12.9		
23	Biesoygan	1968	6.5	4.3	2.4	(0.1)	P	11	70	48°05’01.3”N 69°31’56.3”E
		2020	6.6	4.36	2.4	0.05 (0.1)	0.33	11.4		
24	Kumkol	1968	2.9	2.4	1.7	(0.5)	P	13.7	203	48°42’32.9”N 70°36’32.3”E
		2020	1.6	1.7	1.1	0.1 (0.5)	0.16	9.3		
25	Sasykkol	1968	4.0	2.7	2.0	-	-	8.3	75	49°00’33.1”N 71°27’17.0”E
		2020	4.0	2.6	2.1	0.2 (0.6)	0.8	8.1		
26	Karasor	1968	155	43.5	7.3	1.1 (2.5)	160.0	103.0	8750	49°52’30.1”N 75°21’48.8”E
		2020	147	39.2	8.2	1.1 (5.0)	161.0	107.0		
27	Balyktykol	1968	26.5	6.8	6.0	2.6 (3.8)	69.0	25.5	565	49°47’36.3”N 75°56’07.2”E
		2020	28.7	6.3	6.1	2.6 (3.8)	74.6	25.4		
28	Katynkol	1968	9.5	5.5	2.3	(3.2)	17.0	16.3	364	49°44’08.9”N 75°09’00.8”E
		2020	16.2	7.2	2.3	2.0 (5.5)	32.4	28.1		
29	Saumalkol	1968	6.5	3.6	2.7	(2.7)	9.0	13.3	107	50°02’56.3”N 75°59’46.2”E
		2020	6.6	3.3	2.9	1.3 (2.7)	8.6	16.9		
30	Tuzkol	1968	3.0	4.0	1.1	(0.15)	P	9.2	39	49°46’24.8”N 75°39’24.2”E
		2020	2.95	3.8	1.36	0.1 (0.4)	0.29	10.0		
31	Ashchykol	1968	1.45	1.7	1.5	(1.2)	1.0	4.8	10	49°29’34.6”N 75°13’05.0”E
		2020	1.25	1.3	1.06	0.6 (1.1)	0.75	4.3		
32	Zhartas	1968	1.4	1.9	1.0	(2.8)	2.1	4.5	61	49°30’07.7”N 75°14’40.7”E
		2020	1.3	1.8	1.1	1.5 (2.8)	1.65	6.5		
33	Shengel	1968	1.1	1.4	1.0	(0.3)	P	4.8	33	49°31’41.5”N 75°09’07.7”E
		2020	1.12	1.7	1.02	1.1 (2.8)	1.2	5.0		
34	Karakol	1968	3.0	4.0	1.4	(0.05)	P	10.3	178	49°43’20.4”N 76°18’11.3”E
		2020	2.17	1.96	1.53	0.1 (0.5)	0.21	5.7		
35	Baytarkol	1968	1.15	2.3	0.8	(1.0)	0.5	5.5	43	49°36’08.3”N 75°13’08.9”E
		2020	1.76	2.4	1.4	2.0 (3.5)	3.52	7.3		
36	Koytas	1968	1.2	1.4	1.0	(1.1)	0.8	3.7	10	49°35’25.6”N 75°08’19.6”E
		2020	1.7	1.67	1.2	0.8 (1.3)	1.36	5.5		
37	Ozero Bolshoe	1968	2.23	2.3	1.5	3.0 (4.6)	6.8	6.3	24	49°22’57.8”N 75°30’46.4”E
		2020	1.9	1.8	1.5	3.0 (4.6)	5.7	6.0		
38	Akkol	1968	1.0	1.8	0.6	(0.4)	P	4.5	15	49°46’40.1”N 75°17’07.7”E
		2020	1.01	1.7	0.7	0.3 (0.6)	0.3	4.7		
39	Saumalkol	1968	13.2	5.2	4.0	(1.75)	13.3	16.8	307	49°48’47.6”N 74°59’24.0”E
		2020	13.4	5.2	3.9	1.0 (2.7)	13.4	16.6		
40	Dogalan Karasory	1968	1.9	2.7	0.9	(0.05)	P	8.2	56	49°34’01.3”N 76°53’40.1”E
		2020	2.03	3.3	0.9	0.1 (0.15)	0.2	8.2		

