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A. G. Valeyev [1], F. Zh. Akiyanova[2], A. D. Abitbayeva[1], Ye. Ye. Khalykov[1], M. M. Togys[1]

[1]Institute of Geography, Almaty, Kazakhstan,
[2]Institute of Geography and Nature Management of the “Astana” ISC, Astana, Kazakhstan.
E-mail: adiletv@gmail.com, akiyanovaf@mail.ru, abitbayevainagul@gmail.com

DEVELOPMENT OF ABRASION SHORES OF ALAKOL LAKE ACCORDING TO THE FIELD RESEARCH MATERIALS

Abstract. In recent years, Alakol Lake is becoming a center of recreation and tourism, its infrastructure is developing with a pronounced man-made load on the coastal areas. In addition, the nature of shore formation becomes aggravated under the impact of instability of natural-anthropogenic conditions, which leads to the destruction of infrastructure facilities, loss of land reserves, material damage. A review of scientific papers revealed that the latest studies were conducted fifty years ago. Therefore, the obtaining of new monitoring data with the use of modern measuring instrumental devices is relevant. The identification of effective methods for obtaining accurate parameters made it possible to understand and analyze shore formation. Sites for conducting field studies were allocated using a regional approach with the application of satellite images. The method of instrumental measurements of distances from reference benchmarks was used in the field researches. As a result, the dynamics of the marginal erosion over a three-year period on the south-western and eastern shores of Alakol Lake was determined. 6 monitoring sites were established on the southwestern shore. The results of observations of the dynamics of erosion of the cliff in the active zone were from 3 to 9.9 m over a three-year period. The change in the height of the coastal cliff from 5-6 meters (1964) to 9 meters was identified. Two monitoring sites were organized on the eastern shore. The dynamics of erosion of the coastal cliff in the active zone ranged from 3.7 to 14 m over a three-year period. We assume that there is a disturbance of the alongshore transport of sedimentary rocks at this site by a 168-meter breakwater, which enhances the dynamics of abrasion.

Key words: field studies, monitoring of shoreline erosion, coastal cliff, abrasion, dynamics of relief formation.

Introduction. Field studies of relief formation of the shores of Alakol Lake were carried out by the Laboratory of Geomorphology and Geoinformation Mapping and the works were partially continued in 2016 in order to monitor the dynamics of abrasion shores. As a result, it becomes possible to preliminarily analyze and determine the dynamics of the development of abrasion coastal cliffs on the basis of field and cameral studies.

The coastal zone of the lake under study is a place of active manifestation of unfavorable exogeodynamic processes. Dynamics of destruction of abrasion-denudation shores in places of economic and recreational development, in some places reaches a retrogression of more than 3 meters per year. Several residential streets of the Koktuma village on the south-western shore of Alakol Lake (Almaty region) were lost as a result of erosion of the cliff. Similarly, the capital structures of recreational facilities on the eastern shore of Alakol Lake were submerged (East Kazakhstan region).

Over the last years, the shores of the lake are experiencing a high anthropogenic load associated with a sharp increase in comprehensive tourism to Alakol Lake. A fertile climate, comfortable beaches, curative properties of the lake water, transport accessibility required the development of the routing of passenger transportation by railroad and improving the quality of highways. Accordingly, a rapid development of construction of various necessary kinds of infrastructure (sanatoriums, rest homes, etc.) is observed in the coastal territory, unfortunately, not always taking into account the factors of relief formation of the above-water part of the coastal zone. The solution of this problem requires a comprehensive research, which is impossible without detailed field monitoring. The obtained data of field studies will allow to make an effective analysis and to elaborate a system of measures for the sustainable development of the Alakol Lake shore in the future.

Review of previous scientific works. Studies of the coastal zone of Alakol Lake began quite long ago. General characteristics of the structure of the Alakol Depression, climate, water resources, soil cover, vegetation were given in the 12th edition of the Questions of Geography of Kazakhstan "Alakol Depression and its lakes" edited by N.N. Palgov (1965) [1]. Studies of the morphology and dynamics of the shores of Alakol Lake were conducted by Ye.A. Kazanskaya (1961-1964). During the study, it was recorded by her that denudation processes prevailed over accumulative ones in the shore formation over the most part of the entire shore, due to the increase in the water level in the lake. A cumulative classification was made by the types of shores of the entire study area. The morphology and structure of the shores and islands were considered in detail. According to Ye.A. Kazanskaya, the south-western, southern, eastern, north-eastern, northern, north-western, western coastal areas of Alakol Lake were distinguished with detailed explanation of the geomorphological conditions of each of them and the proposal of applied methods of shore protection measures taking into account transverse and longitudinal shore depositions [1, 2].

T.N. Dzhurkashev studied the history of the formation of the Balkhash-Alakol Depression in the Quaternary period. His monograph "Anthropogene history of the Balkhash-Alakol Depression" gives geological-geomorphological characteristics of the Balkhash-Alakol Depression, including a description of the territory under study [3]. It is necessary to note the papers of K.V. Kurdyukov (1952) [4], Z.A. Svarichevskaya (1952) [5] from earlier works on the study of the geology of the territory under study.

Geological-geomorphological conditions were later studied by L.K. Didenko-Kislitsina (1964-1966, 1971) [6], Yu.A. Tverdislov [7], N.I. Mikhailova [8], A.N. Mitrofanova and R.Sh. Kalita [9]. The study of morphometry using the SRTM digital terrain model, monitoring of the formation of shores according to the data from different-time satellite images were performed by A.G. Valeyev, F.Zh. Akiyanova, A.D. Abitbayeva [10, 11].

