

RESEARCH OF ENGINEERING-GEOLOGICAL CONDITIONS OF RESERVOIRS LOCATED IN THE HIGH-SEISMIC ZONE OF UZBEKISTAN, USING GIS TECHNOLOGIES AND REMOTE SENSING MATERIALS (ON THE EXAMPLE OF THE SOUTH SURKHAN RESERVOIR)

***Bakhtiyor Tokhtaevich Kurbanov¹, Sharofiddin Ismatullayevich Yodgorov² and Ahror Sabritdinovich Husamitdinov²**

¹*National Center of State Cadastres, Geodesy and Cartography (NCSCGC), State Committee of The Republic of Uzbekistan on Land Resources, Geodesy, Cartography and State Cadastre, Bunyodkor Avenue-28, 100097, Tashkent city, Republic of Uzbekistan*

²*Institute of Seismology, Academy of Sciences of Uzbekistan, Zulfyakhonim-3 Street., 100128, Tashkent city, Uzbekistan*

**Author for Correspondence*

ABSTRACT

The article presents the results of a study and comparative analysis of the engineering and geological conditions of the South Surkhan reservoir, which is located in a highly seismic zone. The analysis was carried out for the period from the beginning of the operation of the reservoir to the present. A map of the current state of the processing zones of the reservoir was developed. According to the data for 1979 and 2018, the coastline territory with a different degree of processing is determined. Recommendations on the organization of monitoring the territory of the reservoir and adjacent territories based on the use of remote sensing have been developed.

Keywords: *Monitoring of Environment, Engineering Geology, Hydrogeology, Environmental Protection, Ecology, Integrated GIS Technologies, Digital Mapping, Remote Sensing*

INTRODUCTION

The development of the economy and the formation of economic potential in the Surkhandarya region of Uzbekistan is associated with the intensive use of land, water, energy and mineral resources. Their rational use ensures long-term and sustainable socio-economic development of the region. At the same time, the effective use of natural resources is adversely affected by various dam-forming, seismotectonic, geotechnical factors, dangerous geological processes and phenomena, especially strong earthquakes. The construction and operation of large reservoirs, intended mainly for the development of new and optimal use of existing land, are important. The construction and operation of reservoirs has both positive and negative consequences. They can cause significant negative changes in the nature of adjacent territories. Such phenomena include the flooding of vast territories. Valuable agricultural land, forests, industrial enterprises, settlements, mineral deposits and other objects are often flooded. The greatest extent of flooding is observed when creating reservoirs on lowland rivers. Groundwater pressure creates a new wetting of coastal areas, flooding of low coasts and built-up areas. The wetting of shores composed of loess rocks causes subsidence phenomena. With annual fluctuations in the water level in the reservoir, processes of dissolution, weathering of rocks and loss of their strength occur. Suffusion phenomena are becoming more likely. New landslide processes appear or are activated. Cracks and signs of subsidence of slopes appear in certain sections of steep banks. Due to the increasing creep of clay rocks, slow slope deformations are detected. As a result of processing the coastal slope, hanging gullies are often formed. In this regard, erosion processes are activated in them. In the study area, such damaging factors, their types and quantities can vary during the construction period and during the operation of the reservoir. During the long-term operation of the reservoir, some of them can stabilize. The construction and operation of the South Surkhan reservoir significantly affects the environment, including the geological environment. In

Research Article

order to minimize or prevent damage caused by these factors, a comprehensive study of the state of the environment in the area of the reservoir is necessary. It is necessary to identify a number of patterns of seismological and engineering-geological conditions and develop criteria for their assessment. In the areas where hydraulic structures are located, the main changes in the geological environment are associated with the violation of the regime of surface and groundwater, the activation of geodynamic processes along the banks of reservoirs.

The object of the study are damaging factors in the territory of the South Surkhan reservoir.

The purpose of the research is to identify patterns of formation and development of geological and engineering-geological processes in the periods before construction, after construction and during the long-term operation of the reservoir, to identify damaging factors on the territory of the reservoir.

The main factual materials used were data from long-term observations, stock and literary materials on geology, seismology, hydrogeology and engineering geology in the study area. We also used materials from field work carried out by us in areas of active development of geodynamic processes in the territory adjacent to the South Surkhan reservoir.

MATERIALS AND METHODS

The environmental impacts of human engineering have been studied by many researchers. The issue of the impact of human engineering on the environment has been studied by many researchers. It was considered in the works of E.M. Sergeev (1985), G.S. Zolotarev (1961, 1973), A.M. Khudaibergenov (2001) and others. We took into account the experience and research results of these scientists to study the territory of the South Surkhan reservoir. At the same time, the features, nature and scale of development of engineering and geological conditions were taken into account. Damage-causing factors in the reservoir were studied.