Table continuation

№	Titles	Year of study	Area of lakes, km^2	Length, km	Maximum width, km	Average depth (maximum depth), m	Water volume million m^3	Coastline length, km	Lake catchment area, km^2	Coordinates
41	Sarykol	1968	1.5	3.1	0.8	(0.07)	P	8.0	31	49°34’17.1”N 76°51’03.4”E
		2020	1.2	2.34	0.7	0.08 (1.0)	0.09	8.3		
42	Karasor	1968	3.0	3.1	1.8	(0.05)	P	7.5	149	50°00’11.7”N 76°59’54.6”E
		2020	4.0	2.86	2.15	0.5 (1.2)	2.0	8.42		
43	Sarykaska	1968	7.2	5.2	2.3	0.5	-	17.2	66	50°29’53.6”N 77°00’29.1”E
		2020	7.8	5.8	2.6	0.07 (0.5)	0.54	17.2		
44	Kokozek	1968	1.68	2.0	1.3	-	-	7.9	49	50°40’00.1”N 77°02’50.6”E
		2020	1.8	2.1	1.4	0.3 (1.0)	0.54	8.3		
45	Baltabek	1968	3.2	3.3	1.5	-	-	8.7	62	50°37’09.2”N 77°04’02.4”E
		2020	3.0	3.33	1.55	0.2 (0.9)	0.6	9.0		
46	Barakkol	1968	12.0	4.3	3.5	2.0 (2.9)	24.0	12.5	82	49°18’52.0”N 67°16’29.7”E
		2020	11.8	4.2	3.5	2.0 (2.9)	23.6	13.6		
47	Koskol	1968	5.0	2.8	2.2	1.2 (2.3)	7.0	8.0	56	49°31’01.7”N 67°03’29.8”E
		2020	4.72	2.8	2.1	1.2 (2.3)	5.6	8.12		
48	Ashchykol	1968	16.0	6.2	4.2	0.8 (1.4)	12.0	19.6	117	49°15’56.1”N 67°31’11.9”E
		2020	16.0	6.6	4.0	0.8 (1.4)	12.0	18.3		
49	Karakoyin	1968	75.3	16.3	8.3	-	-	65	612	46°07’36.8”N 68°39’52.3”E
		2020	77.1	12.4	8.5	0.1 (0.3)	7.71	70.5		
50	Burshyktykol	1968	5.9	4.0	1.8	(2.0)	3.0	9.3	76	49°12’49.0”N 67°37’26.3”E
		2020	6.3	4.0	1.86	0.5 (2.0)	3.15	10.9		
51	Kishkenekol	1968	1.5	1.5	1.0	(0.3)	P	4.9	39	49°17’20.2”N 67°39’40.8”E
		2020	2.1	1.9	1.2	0.2 (0.3)	0.42	7.0		
52	Tomarmyskol	1968	2.5	2.4	1.3	(0.5)	P	6.0	36	49°17’54.5”N 67°43’45.0”E
		2020	2.3	1.97	1.5	0.2 (0.5)	0.46	5.9		
53	Basbaytal	1968	3.0	2.5	1.6	-	-	6.5	50	49°03’19.2”N 67°17’34.0”E
		2020	2.9	2.3	1.7	0.1 (0.4)	0.1	6.4		
54	Kamystykol	1968	10.1	4.7	3.1	(0.6)	0.9	12.5	303	49°34’09.4”N 67°04’08.8”E
		2020	4.8	3.0	1.85	0.09 (0.6)	0.4	8.4		
55	Baysuigen	1968	6.5	4.3	2.4	(0.1)	P	11.0	70	48°05’09.1”N 69°31’39.9”E
		2020	6.4	4.2	2.3	0.05 (0.1)	P	11.1		
56	Igilik	1968	1.64	2.0	1.0	-	-	5.0	58	47°45’56.3”N 65°00’39.3”E
		2020	1.17	1.65	0.7	-	P	4.3		
57	Koga	1968	1.22	2.2	0.7	-	-	4.8	47	48°45’47.7”N 65°11’44.0”E
		2020	2.0	2.8	0.9	-	P	6.5		
58	Obala	1968	4.75	3.8	1.9	-	-	9.3	93	48°52’58.8”N 65°07’39.0”E
		2020	5.9	3.9	2.1	-	P	10.1		
59	Shoshkaly	1968	1.8	1.7	1.6	-	-	5.2	47	47°52’30.9”N 64°37’51.2”E
		2020	0.6	1.7	0.7	0.05 (0.1)	0.03	5.6		
60	Koktenkol	1968	13.2	4.4	3.7	1.1 (2.5)	13	16.2	2584	48°31’30.4”N 72°06’13.8”E
		2020	12.4	4.7	4.0	1.1 (4.0)	13.6	14.1		