The analysis of published scientific literature showed that valuable material has been accumulated, including the classification of the Alakol Lake shore according to the leading exogenous processes. However, recent data on the study of the negative impact of the development of exogeodynamic processes in the coastal zone are fifty years old. During this time, the hydrological situation has changed, recreational and economic loads have increased, climate change has been occurring and, most importantly, new effective methods of research have appeared. Therefore, the relevance of obtaining new monitoring data using modern measuring instrumental devices is beyond doubt.

Methods. The different-time satellite images of medium resolution (landsat, Alos and Sentinel) were used for the regional identification of monitoring sites [12]. The most active areas of shoreline erosion were identified by the method of interpretation and comparison of the results of the remote sensing data processing [10]. The following criteria were developed in order to select the monitoring sites: active exogeomorphogenesis within the above-water part of the coastal zone, the risk of negative impact of exogeodynamic processes of shore formation on the socio-economic and recreational infrastructure, the availability of facilities of engineering protection of the shores (breakwater, pier, cut-waters, etc.), location of objects of technogenic impact, enhancing the dynamics of relief formation of the shores.

There are several methods of monitoring the dynamics of the abrasion cliff in field studies:

1) measurement of the distance of the planned displacement of the edge of the shore along a previously marked section line for a certain period of time;

2) determination of the position of the line of the cliff with the help of the theodolite and comparing of its planned position with the position of the shore edge determined earlier;

3) investigation of erosion of abrasion cliffs using a ground-based laser scanner. The main stages of data processing: georeferenciation and stitching point clouds; interpolation of data to create a digital elevation model; creation of a digital terrain model (DTM) [13-15] and etc.

Methods for measuring and documenting the dynamics of erosion of the cliff in the papers of T. Sunamura (1992) include sequential aerosurveying, analysis of historical maps, field instrumental studies (measuring distances from benchmarks) [16]. Methods of research of A.Sh. Khabidov [17] pay special attention to the analysis of the geomorphological conditions of the coastal zone – the morphometry of the shore is determined, soil samples are taken from the cliffs to determine the mechanical properties of rocks, the dynamics of the displacement of the coastal cliff toward the land is determined using special equipment.

In the studies of the shores of Alakol Lake, we used the method of instrumental measurements of benchmarks along the transversal profile. The method of instrumental measurements along the profile is reasonable and does not require special expensive equipment. Profile lines are marked on the terrain when organizing observations with the help of this method. First, parallel lines of the profile are laid to the cliff, and then perpendicular lines of the alignment along the magnetic azimuth to the shore cliff are determined from the set benchmarks with the compass. Benchmarks with the use of concrete and reinforcement (12 mm in diameter, 50-60 cm in length) are set as the initial ones. In addition, stationary objects (trees, corners or supports of capital embankments, foundations of buildings, towers, wells, concrete supports, lighting pillars, etc.) can be used as a benchmark, since the working group had experience in the loss of benchmarks as a result of active shoreline erosion on the territory under study.

Depending on the length of the profile between the main benchmarks, additional intermediate benchmarks are set to fix the direct profile and to exclude the loss of information in the case of the accidental loss of one of them. Measurements are done after a period of time using a laser rangefinder or measuring tape, determining the distance between the benchmark and the edge of the cliff along the line of the perpendicular alignment. The retreat of the edge is the difference between the two measurements. In order to display the monitoring profiles in the GIS programs and determine the location of the benchmark in the future, GPS coordination of all benchmarks of the profile is carried out [18]. The accuracy with such measurements is 1 cm for every 20 m of the line being determined. In order to proceed to dynamic indicators, it is necessary to obtain an average retreat of the edge across all section lines of the station for the selected time interval [14]. Documentation of the obtained data was carried out in the form of filling in the passports of the monitoring site with the introduction of all the main quantitative and qualitative data. Drawings and description of the site, schemes of transverse coast profiles are recorded in field logs in detail, preliminary granulometric composition is described, photo-fixing of benchmarks, profiles, coastal zone, infrastructure facilities of the shores, etc. is carried out.

Results and discussion. The interpretation and comparison of the results of the processing of satellite images allowed determining the monitoring sites at the regional scale for carrying out field studies in accordance with the developed criteria (figure 1) [19].

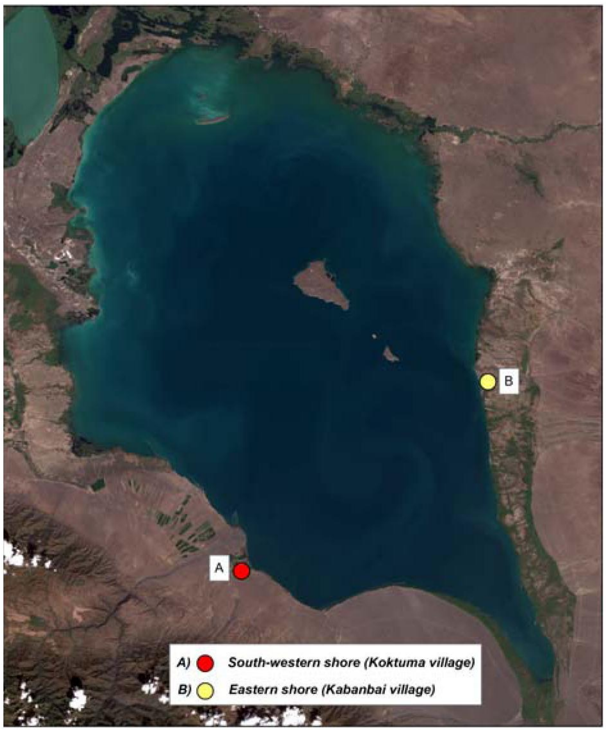

Figure 1 – Alakol Lake,
A – south-western abrasion shore (Koktuma village),
B – eastern abrasion shore (recreational zone of Kabanbai village) [12]

South-western shore (Koktuma village). The leveled section of the south-western coastal zone of Alakol Lake stretches from the Zhamanty river delta and its turning to the east (the length of 14 km). The development of the shore is conditioned by abrasion-accumulative processes. The land is a train of debris cones, formed by rivers and temporary channels, flowing down Zhetysu Alatau. The space from the lake to the mountains is occupied by a foothill gently-sloping, debris-stony plain with elevation marks of 600-700 m at the mountains, and 350 m at the lake. In other words, the shore is composed of proluvial-alluvial sediments of Quaternary age [20].