The environmental impact of reservoirs is enormous. During and after the construction of the reservoir, not only sharp changes in the dynamics of water masses in natural watercourses occur, but also the activation of old and the emergence of new exogenous geological processes occurring in the coastal zone of reservoirs.

One of the main exogenous geological processes that arise and are activated as a result of the formation and operation of reservoirs are slope processes, including coastal processing, activation of landslides and the development of subsidence, ravine formation, abrasion, etc. A special and leading place in these studies is the study of the laws governing the influence of the reservoir on the geological environment and the development of reliable methods for predicting geotechnical processes, since the laws and forecasts are of immediate practical interest. In addition, the prediction of engineering and geological processes and verification of forecasts, by comparing them with the actually observed processes, will allow a deeper study of the physical nature of the process and improve methods of its physical and mathematical modeling.

The study of processes occurring on the banks of reservoirs, and their dynamics are of great engineering and geological importance. They allow you to determine the damage to the stability of the adjacent territories of reservoirs (loss of useful land), the reliability and durability of the operation of hydraulic structures. The identification of natural and technogenic processes that can cause damage both to the stability of engineering structures and to the surrounding geological environment (where the object of study is located) is carried out by a detailed study of the geotechnical conditions of the territory.

To identify damaging factors on the territory of the investigated object, their formation and development, the existing research materials were studied. To analyze the types, forms of processes and phenomena on the area of their distribution, which took place in the period before construction and at the beginning of the operation of the reservoir, these materials were systematized. Next, they are compared with the current state, i.e. in the period after prolonged use.

Research Article

Before the commissioning of the reservoir, construction work related to hydraulic structures (canals, dams, etc.) was started in 1958, and the engineering and technical impact on the geological environment in this area began from that time.

After commissioning of the reservoir, studies have been conducted for more than 50 years. For this period, engineering-geological and hydrogeological and other natural and technological conditions of the territory are different. The systematization and analysis of materials from different periods of observation, the identification of damming factors and their dynamics using satellite imagery and GIS technologies over the past 10-20 years allow us to develop digital maps for assessing damaging factors at research objects.

The South Surkhan Reservoir was designed by the Sredazgiprovdokhlopok Institute in 1958. Its construction was carried out in the period from 1958 to 1966. Since 1962, the filling of the reservoir began. In 1972, for the first time, water in the reservoirs reached the design flooding area of 65 km². The beginning of the permanent operation of the reservoir is considered to be since 1967. Until the design, construction and operation of the reservoir, the territory until 1996 belonged to zone 7 point seismicity. Then, since 1996, these territories were transferred to zone 8 of seismicity. The reservoir belongs to the II class in terms of capital construction.

Some basic parameters of the reservoir:

- full design volume - 800mln. m³;
- the length of the reservoir 20 km;
- maximum width of 6.2 km;
- maximum depth 27 m;
- area 65 km²;
- the length of the coastline (with the design volume of the reservoir) 60km, 4km consists of abrasion banks (Figure 1).

