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WATER LEVEL VARIATIONS ON THE BALKASH LAKE IN THE MODERN PERIOD

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The article considers the nature of long-term and storm surge fluctuations in the level on the Balkash Lake. Statistics are presented and their seasonal distribution in different parts of the lake is described. It is noted that a change in the level entails a change in the morphometric characteristics of the lake; there is a tendency to reduce the area and, accordingly, the water volume of lake. The most vulnerable is the southern coast, which is a low-lying accumulative sandy plain. With wind surges, the coast is flooded in a strip from several hundred meters to several kilometers. Even fluctuations in the lake level (20...30 cm) lead here to significant displacements of the coastline. Surge phenomena in this area are the main factor in the formation of the relief. The amplitude of surge fluctuations of the Balkash Lake level significantly exceeds the annual amplitude of changes in the filling of the lake. The highest amplitude of surge oscillations is observed in Western Balkhash and at the end sections of the lake.

Keywords: Balkhash Lake, long-term level fluctuations, storm surge phenomena, water surface area, water volume

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INTRODUCTION

Balkash Lake is the second largest reservoir in Kazakhstan. It is located in the vast Balkash-Alakol Basin at an altitude of 340 m above sea level. Balkash Lake is one of the largest inland water bodies in the world. It consists of two parts - Western Balkash and Eastern Balkash, which are connected by the Uzun - Aral Strait. These parts differ in depth, volume and water mineralization. The area of the Balkash Lake at an elevation of 342,5 m is 19224 km², its length is 605 km, its width is 9...19 km in the eastern part and 74 km in the western part. Saryesik Peninsula, located in the middle of the lake, hydrographically divides it into two very different parts. The western part is relatively shallow and almost fresh, and the eastern part has greater depth and salt water. Through the Uzynaral Strait formed by the peninsula (wide is 3,5 km) water from the western part fills the eastern part. The depth of the strait is about 6 m (Assessment of the current and forecast dynamics of the Balkash Lake, Caspian Sea and Aral Sea hydrological regime, 2012).

Lake depression consists of several small depressions. In the western part of the Balkash Lake, there are two depressions with a depth of 7...11 m - one of them stretches from the western coast of Tasaral Island to Cape Korzhyntubek, the second one stretches south from Bertys Bay, which is the deepest place in Western Balkash. (Large Asian Lakes in a Changing World. Natural State and Human Impact, 2020). The depth of the basin of Eastern Balkash reaches 11 m, the greatest depth of the entire eastern part is 27 m. The average depth of the entire lake is 5,8 m, the total volume of water is about 106 km³ (Actual hydrometeorological problems of the Balkhash Lake and its region, 1995). The western and northern shores of the Balkash Lake are high (20...30 m) and rocky, composed of Paleozoic rocks (porphyries, sinter deposits, granites, shales, limestones) and have traces of ancient terraces.

The southern shores, from the Karashagan Bay to the Ele River Delta, are low (1...2 m) and sandy, pe-riodically flooded by high water (which is why they are dotted with numerous small lakes), in places there are coastal hills with a height of 5...10 m. The coastline is very winding and divided by numerous bays.

RESEARCH MATERIALS

For the research, the material used observations about water level and wind characteristics of the Kazakh National Hydrometeorological Service (RSE «Kazhydromet») for the period from 1938 till 2021, as well as literary sources. Starting materials for calculating the average annual values of the Balkash Lake water level served «Annual data about the regime and resources of surface waters».

Due to gaps in the series of observations, it became necessary to restore the water level according to regression equations. The longest gauging station is Balkash - Balkash City. Table 1 shows the equation of the dependence of the water level measured at this station (y) with the water levels measured at Algazy, Mynaral and Saryshagan stations (x). The work also used water level data for 1939, restored by G.R. Yunusov and in 1949...1950 restored by Hydroproject (Resources of Surface Waters of the USSR, Vol. 13, Central and Southern Kazakhstan, Issue 2, Balkhash Lake Basin, 1970).