Table continuation

№	Titles	Year of study	Area of lakes, km^2	Length, km	Maximum width, km	Average depth (maximum depth), m	Water volume million m^3	Coastline length, km	Lake catchment area, km^2	Coordinates
61	Alakol	1968	5.4	4.5	1.7	(1.4)	2.4	12.0	125	49°47’55.4”N 70°29’18.7”E
		2020	4.7	4.1	1.6	0.5 (1.4)	2.3	10.8		
62	Sasykkol	1968	2.0	2.4	1.2	(1.8)	1.2	8.5	42	49°59’07.0”N 70°22’40.9”E
		2020	2.14	2.3	0.9	0.5 (1.5)	1.07	7.0		
63	Izendy	1968	5.5	4.6	1.8	(0.7)	1.9	11	127	49°51’51.7”N 70°58’13.3”E
		2020	5.8	4.1	2.2	0.3 (0.7)	1.7	10.4		
64	Karatomar	1968	5.0	3.0	2.6	(1.0)	2.95	9.0	41	49°55’29.3”N 70°57’13.4”E
		2020	4.6	3.1	1.7	0.6 (1.0)	2.76	8.5		
65	Tuzkol	1968	3.6	2.6	1.8	(0.5)	P	9	35	49°56’53.9”N 70°48’48.6”E
		2020	3.8	2.6	1.5	0.1 (0.5)	0.38	10.6		
66	Alabas	1968	2.0	2.1	1.4	(0.3)	P	5.9	43	49°59’13.1”N 70°50’28.1”E
		2020	2.03	2.0	1.4	0.1 (0.4)	0.2	6.2		
67	Seitkazy	1968	1.3	1.7	1.2	(0.15)	P	4.6	40	50°02’12.0”N 70°49’20.9”E
		2020	1.6	1.7	1.27	0.1 (0.3)	0.16	5.2		
68	Zhaykopa	1968	1.12	1.6	0.9	-	P	4.4	28	50°07’54.9”N 70°53’31.3”E
		2020	1.25	1.54	1.3	0.1 (0.2)	0.12	5.5		
69	Arykty	1968	1.51	1.8	1.3	0.9 (2.2)	1.4	4.5	58	50°08’20.8”N 70°56’54.2”E
		2020	1.5	1.4	1.3	0.9 (2.2)	1.35	6.3		
70	Arykty	1968	1.65	2.0	1.5	(2.0)	1.4	6.6	41	50°20’31.6”N 71°21’48.0”E
		2020	1.8	1.7	1.2	0.9 (2.6)	1.6	5.9		
71	Karaukamys	1968	6.2	4.5	2.5	(2.0)	6.5	12.8	94	50°08’44.9”N 71°01’51.8”E
		2020	8.4	4.9	2.7	1.1 (3.0)	9.2	17.05		
72	Ashchysor	1968	7.2	4.4	2.0	(0.6)	2.2	11.0	157	50°11’46.2”N 71°05’26.0”E
		2020	6.9	4.3	1.8	0.3 (0.6)	2.07	11.2		
73	Karatay	1968	6.5	3.8	1.8	(1.2)	2.7	10.5	89	50°12’39.9”N 71°11’02.4”E
		2020	6.7	3.9	2.3	0.4 (1.0)	2.68	11.2		
74	Taskol	1968	1.55	1.6	1.2	(0.3)	P	5.6	19	50°10’42.6”N 71°16’07.3”E
		2020	1.7	1.65	1.3	0.3 (0.9)	0.5	5.8		
75	Kumkol	1968	9.1	4.9	2.8	1.7 (3.0)	16	12.3	107	50°08’25.6”N 71°15’19.8”E
		2020	9.6	4.4	2.9	1.5 (3.6)	14.4	13.1		
76	Zhamankol	1968	1.3	1.5	1.2	(2.0)	1.3	4.3	31	50°05’43.6”N 71°25’23.0”E
		2020	1.6	1.6	1.2	1.0 (2.0)	1.6	4.8		
77	Bayatarkol	1968	3.0	2.8	1.8	(1.3)	2.1	6.5	66	49°27’31.5”N 71°17’41.4”E
		2020	2.2	1.9	1.5	0.5 (1.0)	1.1	5.6		
78	Saryala	1968	2.9	2.5	1.9	1.0 (2.5)	2.8	7.0	33	50°03’22.1”N 71°46’08.0”E
		2020	3.7	2.7	1.8	0.9 (2.7)	3.3	9.3		
79	Kurenala	1968	2.2	2.3	1.1	1.0 (2.5)	2.2	6.2	29	50°00’39.7”N 71°42’38.1”E
		2020	3.7	3.09	1.7	1.0 (2.5)	3.7	8.2		
80	Kultansor	1968	16.0	5.7	3.0	(0.4)	P	33.8	134	49°45’10.9”N 71°27’55.8”E
		2020	11.3	3.9	2.6	0.05 (0.4)	0.6	27.8		