According to Ye.A. Kazanskaya, a cliff with a height of 5-6 m, accompanied by a narrow pebbly beach with a width of up to 10 m stretched to the north and south of the Koktuma village in 1961-1964. Nowadays, the width of the beach remains unchanged, while the height of the cliff in the mentioned places reaches more than 9 m.

The cliff is the natural boundary of the residential area of the Koktuma village. Six monitoring sites were established within the coastal cliff near the Koktuma village in 2013-2014. Repeated instrumental measurements were carried out in November 2014 and 2016. The results of observations of the dynamics of the reformation of the cliff in the active zone were from 3 to 9.9 m over a three-year period. It should be noted that there is uneven shoreline erosion at the monitoring sites. However, there is a steady movement of the edge of the cliff toward the land according to all the benchmarks.

The monitoring site № 4 (figure 2) was founded in 2013. Two main benchmarks were installed at it, and geographic coordinates from two concrete supports were taken as additional benchmarks. According to the 1st and 2nd benchmarks, the dynamics of the retreat of the edge of the cliff toward the land is 9.4 m for three and a half years. At the 7th benchmark, located in the southern part of the monitoring site, the three-year values amounted to 9.9 meters. Residential buildings and infrastructure facilities are located in 50-60 meters from the coastal cliff. Local residents state the fact of the annual approaching of the coastal cliff to their houses. The asphalt road is cut off by the cliff in the south direction. The analysis of the obtained results showed an increase in the rate of shoreline erosion at the reference site from north to south.

Two main benchmarks were installed at the monitoring site № 5 in 2014 (figure 3). According to the 1st and 2nd benchmarks, the distance to the edge of the cliff at the time of the laying was 43 and 25 meters, respectively. When carrying out repeated observations in 2016, anthropogenic disturbance of the