Table 1

Information about the restoration of the average annual water level

Station	The equation dependencies	Correlation coefficient R	Calculation period equations (number of years)	Refurbished years
Balkash - Saryshagan railway station	y = 1,0136x -1,7061	0,99	49	1938, 1941...1948, 1951...1954, 1956, 1958...1960, 1998...2007, 2010
Balkash - Mynaral railway station	y = 0,9699x + 2,4025	0,986	53	1938, 1941...1948, 1951...1954, 1956, 1958...1961, 1998...1999, 2004…2007
Balkash - Algazy Island	y = 0,9642x -2,4841	0,985	56	1938, 1941...1948, 1998...1999, 2006, 2015...2021

RESULTS

Water level monitoring. Water level observations of the Balkash Lake began in 1912...1918. (Karashigan Bay), from 1932 to the present at the Balkash City gauging station, which operated in past years un-der various names (Bertys Bay, PBS pier). In 1954...1960 there were 4 stations operating on the lake, relatively evenly distributed over the lake, which made it possible to calculate the average water levels for the lake for this period. In 1960...1967 there were 10...12 gauging station on the Balkash Lake, which made it possible to increase the accuracy of determining the average water level of the lake (Skotselyas I.I. et al., 2003).

At present observations RSE «Kazhydromet» conducts hydrological monitoring at 4 lake hydrological gauging station: Balkash - Balkash City; Balkash - Saryshagan Railway station; Balkash - Mynaral Railway station; Balkhash - v. Karakum (opened instead of the gauging station of Algazy Island). According to them,

the average water level of the lake is calculated.

It should be noted that due to the vast size and dissection of the lake depression, the difference in the water balance of individual parts of the lake and the impact of wind, the water surface of the Balkash Lake is almost never horizontal.

As a result, differences in the water levels of individual sections of the coast are manifested not only in the average daily, but also in the average monthly, average annual, and even in the long-term average.

Long-term fluctuations of the water level. In the course of a long-term analysis of changes in the average level of Balkash Lake, it can be noted that in the period from 1938 to 1952. From 1953 to 1961 the level began to rise quite intensively and reached its maximum value in 1961, which was 342,99 m, and at the Saryshagan Railway station – 343,03 (Fig. 1). From 1962 to 1068 the amplitude of fluctuations was 17 cm. Starting from 1970, the water level began to decrease sharply, which is associated with the commissioning of the Kapshagay Reservoir, and in 1987 it reached a minimum of 340,66 m. Since 1988, the water level of Balkash Lake began to rise slightly and, from 1998 to 2005, there was a sharp increase. By 2005, it reached 342,6 m.