Table continuation

№	Titles	Year of study	Area of lakes, km^2	Length, km	Maximum width, km	Average depth (maximum depth), m	Water volume million m^3	Coastline length, km	Lake catchment area, km^2	Coordinates
81	Tatyrsor	1968	4.0	3.2	1.5	(1.3)	2.5	9.3	71	49°46’46.5”N 71°28’26.4”E
		2020	5.3	3.32	1.8	0.5 (1.3)	2.65	12.0		
82	Shoptykol	1968	6.4	3.4	2.7	-	P	9.3	175	50°22’29.4”N 71°34’05.1”E
		2020	6.1	3.4	2.7	-	P	9.7		
83	Kobykol	1968	1.15	2.3	0.8	(2.0)	P	5.6	31	49°50’46.7”N 71°53’40.0”E
		2020	1.0	2.06	0.8	0.2 (1.1)	0.2	5.6		
84	Tapalkol	1968	3.3	2.5	1.6	(1.2)	1.5	7.3	49	49°47’36.8”N 70°39’33.7”E
		2020	3.1	2.35	1.6	0.4 (1.2)	1.2	7.5		
85	Balykty	1968	3.2	3.2	1.6	1.0 (2.3)	3.5	10.3	214	49°26’01.5”N 71°39’12.7”E
		2020	2.65	2.11	1.5	1.0 (2.3)	2.6	7.24		
86	Alabotaly	1968	2.5	3.3	1.2	-	P	7.8	28	49°56’17.9”N 70°53’38.0”E
		2020	5.3	4.36	1.6	1.2 (2.8)	6.3	11.0		
87	Baysal	1968	2.4	3.1	1.2	-	P	8.8	62	49°51’22.1”N 71°08’51.5”E
		2020	3.8	3.4	2.1	1.4 (3.2)	5.3	9.6		
88	Tassuat	1968	16.5	7.6	2.6	(1.7)	8.0	37.3	67	49°50’26.7”N 71°18’19.1”E
		2020	18.6	7.9	3.3	0.4 (2.3)	7.5	29.6		
89	Balykshy	1968	1.66	1.7	1.6	(0.7)	0.7	5.0	48	50°05’46.8”N 71°40’34.3”E
		2020	2.1	1.71	1.53	0.4 (0.6)	0.84	6.1		
90	Zharlykol	1968	2.0	2.7	1.6	1.2 (3.2)	2.3	7.3	50	50°02’30.5”N 70°29’20.4”E
		2020	1.9	1.8	1.56	1.7 (3.5)	3.2	6.4		
91	Sarybulak	1968	2.0	2.2	1.4	(0.4)	P	6.0	28	49°43’02.4”N 71°36’26.3”E
		2020	2.1	2.2	1.4	0.05 (0.4)	0.1	6.2		
92	Saumalkol	1968	2.58	2.4	1.7	(1.7)	1.9	8.0	56	50°28’10.3”N 71°38’07.8”E
		2020	3.1	2.5	1.7	0.8 (1.7)	2.4	8.4		
93	Baytugan	1968	1.1	1.6	0.8	(0.35)	P	3.9	34	50°21’12.5”N 71°26’32.3”E
		2020	1.2	1.6	0.9	0.15 (0.35)	0.18	4.2		
94	Sulukamys	1968	2.7	2.9	1.2	(0.15)	P	6.9	17	49°51’53.9”N 71°21’38.7”E
		2020	2.8	2.8	1.27	0.1 (0.15)	P	6.93		
95	Dosantomar	1968	2.4	2.5	1.3	-	P	6.8	29	50°01’14.8”N 71°09’30.2”E
		2020	2.0	2.3	1.2	0.06 (0.3)	0.12	6.8		
96	Aysakol	1968	1.08	2.7	0.6	-	P	6.7	25	50°16’42.6”N 71°39’02.7”E
		2020	1.2	2.7	0.6	0.02 (0.4)	0.02	6.9		
97	Sor	1968	5.15	3.0	2.4	(0.6)	1.3	8.7	81	50°14’58.5”N 71°19’39.0”E
		2020	5.7	3.26	2.5	0.3 (1.05)	1.7	9.3		
98	Ostemir	1968	8.8	5.8	2.4	-	P	20.5	127	49°52’18.5”N 70°41’11.9”E
		2020	8.1	5.9	2.2	0.05 (0.5)	0.4	19.6		
99	Korpesh	1968	1.2	1.6	1.1	(2.5)	1.2	4.3	67	50°30’57.3”N 71°31’31.0”E
		2020	1.3	1.6	1.1	1.0 (2.5)	1.3	4.6		
100	Agashtykol	1968	2.75	2.8	1.4	1.7 (2.7)	4.3	7.3	96	50°09’14.6”N 72°01’21.9”E
		2020	1.88	2.3	1.2	1.5 (2.7)	2.82	6.0		