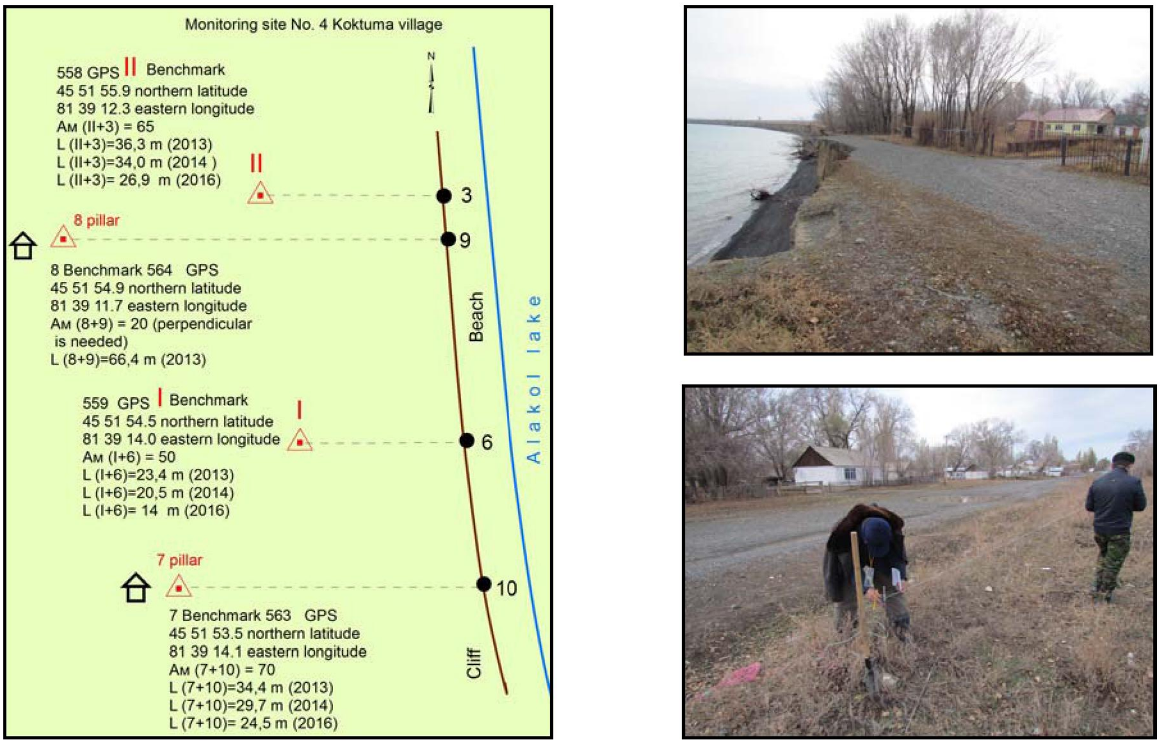

Figure 2 – Data of the monitoring site № 4, Koktuma village, Almaty region

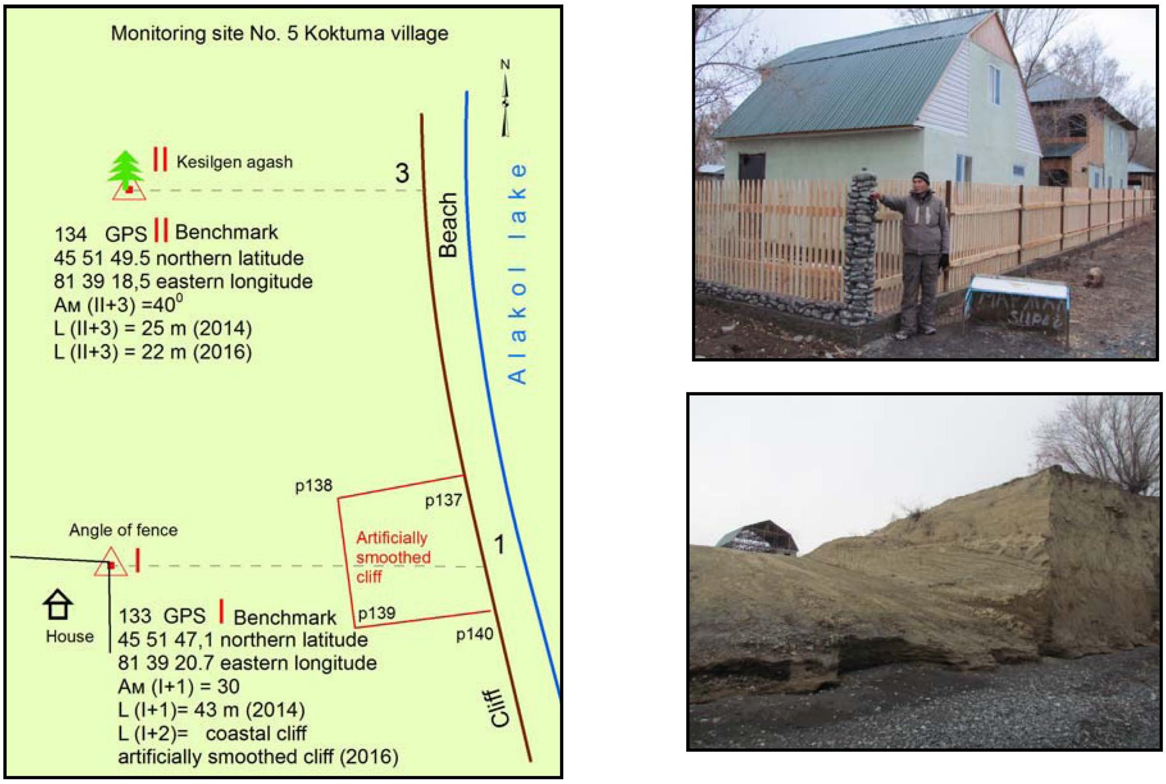

Figure 3 – Data of the monitoring site № 5, Koktuma village, Almaty region

coastal cliff was revealed opposite the buildings of the recreation center. The underlying soil with a volume of more than 1000 m^3 was removed from the surface of the cliff to the beach with the help of heavy equipment. The dimensions of the disturbed coastal area were the following: width - 25–30 meters, length - 20 meters, depth - up to 8-9 meters at the beach bottom.

Therefore, the data for the first benchmark were not measured, and the dynamics for the second benchmark was 3 meters in 2 years. The corners of this section were tied to the coordinate system for further monitoring. It is assumed that this technogenic effect pursued 2 objectives. The first was to reduce or exclude the dynamics of shoreline erosion in order to keep the summer recreation centers from destruction, and the second was to make the access to the beach area of the shore convenient. Further development of shoreline erosion will be clarified with regular field studies.

The monitoring site № 3 was laid in 2013 (figure 4). The reference site is located in the central part of the coastline of the settlement. Four benchmarks were set along the profile at a distance of an average length of 33 meters from the edge of the cliff. The territory is an undeveloped open area. Dynamics of displacement of the edge of the cliff for three and a half years at the 1st benchmark was 6.7 m, at the 2nd benchmark - 7 m, at the 3rd benchmark - 4.1 m, at the 4th benchmark - 4.8 m. The average rate of the retreat of the abrasion cliff was equal to 1–2 meters per year. Samples were taken from the steep wall of the coastal cliff for physicochemical analysis. The granulometric composition of the main strata of the coastal cliff and their thickness were determined visually.

Eastern shore (Kabanbai village). According to Ye.A. Kazanskaya, the site under study is gradually rising to the south of the base of the Zharbulak spit (the cape to the north of the recreational zone of the Kabanbai village), a low loamy cliff appears, relative height of which opposite to the Kabanbai village reaches 5 meters. In the outcrops of the cliff, there are clay loams and thin-sandy clays, buried soils, indicating that the shore has repeatedly experienced a transgression of the water body. The cliff of the coast is prone to intensive abrasion, various forms of destruction of the shore - erosion niches, columnar remains, etc. can be observed here. A narrow pebble beach stretches as an almost continuous strip along the shore. Its height is up to 1 m, the average width is up to 7 m, the prevailing sizes of pebbles are 1–4 cm, less often - up to 7–10 cm. In some places, the beach strip is still flooded with water, which is washing the bottom of the cliff [20].