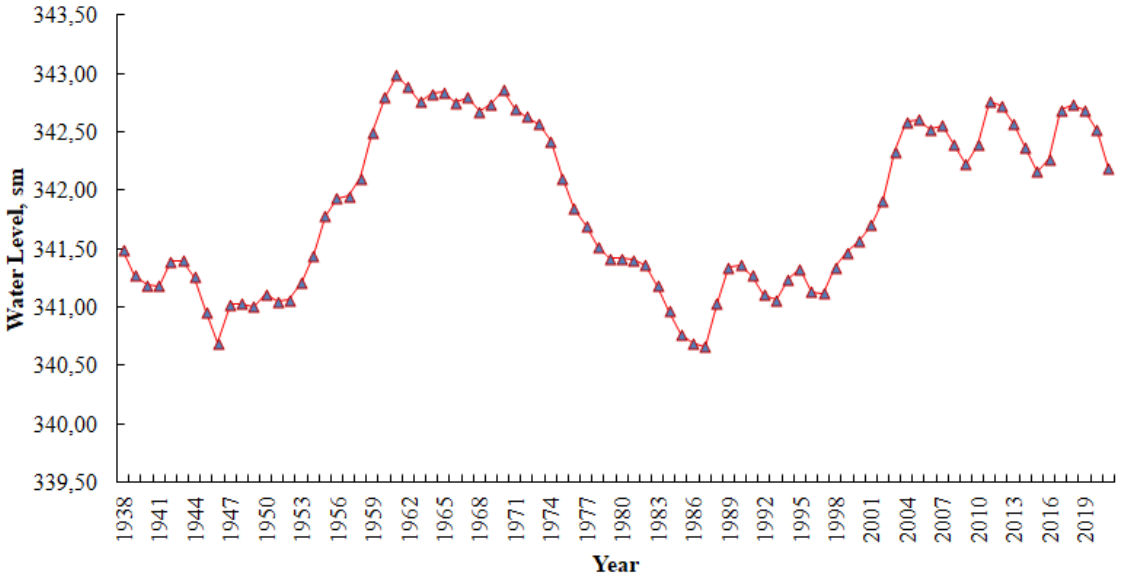

Fig.1. *Average annual fluctuations in the level of the Balkash Lake for the period 1938 ... 2021.*

This was due to an increase in the inflow of water into the lake due to an increase in this period of humidification of the area, air temperature and the inflow of an additional amount of water into the Ele River due to the degradation of mountain glaciation (Galaeva A.V., 2014). Since 2006, the lake level began to decrease again, in the high-water year 2011 the situation changed, the lake level imme-diately increased by 36 cm. (Burlibayev M.ZH. et al., 2017). In 2018, the low-water phase has begun. The decrease in the level in 2021 compared to 2020 was 33 cm. At present, the level fluctuates around the mark of 342,18 m Baltic System (BS).

A change in the level entails a change in the morphometric characteristics of the lake. The areas and volumes were calculated according to the method proposed by A.P. Braslavsky and S.P. Chistyaeva (Chistyaeva S.P., 1977). Based on aerial photographs of the Balkash Lake, they derived the de-pendence of the water surface area (Fig. 2) and volume on the lake level (Fig. 3).

Table 2 shows the calculated areas and volumes of the Balkash Lake for the last 10 years.

As can be seen from this table, over the past 11 years (from 2010 till 2021), the water surface area, depending on the water level, ranged from 19,1 (2015, 2021) to 20,2 (2011) thousand km2, and the volume water – from 117 (2015) to 126 km3 (2011…2012) . There is a trend towards a decrease in the area and, accordingly, the volume of water in the lake.

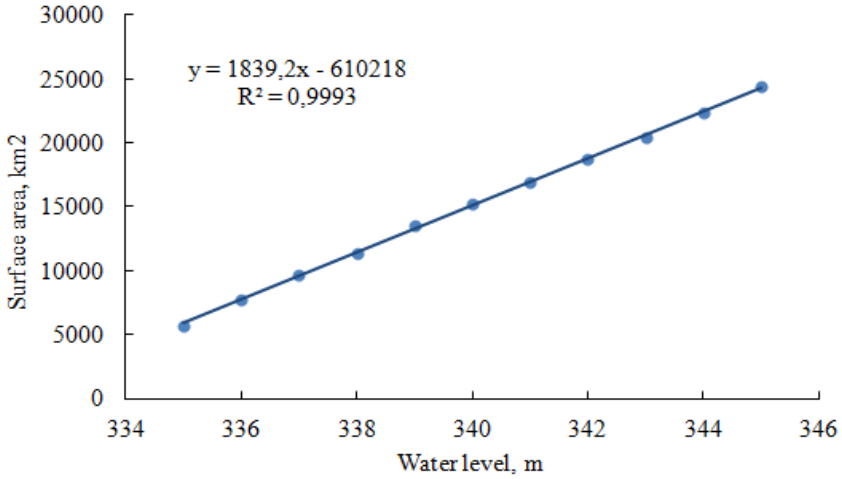

Fig.2. *Curve of the surface area of the Balkash Lake, constructed from the data A.P. Braslavsky and S.P. Chistyaeva.*