Table continuation

№	Titles	Year of study	Area of lakes, km^2	Length, km	Maximum width, km	Average depth (maximum depth), m	Water volume million m^3	Coastline length, km	Lake catchment area, km^2	Coordinates
101	Zhamankol	1968	3.0	2.6	1.6	1.8 (4.5)	5.3	6.5	65	49°56’51.7”N 72°01’39.3”E
		2020	4.09	3.08	1.85	1.7 (4.5)	6.9	8.55		
102	Marzhankol	1968	2.87	2.2	1.5	1.2 (2.2)	2.8	6.5	64	50°07’06.5”N 71°53’31.4”E
		2020	2.65	2.1	1.4	0.9 (2.2)	2.4	6.1		
103	Taldykol	1968	2.9	2.8	1.5	(1.5)	2.0	7.0	37	50°22’56.2”N 72°07’51.2”E
		2020	3.46	3.07	1.58	0.6 (1.0)	2.07	7.7		
104	Taldykol	1968	2.1	2.2	1.5	(1.0)	P	5.7	43	50°53’12.1”N 73°01’02.4”E
		2020	2.5	2.4	1.52	-	P	6.58		
105	Toksumak	1968	6.2	3.2	2.8	2.0 (2.8)	12	10.7	68	50°39’37.9”N 72°30’13.1”E
		2020	4.6	2.9	2.1	2.0 (2.8)	9.2	8.3		
106	Karakol	1968	7.15	4	2.3	2.0 (3.0)	15.0	12.5	160	50°48’42.9”N 73°17’23.4”E
		2020	8.49	4.8	2.47	2.0 (3.0)	16.9	13.2		
107	Shoptykol	1968	1.96	2.0	1.3	(0.1)	P	4.0	48	50°42’00.2”N 73°20’55.6”E
		2020	3.8	2.8	2.04	0.03 (0.3)	0.1	8.2		
108	Kochkarnoe	1968	1.0	1.6	1.2	(0.5)	P	4.3	22	50°26’18.3”N 72°37’12.3”E
		2020	1.0	1.66	1.2	0.03 (0.5)	0.03	4.9		
109	Shybyndy	1968	36.0	8.7	5.4	(0.15)	P	22.6	617	50°34’04.1”N 73°40’56.4”E
		2020	30.1	8.5	5.2	0.2 (0.5)	6.0	21.2		

Note: P (parched lake) - lakes dried up at the time of the study

Of the 109 lakes studied, 63 lakes (58%) are non-drying and 46 lakes (42%) are ephemeral. Non-drying lakes in the studied region retain their water mass throughout the year, while in drying lakes, by the end of summer, the water level sharply decreases until the formation of medium and small puddles. Of the drying lakes in 1968, 38 out of 46 lakes were dry, and in 2020 only 8 lakes out of 46 lakes were dry.

The catchment areas of lakes vary from a few square kilometers for very small water bodies to several thousand square kilometers for large lakes. In the north of the region, in the Nura river basin, there is an average of 80 km^2 of drainage area per 1 km^2 of the lake surface, and 320 km^2 in the Sarysu river basin, that is, 4 times more. The catchment area of the lake Karasor is approximately 8750 km^2.

Most lakes, including large ones, have an average depth of 1 to 1.5 m. The maximum depth of lakes varies on average from 4.3 to 8.5 m.

For the convenience of the analysis of water surface areas and water volumes, all studied lakes were divided into 5 groups by area. The variation in the depth of lakes was not considered, since the vast majority of lakes have a similar origin, are located on a more or less uniform relief, and therefore the dependence of the depth and area of most lakes have similar values. But the total volume of water was calculated separately, which is determined by the average depth and area of the lake. As a result, area-volume water charts for 2020 were compiled (Figure 3). At the same time, a diagram for 1968 was compiled for the same lakes, where the areas of lakes had other indicators (Figure 4).

The first group includes 34 lakes up to 2 km^2 in area, which is 32% of the total number of water bodies. The total area of these lakes in 1968 was 53.03 km^2, and in 2020 their total area has remained almost the same - 50.1 km^2. However, some of the lakes were dry in 1968, so the total volume of water contained in this group in 1968 was 30.12 million m^3, while in 2020 it was 36.06 million m^3. That is, the volume of water increased by 19.7%.