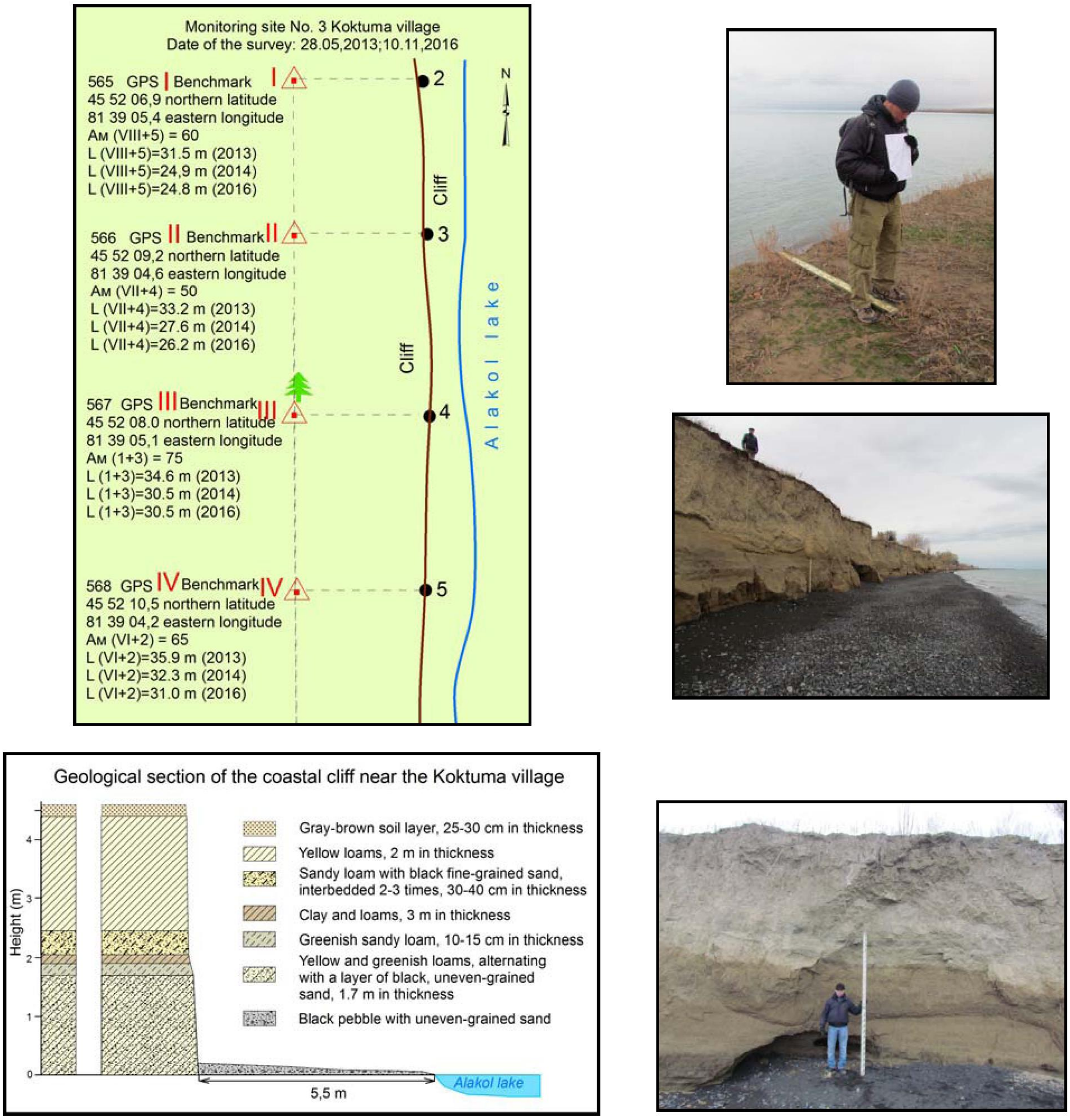

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Figure 4 – Scheme of the monitoring site № 3, Koktuma village, Almaty region

Monitoring sites were organized on the abrasion shore in the western part of the recreation area of the Kabanbai village. In 2013, two sites were laid and the first instrumental survey of the shore profile along the line gauges was carried out. The nearness of recreational and infrastructure facilities to the active zone of shore reformation was a criterion for the selection of reference sites, taking into account the coast-protecting engineering structures on the abrasion shore. The site under study is located three kilometers to the west of the Kabanbai village. In recent years, the territory of the summer recreational center has increased in area. Capital construction of summer holiday homes and infrastructure facilities is carried out both along the shore in the southern and northern directions, and deep into the land. These lands need additional backfilling of soil, since salinization of soil is observed everywhere due to the close occurrence of groundwater to the surface.