Table 2

Calculated areas and volumes of the Balkash Lake for the period 2010…2021

Year	Water Level, m BS	Lake area, thousand km^2	Water volume, km^3
2010	342,39	19,5	121
2011	342,76	20,2	126
2012	342,73	20,1	126
2013	342,57	19,8	123
2014	342,37	19,5	120
2015	342,16	19,1	117
2016	342,27	19,3	119
2017	342,68	20,0	125
2018	342,73	20,1	126
2019	342,69	20,1	125
2020	342,52	19,7	123
2021	342,18	19,1	118

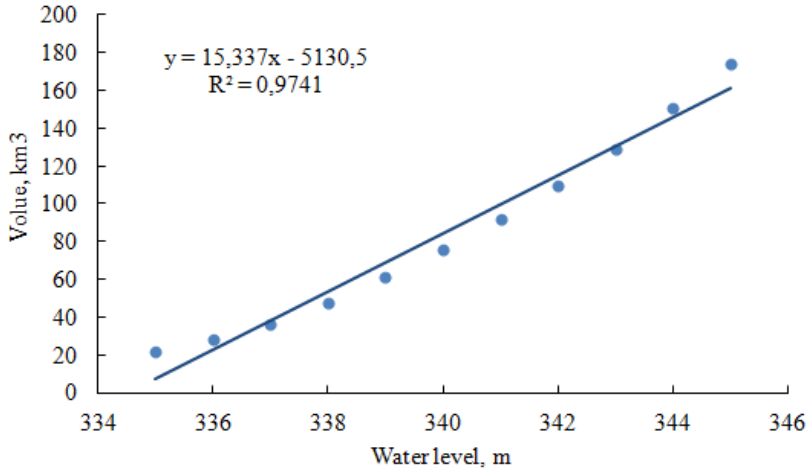

Fig.3. *Curve of the water volume of the Balkash Lake, built according to the data.*

Seasonal fluctuations of the water level. The water level Balkash Lake is subject to intra-annual fluctuations. Figure 4 shows graphs of the average monthly levels of Balkash Lake for high-water years: before the construction of the Kapshagay Reservoir – 1965, after the construction and commissioning of the reservoir – 2011.

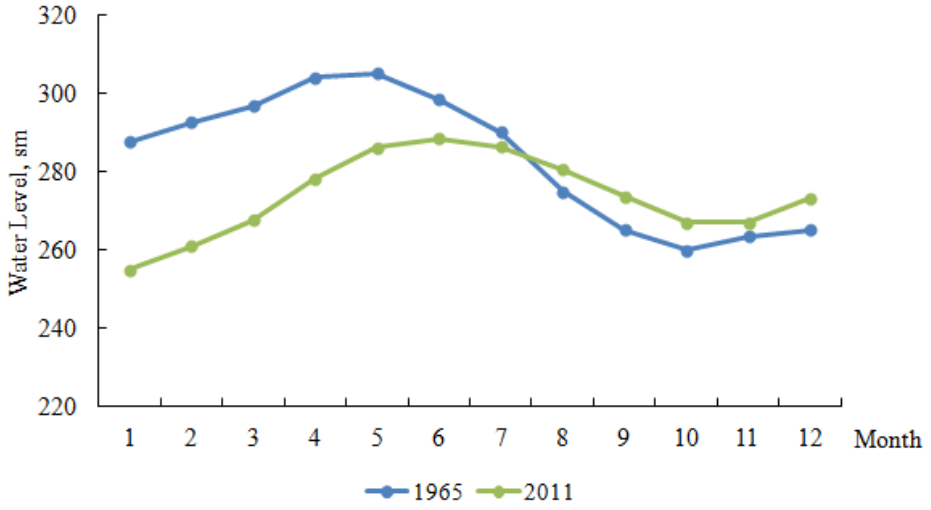

Fig.4. *Intra-annual variation of the Balkash Lake levels for 1965 and 2011.*

As can be seen in Fig. 4, the maximum level values in 1965 are in May (305 cm), and the minimum level values (264 cm) are in October. The range of level fluctuations was 41 cm. The intra-annual level distribution for 2011 shows that the maximum and minimum levels occur in June and January, respectively, the peaks are smoothed out, and there is an increase in the level in the spring-summer period, which is extended in time. This is due to the commissioning of the Kapshagay Reservoir and the regulation of the flow. The maximum level values averaged over 3 posts are 289 cm, and the minimum values are 255 cm. The range of level fluctuations was 44 cm.