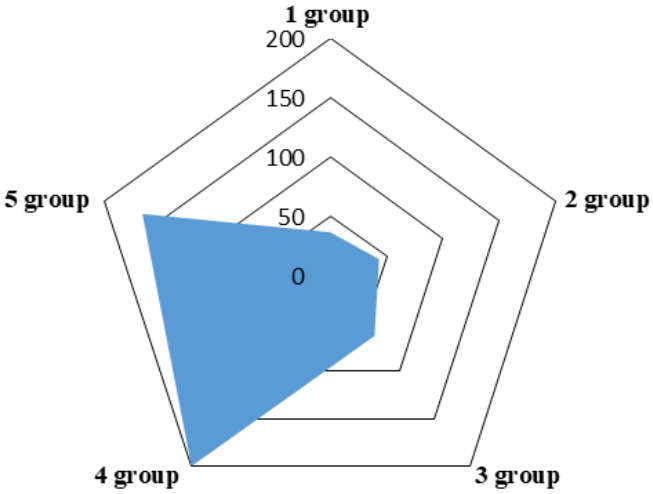

Figure 3 – Water volumes in different groups of lakes for 2020

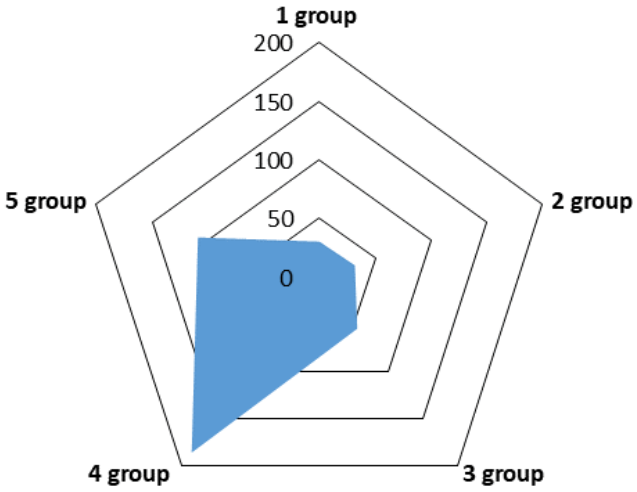

Figure 4 – Water volumes in various groups of lakes for 1968

The second group consisted of lakes with an area from 2 to 4 km^2 – 32 lakes (29.3% of all lakes). At present, this group is experiencing a relative increase in the share of water compared to 1968, with an absolute increase of 11.52 million m^3 - from 31.7 million m^3 to 43.22 million m^3. The total area of these lakes increased accordingly from 83.44 km^2 in 1968 to 89.88 km^2 in 2020.

The 3rd group of lakes with an area from 4 to 6 km^2 included 15 reservoirs. In this group of lakes, similar changes in the total area and total volume of water occurred, namely: 74.5 km^2 and 54.77 million m^3 - in 1968 and 75.11 km^2 63.53 million m^3 in 2020.

Lakes with an area from 6 km^2 to 20 km^2 were included in group 4 (19.2%). This group of lakes (with a total area of 193.91 km^2 in 1968 and 201.39 km^2 in 2020) contains the largest amount of the total volume of water: 185.5 million m^3 in 1968 and 199.47 million m^3 in 2020.

Particular attention is drawn to the lakes of the 5th group (over 20 km^2 in area), with the exception of the largest lake Karasor. This is a small group of lakes (5.5% of all water bodies), the total water surface area of which increased from 193.26 km^2 in 1968 to 206 km^2 in 2020. At the same time, there was also a significant increase in the volume

of water from 109 million m^3 in 1968 and 166.81 million m^3 in 2020. That is, with an increase in the area of lakes by 6.5%, the volume of total water increased by 53%.

Lake Karasor, as the largest body of water in the Karaganda region, should be considered separately. In 1968, the area of the lake was 155 km^2. For half a century, the area of the lake has slightly decreased to 147 km^2, the volume of water in the lake has accordingly decreased from 160 million m^3 to 151 million m^3. Lake Karasor is fed by the waters of 14 rivers, and the main reason for the decrease in water content in this lake against the background of an increase in water content in the region in general, most likely, is the drying up of these rivers in the summer.

Thus, in medium and larger lakes (from 4 to 20 km^2 in area), there is a significant increase in both the area and volume of water: 366.38 km^2 (area) and 306.22 million m^3 (volume) - in 2020 compared to 351.85 km^2 (area) and 271.97 million m^3 (volume) - in 1968. This in percentage terms is: an increase in area by 4.12% and an increase in volume by 12.6%.

As can be seen from the diagram (Figure 3), the increase in the volume of water in lakes with different areas occurs unevenly. The slowest increase in water volume occurred in lakes of the 4th group - by 7%, and at a faster pace there was an increase in water content in lakes of the 5th group - by 34%.

It should be noted that lakes of the 4th group are mainly northern lakes, where a denser hydrographic network and precipitation have always been more abundant than in the southern regions [21].

In the 5th group, the lakes have a larger area and greater depth, which contributes to less evaporation of water volumes, and more precipitation has begun to fall in these areas over the past period. At the same time, the increase in precipitation falls on the winter period, in one of the main seasons of water accumulation for lakes of this type in Central Kazakhstan [22,23].