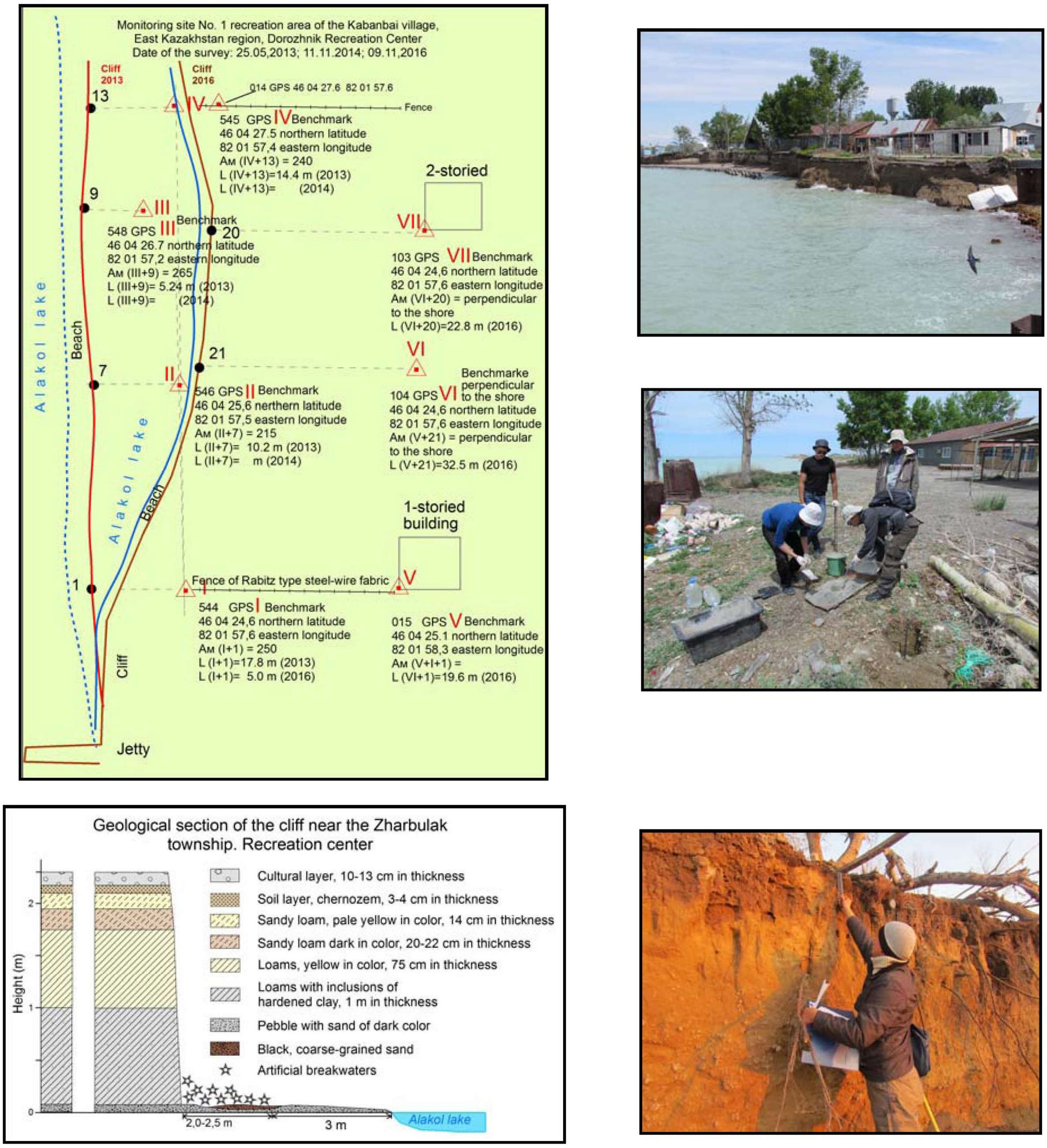

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Figure 5 – Scheme of the monitoring site № 1, recreational center of the Kabanbai village, East Kazakhstan region

Four benchmarks were installed along the profile at the monitoring site № 1 in 2013 (figure 5). The group had no data on the current dynamics of erosion of this shoreline when choosing a profile at a distance of 5 to 17 meters from the edge of the cliff. The abovementioned short distances turned to be unacceptable for the laying of reference sites and conducting monitoring. It was recorded that a bench was developed on the place of the profile along three benchmarks during repeated instrumental measurements in 2014. The coastal cliff was destroyed together with the benchmarks. Only one benchmark № 1 was preserved. Thus, the dynamics of the retreat of the edge of the coastal cliff amounted to 12.8 m for the benchmark № 1, more than 10 m for the 2nd benchmark, more than 6 m for the 3rd benchmark, more than 14 m for the 4th benchmark for three and a half years. The data for the last three benchmarks are approximate.

In 2016, during the reconnaissance of the territory adjacent to the reference point № 1, the relevant stationary objects were identified as new line gauges. Binding of three benchmarks was carried out using a satellite navigation device, two of them were the foundations of buildings, and the third line gauge was the base of the water-pumping station. Instrumental measurements of the distance from the benchmark to the edge of the cliff were carried out. Samples were taken from the steep coastal cliff for physicochemical analysis. The granulometric composition of the main strata of the coastal cliff and their thickness were determined visually.

According to the data of field observations, the south-west wind “Saikan” and the spring eroding of the shores by surface ice actively participate in the marginal erosion. Disburdening water points were recorded, they were found in the coastal zone of the lake as a result of the retreat of the shores.

Field observations made it possible to assume than one of the reasons for the active dynamics of shoreline erosion is the disturbance of the longshore transport of sedimentary rocks due to anthropogenic engineering and technical activities in the coastal zone of the lake. In 2009, a transversal breakwater with a length of 168 meters was built on the site to protect the coastal cliff from the destructive effects of waves