Storm surge phenomena. Balkash Lake is characterized by intense wind activity. Winds from the northern (in the western part) and northeast (in the eastern part) directions prevail. Winds cause constant strong excitement on the lake, in certain directions storm surge phenomena are formed. Max-imum wind speeds can reach 28 m/s and gusts up to 40 m/s. In the western part of the lake, strong winds are observed less frequently than in the eastern part. But sometimes the wind speed reaches hurricane values (Ivkina N.I., 2011).

Balkash Lake level, due to its vast size and shallow water in the ice-free period, is subject to frequent and significant fluctuations (denivelations) due to the effect of wind on the water surface.

Not in all parts of the Balkash Lake there is a body of water open for wave dispersal. In the eastern, deeper, narrower and dissected part, there are no conditions for the formation of significant storm surge phenomena.

The western part of the lake is shallow, which also contributes to the formation of storm surge phenomena, since with a decrease in depth, the surge wave becomes steep and even a weak wind blowing for a long time over a large body of water can cause more significant excitement than a strong short-term wind on a small water surface. At the same time, the western and northern shores are rocky of the abrasion type, and a storm wave cannot go deep into the shore and flood considerable distances. Stormy waters cause a sharp rise in water levels and this can contribute to the formation of standing waves. Also, as a result of the impact of surge waters and unrest, the destruction of bedrock occurs. (Natural Hazards, section « Natural hazards of large water bodies», Report on scientific research, 2011).

The most vulnerable is the southern coast, which is a low-lying accumulative sandy plain. With wind surges, the coast is flooded in a strip from several hundred meters to several kilometers. Even fluctuations in the lake level (20...30 cm) lead here to significant displacements of the coastline. Storm surges phenomena in this area are the main factor in the formation of the relief.

The amplitude of storm surge level fluctuations in the Balkash Lake significantly exceeds the annual amplitude of changes in the filling of the lake. The largest amplitude of surge oscillations is observed in Western Balkhash and at the end sections of the lake. In the deeper, narrower, and more dissected eastern part of the lake, they are much smaller. Storm surge statistics on the Balkash Lake, performed according to the data of the stations of Balkhash, Algazy, Saryshagan and Mynaral, shows that an average of 8...10 storm surge events of varying intensity occur here per month. In the winter period (January-February), these phenomena are insignificant (7…13 cm), in the ice-free period they increase to an average of 40…70 cm, however, under extreme wind conditions (winds of the eastern quarter), their magnitude can reach 1,5 m in the south-west and west coast. For different parts of the lake, the characteristics and frequency of such phenomena are different. It should be noted that surges of 30...50 cm can cause coastal flooding in a strip of several kilometers.

On the northern coast, as analysis of data from Balkhash station shows, storm surge phenomena (more than 30 cm) are observed from March to December (Fig. 5). They reach their highest height in April-June and September-November.

At the same time, the frequency of storm surges is not the same. Here, wind set down phenom-ena is most often observed, on average by 35%. This is due to the predominance (about 40% per year) in this area of northeasterly winds. Winds set down events are usually the most intense and their height often exceeds 60 cm. The most active months for wind set up phenomena are May, August and October. Winds set down phenomena are more often observed in the period from June to September. March is the quietest month.