The greatest variability from year to year has an inflow from the surface of the watersheds. In some high-water years, it can exceed the norm by several times, contributing to the rapid filling of lakes.

In general, the picture of the distribution of all water in the lakes of the Karaganda region showed that from 1968 to 2020, the total area of all lakes slightly increased from 753.1 km2 to 769.4 km2, that is, by 2.1%. The total volume of water in the lakes, respectively, in 1968 was 229 million m3, and in 2020 it amounted to 235.6 million m3, that is, it increased by 2.8%.

In dry years, the surface inflow can be 5-10 times lower than the norm. However, 1968, according to Philonets and Omarov [9], was not a dry year, and 2020, in terms of the amount of winter and summer precipitation, does not belong to a high-water period in the region [Pogoda and Klimat], that is, the indicators of these years are not extreme. Therefore, there are grounds to assert that the results obtained by us reflect the general trend of changes in the morphometric parameters of lakes.

An increase in the indicators of drying up of lakes, areas and volume of water in lakes can be both evidence of cycles in water content, and, most likely, evidence of a change in the precipitation regime in the region. According to the official website "Climate and Weather" in the Karaganda region over the past decade, due to the warming of winter, the climate of the region has warmed significantly and there has been an increase in annual precipitation. The positive trend of the average annual air temperature has reached its maximum level and has not changed over the past 20 years. In general, over 80 years, the average annual rainfall has increased by 145 mm. At the same time, the amount of precipitation in the cold months increased sharply by 105 mm compared to the warm months, with an increase of 45 mm [24, 25, 22].

Conclusion

We carried out a comparative analysis of several morphometric indicators of medium and small lakes in the Karaganda region from 1968 to 2020. Neither 1968 nor 2020 are periods of high water or low water. It was assumed that over the past decades, there have been changes in the hydrological indicators of surface waters in the Karaganda region. The study of the number of lakes, the total area of water, the total volume of the water mass confirmed this assumption.

Thus, based on the results of our work, we can draw the following conclusions:

Compared to 1968, in 2020, the total area of small lakes remained practically unchanged: 53.03 km^2 in 1968 and 50.1 km^2 in 2020, however, some of the lakes were dry in 1968, so the total volume of water group has grown by 19.7% since 1968.

In medium and larger lakes (from 4 to 20 km^2 in area), there is a significant change in both the total area and the volume of water: an increase in area by 4.12% and an increase in volume by 12.6%.

In the largest lakes of the region (more than 20 km^2), with an increase in the area of lakes by 6.5%, the volume of total water increased by 53%.

Thus, with a general increase in the average annual temperature and changes in the precipitation regime in the region, the area of reservoirs and the volume of the total water mass increased, while the dynamics of indicators depends on the specific area of the reservoir.