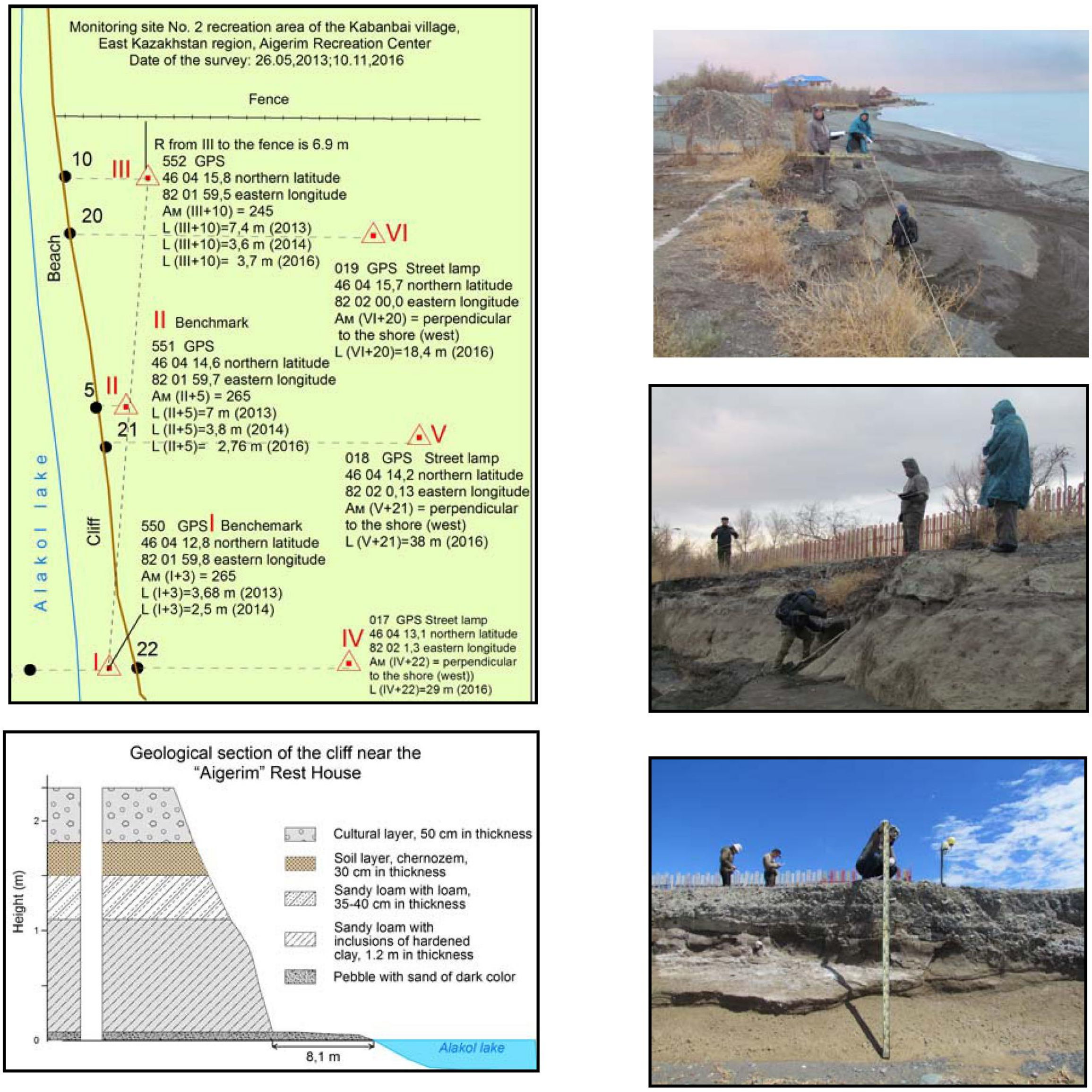

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Figure 6 – Scheme of monitoring site № 2, recreational center of the Kabanbai village, East Kazakhstan region

[21]. The analyses of field observations and satellite images revealed the accumulation, growth of the beach zone, composed of pebbles and sand on the territory located to the south of the breakwater. On the contrary, on the shore to the north of the breakwater, the dynamics of the shoreline erosion has intensified, and there is an active displacement of the cliff towards the land. According to the studies of Jeffrey H. List, one of the causes of shore erosion is the disturbance of the longshore transport of sedimentary deposits in the littoral zone. There is a disturbance in the balance of the arrival, consumption and the volumes of the reserve of sediments within the littoral zone, in which the longshore and transverse transport, river runoff, anthropogenic interference, and etc. participate [22].

Three benchmarks were installed along the profile on the monitoring site № 2 in 2013 (figure 6). Distances from the edge of the cliff to the benchmarks were from 3.5 to 7 meters. There is a metal fence of the private rest house parallel to the cliff at the indicated distances. Only two benchmarks along the lines of the profiles № 2 and 3 were kept when carrying out instrumental measurements in 2016. The first benchmark was destroyed by abrasion. In May 2013, the distance from the benchmark to the edge of the cliff was 3.68 m. Dynamics of development of shoreline erosion at the reference site № 4 was determined for each benchmark with a perpendicular direction to the cliff. At the 1st benchmark, it is presumably 4 m for three and half years, at the 2nd benchmark – 4.24 m, at the 3rd benchmark – 3.7 m.

New benchmarks were installed to fix the dynamics of the abrasion process for further field monitoring of the abrasion process. Three street lamps located on the territory of the summer recreation center were selected as benchmarks. They are located at a considerable distance from the edge of the cliff and are oriented along the shoreline. The coordination of new benchmarks, fixing the distances to the edge of the cliff in the west direction relative to all three lamps, was carried out.

Conclusion. The conducting of monitoring field studies of denudation-abrasion shores was caused by the need to solve the problems of sustainable recreational development of the coastal territory of Alakol Lake in order to reduce the threats and negative impact of exogeodynamic processes on valuable recreational areas, agricultural lands and residential areas. In order to solve the tasks of preserving the coastal abrasion cliff and increasing the recreational potential of Alakol Lake, the research group adapted the field method for monitoring the transformation of the relief of the shores. The method was tested in field studies. The experience of monitoring field works showed the need to install benchmarks along the profile at the distance of at least 20 m from the edge of the cliff.

The results of field studies showed a high rate of reformation of the abrasion cliff of the south-western and eastern shores. Areas with the dynamics of more than 3-4 meters per year were revealed. Uneven relief formation is observed in the coastal zone with functioning engineering shore protection structures, for example, accumulation occurs on one side of the breakwater, and there is an active denudation on the other side. Additional desktop and field studies are necessary for studying and understanding the current circumstances.

Abrasion refers to the processes that require careful study of its conditioning prerequisites, monitoring the state of the shoreline and conducting shore protection works in places where this process is particularly pronounced. The main attention should be paid to the abrasion development of the lake terrace, cliff, wave-cut notch and the relevant re-deposition of rocks of the coastal zone [19]. The obtained results of the field studies will contribute to a deep understanding of the processes of shore formation of internal lakes, arid zones, the accumulation of quantitative data, as well as the development of effective methods of shore protection and management of coastal territories.