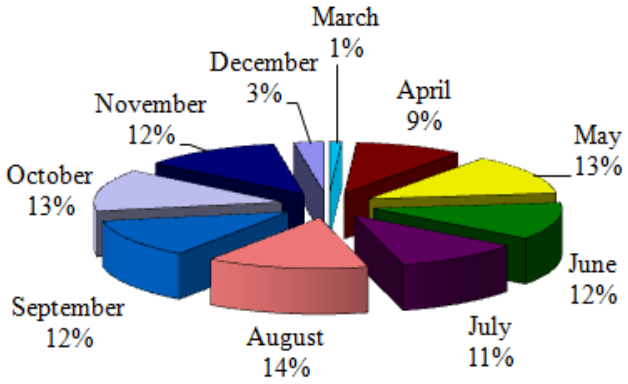

Fig.5. *Recurrence of the dangerous storm surges phenomena during the year.*

As noted above, the largest amplitude of level fluctuations is observed at the end sections of the lake.

The frequency of storm surge phenomena in the ice-free period is almost the same in all months (10 ... 15%). The exception is March-April (up to 7%), however, in April they reach their highest height.

On the west coast, the most active wind set up months are May, July and October. Winds set down over 40 cm are most often observed in June and August. Significant wind distortions of the level are observed along the axis of the Western Balkash: during wind set down at the Balkash post – wind set up at the posts of the southwestern coast; during a wind set up at the posts of the western and southwestern coasts – wind set down at the Balkash post. Often, storm surges phenomena lead to the formation of single-nodal seiches in the Western Balkash.

CONCLUSIONS

Thus, Balkash Lake is characterized by significant level fluctuations, which entail a change in the morphometric characteristics of the lake. There is a clear trend towards a decrease in the area and, accordingly, the volume of water in the lake. At present, the level fluctuates around the mark of 342,18 m BS.

In the intra-annual context, the maximum and minimum levels are recorded in June and January, respectively. An increase in the level is observed in the spring-summer period and is extended over time. In addition, the lake is characterized by surge fluctuations in water levels (1 m or more), and their amplitude significantly exceeds the annual amplitude of changes in the filling of the lake. On average, their value, depending on the time of year, is 7...70 cm, but under extreme wind conditions it can reach 1,5 m, especially on the southwestern and western coasts. These phenomena must be taken into account when designing settlements and other coastal facilities, as well as when constructing protective dams and ramparts on low-flooded shores, since surges of even 30 ... 50 cm can cause coastal flooding in a strip of several kilometers.

REFERENCES

1. Actual hydrometeorological problems of the Balkhash Lake and its region / edited by I.I. Skot-zelas, St. Petersburg: Gidrometeoizdat. – 1995. – P. 103-170.
2. Large Asian Lakes in a Changing World. Natural State and Human Impact / edited by Steffen Mischke, Springer Water. – 2020. – P. 143-175.
3. Water resources of the Kazakhstan: assessment, prognosis, management. Volume IX: Internal and peripheral water bodies of Kazakhstan (Aral Sea, Balkash Lake and Caspian Sea): book 1: Assessment of the current and forecast dynamics of the Balkash Lake, Caspian and Aral Seas hydrological regime / Shivaryova S.P., Lee W.I., Ivkina N.I. – Almaty. – 2012.– 456 p.
4. *Galaeva A.V.* Change in the runoff of the Ili River in the area from the hydrometric cross-section 164 km above the Kapshagay Hydroelectric Power Station to the Kapshagay tract due to the degradation of glaciations and an increase in precipitation // Bulletin of the Kyrgyz-Russian Slavic University, Vol. 14.– N 7.– 2014. – P. 93–95.
5. *Burlibayev M.Zh., Volchek A.A., Burlibayeva D.M.* Fluctuations of the Balkash Lake water level in a changing climate // Hydrometeorology and ecology. – 2017. – No 2.- P. 46-65.
6. *Ivkina N.I.* Storm surges fluctuations of the Balkhash Lake water level // Hydrometeorology and ecology. – 2011. – N 1.- P. 66-74.
7. Natural hazards, section «Natural hazards of large water bodies» / Report on scientific research, responsible for the work of V. P. Blagoveshchensky - Almaty. - 2011. - 47 p.
8. Resources of Surface Waters of the USSR, Vol. 13, Central and Southern Kazakhstan, Issue 2, Balkhash Lake Basin: L. Gidrometeoizdat, 1970. – 645 p.
9. *Skotselas I.I., Popova V.P., Gorkunova T.G.* Water balance of the Balkhash Lake // Hydrome-teorology and ecology.- 2003.- No. 2.- P. 47-61.
10. *Chistyaeva S.P.* The question of practical application of methodical calculation of water miner-alization distribution in the water area of a reservoirs to Balkhash Lake // Trudy KazHIGMI.– Issue 58.– M.: Gidrometeoizdat, 1977.– P. 98-100.