References

1. Meine Pieter van Dijk. "The importance of economics and governance for the water sector in Kazakhstan, the issues and tools for better water management". Central Asian Journal of Water Research. № 5(1). (2019): 1-17. DOI: 10.29258/CAJWR/2019-R1.v5-1/1-17.eng
2. Akbayeva L., Tulegenov E., Omarbayeva A., Kobetaeva N., Nurgalieva Z., NurkeyevY., Martišová P., Vietoris V., Zhanabayev A. "Ecotoxicological studies of akmola region lakes". Potravinarstvo Slovak Journal of Food Sciences vol. 13. no. 1. (2019): 25-31. doi: https://doi.org/10.5219/824
3. Abuduwaili J., Issanova G., Saparov G. "Lakes in the Central Kazakhstan". Water Resources Development and Management. Hydrology and Limnology of Central Asia. © Springer Nature Singapore Pte Ltd. (2019):177-197. https://doi.org/10.1007/978-981-13-0929-8
4. Ogilviea A., Belauda G., Massuela S.,Mulliganb M., Goulvena P., Malaterrea P., Calveza R. "Combining Landsat observations with hydrological modelling for improved surface water monitoring of small lakes". Journal of Hydrology. Vol 566. (2018): 109–121 https://doi.org/10.1016/j.jhydrol.2018.08.076
5. Bhagowati B., Ahamad KU. "A review on lake eutrophication dynamics and recent developments in lake modeling". Ecohydrol & Hydrobiol. Vol.19, No 1. (2019): 155-166. https://doi.org/10.1016/j.ecohyd.2018.03.002.
6. Reshetko M. "Osnovy gidravliki, gidrologii i gidrometrii [Fundamentals of Hydraulics, Hydrology and Hydrometry]". Schoolbook. Tomsk: Tomsk Polytechnic University Publishing House. (2015): 159-161 (in Russian)
7. Luchsheva A. "Prakticheskaiya gidrometriya [Practical hydrometry]". Leningrad. Hydrometeoizdat. (1983):423 - (in Russian)
8. Hanqiu Xu. "Modification of normal-ised difference water index (NDWI) to en-hance open water features in remotely sensed imagery" // International Journal of Remote Sensing. Vol. 27, No 14.(2006): 3025–3033 https://doi.org/10.1080/01431160600589179
9. Philonets P.P., Omarov T.R. "Ozera Karagandinskoi oblasti [Lakes of the Karaganda region]". Nauka, KazUSSR, Alma-Ata. (1968): 123 - (in Russian)
10. Philonets P.P., Omarov T.R. "Ozera Tcentralnogo i Yuzhnogo Kazahstana [Lakes of Central and Southern Kazakhstan]". Nauka, KazUSSR, Alma-Ata. (1973): 40-45 - (in Russian)
11. Lezin V.A. "Lakes of central Kazakhstan". Nauka, KazUSSR. Alma-Ata. (1982): 25-26 (in Russian)
12. Ramazanova N., Toksanbaeva S., Berdenov Zh., Ozgeldinova, Zh., Tursynova, T., Zhakupov, A. 2020. "Analysis of the current state of recreational resources of the nura river basin, the republic of Kazakhstan". GeoJournal of Tourism and Geosites. Vol 31, № 3. (2020): 1043–1048 https://doi.org/10.30892/gtg.31316-539
13. Abdreyeva Sh., Kalmenova U.,Tursinbayeva K. "Karaganda region's water resources assessmentfor tourismand recreation development". KazNU Bulletin. Geography series. №2 (41). (2015):376-381
14. Kenetayeva A .A , Usupayev Sh. E , Akhmetova A. ZH, Kusenova A. S, Shaikhova G .S and Bogzhanova Zh.K. "Characteristics of the natural conditions of the Karaganda region". Journal of Physics. Conference Series 1889 (2021):1-6 doi:10.1088/1742-6596/1889/4/042065
15. Mikhailov A.E. "K voprosu o proishozhdenii nekotoryh ozer severnoj chasti Tcentralnogo Kazahstana [On the question of the origin of some lakes in the northern part of Central Kazakhstan]". Geography: Vol. 4. (1957):252-258 (in Russian)
16. Sladkopevtsev S.A. 1963. "O proishojdenii i tipah kotlovın Tsentralnogo Kazahstana [On the origin and types of depressions in Central Kazakhstan]". Proceedings of the Academy of Sciences of the USSR. Geography Series: №1. (1963): (in Russian)
17. Muravlev G.G. "Malye ozera Kazahstana [Small lakes of Kazakhstan]". Almaty. Kainar. (1973): 98-110. (in Russian)
18. Alekin O. "Osnovy gidrohimii [The basics of hydrochemistry]". Hydrometeoizdat, Leningrad. (1970):44-91 (in Russian)
19. Ryanzhin S.V., Myakisheva N.V., Zhumangalieva Z.M. "Morphometric and hydrochemical characteristics of Kazakhstan lakes". Water Resources. Vol. 42, № 5. (2015): 658–669 https://doi.org/10.1134/S0097807815050139
20. Philonets P.P. 1981. "Ocherki po geografii vnutrennih vod Tcentralnogo, Yuzhnogo i Vostochnogo. Kazahstana (ozera, vodohranilisha i ledniki) [Essays on the geography of inland waters of the Central, Southern and Eastern Kazakhstan (lakes, water reservoirs and glaciers)]". Nauka, KazUSSR, Alma-Ata. (1981): 45 - (in Russian)
21. Kenetayeva A.A, Usupayev Sh. E, Shaikhova G. S, Salkeyeva A. K, Akhmetova A. ZH and Mullagaliyeva L. F. "Natural conditions of the Karaganda region". IOP Conf. Series: Earth and Environmental Science 981. (2022): 1-6 doi:10.1088/1755-1315/981/3/032041
22. Pogoda and Klimat. Source: http://www.pogodaiklimat.ru
23. Bai J., Chen X., Yang L., Fang H. "Monitoring variations of inland lakes in the arid region of Central Asia". Front. Earth Sci. 6, (2012): 147–156. https://doi.org/10.1007/s11707-012-0316-0
24. Salnikov V, Turulina G, Polyakova S, Petrova Y, Skakova A. "Climate change in Kazakhstan during the past 70 years". Quaternary International. Vol 358. (2015):77-82 http://dx.doi.org/10.1016/j.quaint.2014.09.008
25. Yang YU, Yuanyue PI, Xiang YU, Zhijie TA, Sun L., Disse M., Fanjiang Z., Yaoming L., Xi C., Ruide Y. "Climate change, water resources and sustainable development in the arid and semi-arid lands of Central Asia in the past 30 years". Journal of Arid Land. Vol, №1. (2019): 1–14. https://doi.org/10.1007/s40333-018-0073-3.