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А. Г. Валеев [1], Ф. Ж. Акиянова[2], А. Д. Абитбаева[1], Е. Е. Хальков[1], М. М. Тогыс[1]

[1]География институты, Алматы, Қазақстан,
[2]География нституты және табиғатты пайдалану МНК «Астана», Астана, Қазақстан

АЛАКӨЛ КӨЛІ ЖАҒАЛАУЫНДАҒЫ АБРАЗИЯ ДАМУЫНЫҢ ДАЛАЛЫҚ ЗЕРТТЕУЛЕР БОЙЫНША МӘЛІМЕТТЕРІ

Аннотация. Соңғы жылдары Алакөл көлі туризм және демалыс орталығына айналды, инфрақұрылым кеңінен дамыды, жағалаудағы аудандарда айқын техногенді антропогендік жүктеме пайда болды. Сонымен бірге, табиғи-антропогендік жағдайлардың тұрақсыздығы әсерінен жағалаудың қалыптасуы біраз өзгеріске ұшырап, бұл инфрақұрылым нысандарын қирап жойылуына, жер телімдерінің азаюына және материалдық шығындардың ұлғауына әкеліп соқтырды. Ғылыми еңбектердің шолуы елу жыл бұрын жүргізілген зерттеулер екені анықталды. Сол себепті, заманауи өлшемді-инструментальды аспаптар жаңа бақылау, қадағалау алаңдарынан алынған мәліметтерді өңдеу маңызды рөлге ие. Жағалаудың қалыптасуын сараптама жүргізу нақты параметрлерді алудың тиімді әдістерін анықтау түсінуге мүмкіндік берді. Далалық зерттеулер жүргізілген телімдерде белгіленген ғарыштық түсірілімдерді пайдалануда аймақтық тәсілдерді қолдану. Далалық ғылыми зерттеулерінде сілтеме нүктелерінен арақашықтықты аспаптық өлшеу әдісі пайдаланылды. 3 жылдық кезең бойынша Алакөл көлінің шығыс және оңтүстік-батыс жағалау бөліктерінің өңделген жағалау өзгерістерінің нәтижелері анықталды. Оңтүстік-батыс жағалауында 6 бақылау алаңдары орнатылды. Белсенді жүрген бөліктегі өңделген жағалау жарқабақтарының өзгерген динамикасын бақылау нәтижелері үш жылдық кезеңнен 3-тен 9,9 м-ге дейін өзгерді. 5-6 метрден (1964) 9 метрге дейін жағалаудағы жартастың биіктігінің өзгеруі анықталды. Шығыс жағалауында 2 бақылау алаңы ұйымдастырылды. 3 жылдық кезең бойынша жағалаудың белсенді өңделіп өзгеріске ұшыраған бөлігінде 3,7-ден 14 м-ге дейін жетті. Осы алаң бойынша жағалаудағы шөгінді жыныстыарының жағалау бойымен шайылып бұзылуы 168 метрлік құйылған судың абразияның ұлғайып өзгеріске ұшырауын жақсартатын білуге болады.

Түйін сөздер: далалық зерттеулер, жағалауды өңдеуді бақылау, жағалау жары, абразия, жер бедері қалыптасуының өзгерісі.

А. Г. Валеев [1], Ф. Ж. Акиянова[2], А. Д. Абитбаева[1], Е. Е. Хальков[1], М. М. Тогыс[1]

[1]Институт Географии, Алматы, Казахстан,
[2]Институт географии и природопользования МНК «Астана», Астана, Казахстан

РАЗВИТИЕ АБРАЗИОННЫХ БЕРЕГОВ ОЗЕРА АЛАКОЛЬ ПО МАТЕРИАЛАМ ПОЛЕВЫХ ИССЛЕДОВАНИЙ

Аннотация. В последние годы озеро Алаколь становиться центром отдыха и туризма, развивается инфраструктура, с выраженной техногенной нагрузкой на береговые территории. При этом обостряется характер берегообразования под воздействием нестабильности природно-антропогенных условий, что приводит к разрушению инфраструктурных объектов, потере земельного фонда, материальному ущербу. Обзор научных работ выявил пятидесятилетнюю давность исследований проводимых ранее. Поэтому получение новых мониторинговых данных с использованием современных инструментально-измерительных приборов является актуальным. Определение эффективных методов для получения точных параметров позволило понять и проанализировать берегообразование. Региональным подходом с применением космоснимков были выделены участки для проведения полевых исследований. В полевых исследованиях использовался метод инструментальных измерений расстояний от реперов. В результате была определена динамика переработки берегов за трех летний период на юго-западном и восточном берегу озера Алаколь. На юго-западном береге были установлены 6 мониторинговых площадок. Результаты наблюдений за динамикой переработки берегового уступа в активной зоне составили от 3 до 9,9 м за трехлетний период. Выявлено изменение высоты берегового клифа от 5-6 метров (1964 г.) до 9 метров. На восточном берегу были организованы 2 мониторинговые площадки. Динамика переработки берегового уступа в активной зоне составили от 3,7 до 14 м за трехлетний период. На данной площадке предполагаем нарушение вдольберегового переноса осадочных пород 168-ми метровым волнорезом, который усиливает динамику абразии.

Ключевые слова: полевые исследования, мониторинг переработки берегов, береговой уступ, абразия, динамика рельефообразования.

Information about authors:

Valeyev A. G., Researcher, PhD Doctoral student, Institute of Geography, Almaty, Kazakhstan, Laboratory of Geomorphology and Geoinformation Mapping; adiletv@gmail.com; https://orcid.org/0000-0002-9380-351X

Akiyanova F. Zh., Doctor of Geographical Sciences, Director,Institute of Geography and Nature Management of the "Astana" International Scientific Complex, Astana, Kazakhstan; akiyanovaf@mail.ru; https://orcid.org/0000-0002-8395-8497

Abitbayeva A.D., Candidate of Geographical Sciences, Senior Researcher, Head of Laboratory, Institute of Geography, Almaty, Kazakhstan, Laboratory of Geomorphology and Geoinformation Mapping; abitbayevainagul@gmail.com; https://orcid.org/0000-0002-7335-0269

Khalykov Ye. Ye., Researcher, PhD Doctoral student, Institute of Geography, Almaty, Kazakhstan, Laboratory of Geomorphology and Geoinformation Mapping; e.halykov@mail.ru; https://orcid.org/0000-0003-4478-7995

Togys M. M., Junior Researcher, Master, Institute of Geography, Almaty, Kazakhstan, Laboratory of Geomorphology and Geoinformation Mapping; maulenmm@mail.ru; https://orcid.org/0000-0002-6257-0098

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