ҚАЗІРГІ КЕЗЕҢДЕ БАЛҚАШ КӨЛІ СУ ДЕҢГЕЙІНІҢ ӨЗГЕРІСТЕРІ

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Мақалада Балқаш көлі деңгейінің көпжылдық және желшегерме-желкөтерме тербелістерінің сипаты қарастырылған. Статистикалық мәліметтер келтіріліп, және олардың көлдің әртүрлі бөліктерінде маусымдық таралуы сипатталған. Деңгейдің өзгеруі көлдің морфометриялық сипаттамаларының өзгеруіне әкелетіні анықталды; көл суының ауданы мен көлемінің азаю тенденциясы байқалады. Ең көп зардап шеккен оңтүстік жағалау. Төмен орналасқан аккумуляторлы құмды жазық болып келетін оңтүстік жағалау ең осал болып табылады. Желкөтерме кезінде жағалауды бірнеше жүз метрден бірнеше шақырымға дейінгі жолақпен су басады. Тіпті көл деңгейінің ауытқуы (20...30 см) жағалау сызығының айтарлықтай ығысуына әкеледі. Желшегерме-желкөтерме құбылысы бұл аймақта жер бедері қалыптасуының негізгі факторы. Балқаш көлі деңгейіндегі желшегерме-желкөтерме құбылыстарының амплитудасы көлді толтыру өзгерістерінің жылдық амплитудасынан айтарлықтай жоғары. Ең үлкен желшегерме-желкөтерме құбылыстарының амплитудасы Батыс Балқашта және соңғы бөлектерінде көлдің байқалады.

Түйін сөздер: Балқаш көлі, деңгейдің ұзақ мерзімді ауытқуы, желшегерме-желкөтерме құбылыстары, су бетінің ауданы, су көлемі.

КОЛЕБАНИЯ УРОВНЯ ВОДЫ НА ОЗЕРЕ БАЛКАШ В СОВРЕМЕННЫЙ ПЕРИОД

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В статье рассмотрен характер многолетних и сгонно-нагонных колебаний уровня озера Балкаш. Приведены статистические данные и описано их сезонное распределение в разных частях озера. Отмечено, что изменение уровня влечет за собой изменение морфометрических характеристик озера; наблюдается тенденция к уменьшению площади и, соответственно, объема воды озера. Наиболее уязвимым является южное побережье, которое представляет собой низменную аккумулятивную песчаную равнину. При ветровых нагонах побережье затапливается полосой от несколько сот метров до нескольких километров. Даже колебания уровня озера (20…30 см) приводят к существенным перемещениям береговой линии. Сгонно-нагонные явления в этом районе являются основным фактором формирования рельефа. Амплитуда сгонно-нагонных колебаний уровня Балкаша значительно превосходит годовую амплитуду изменения наполнения озера. Наибольшая амплитуда сгонно-нагонных колебаний наблюдается в Западном Балкаше и на концевых участках озера.

Ключевые слова: Озеро Балкаш, многолетние колебания уровня, сгонно-нагонные явления, площадь водной поверхности, объем воды.