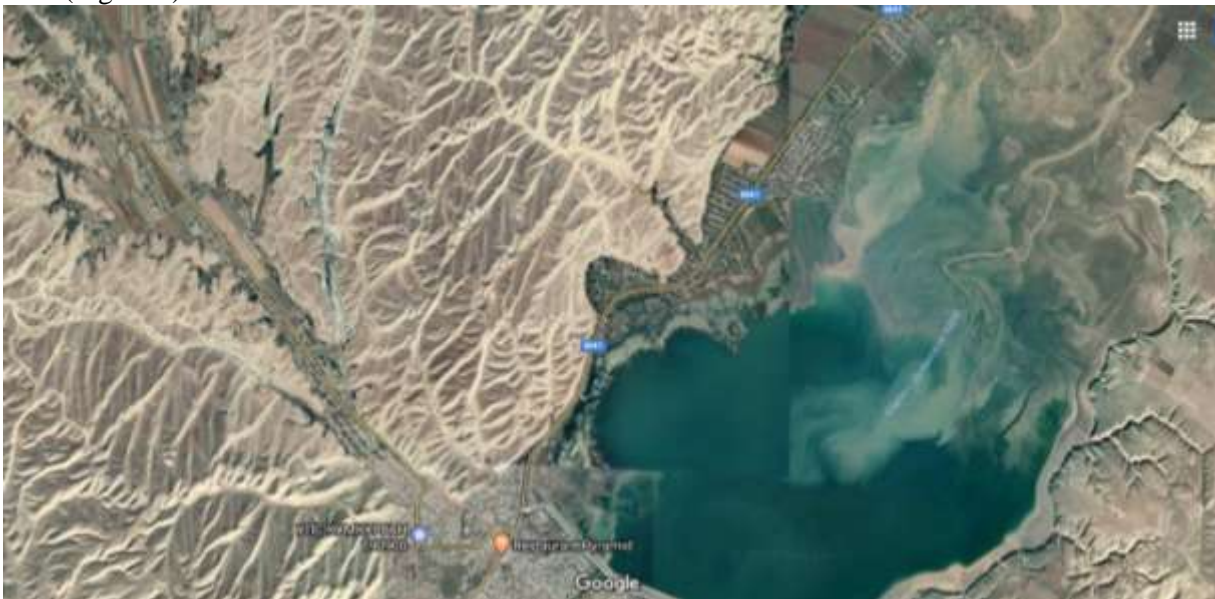


Figure 1: South Surkhan Reservoir

Dam:

- length 5200m; height 30m; base width, approximately 150m; ridge width 8-10m; dam volume 450 thousand km²;
- type of dam - earthen with a core;
- soil composition - heterogeneous soils - sandy loam and loam.

A general view of the cross section of the dam is shown in Figure 2.

Research Article

Field surveys on the territory of the South Surkhan reservoir were carried out by us in October 2018. The main purpose of the survey: 1. Studying the dynamics of changes in engineering and geological conditions from the moment of design and construction to the present. 2. Isolation from the existing modern geological and engineering-geological processes and phenomena of the most usherb-forming factors in the zone of direct influence of the reservoir and the territory adjacent to it.

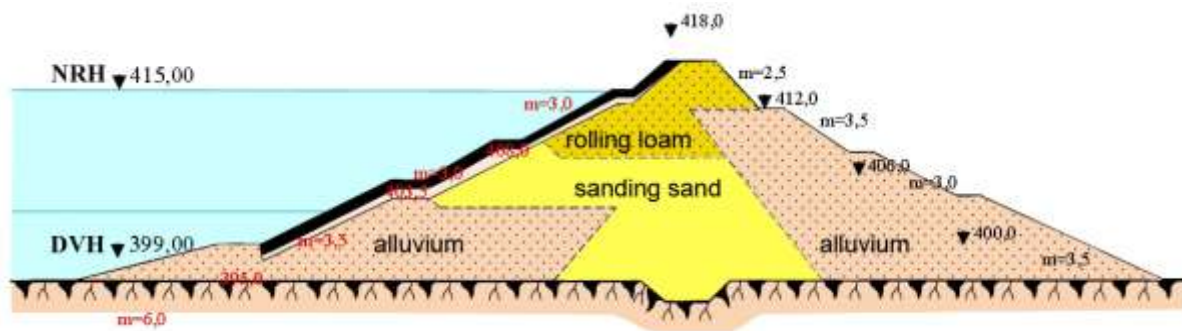


Figure 2: A general view of the cross section of the dam
 NRH - normal retaining horizon; DVH - dead volume horizon.

Based on the results of field surveys on the area of the South Surkhan reservoir, relying on the many years of experience of the authors (Juraev *et al.*, 2018, Yodgorov *et al.*, 2018, Magdiev *et al.*, 2016, Yodgorov *et al.*, 2016a, Yodgorov *et al.*, 2016b, Kurbanov *et al.*, 2018) and the classic works of specialists in this field (Zolotareva *et al.*, 1961), sources and types of natural and man-caused damage-generating factors that change engineering-geological and geoecological were identified and studied conditions. A comparative analysis of the main damaging factors before construction, during construction and operation, and to the present.

Geological and engineering-geological processes and phenomena developed prior to construction now exist with slight changes outside the zone of influence of the reservoir. After the construction of the reservoir, as water accumulates in the reservoir and the territory is flooded, slope processes develop intensively in the coastal zone of the reservoir. These processes and phenomena have been studied in detail for the period of operation (Juraev *et al.*, 2018). Currently, in the coastal zone of the reservoir, the coastal processing process, the collapse of coastal ledges have become less active, and become more active only during the rise and operation of the water level in the reservoir (Fig. 3.).



Figure 3: Processes of coastal processing, collapse of coastal ledges with low activity.

Research Article

Below the dam site, processes such as erosion, abrasion, washing banks, flooding of low terraces, etc. are directly related to the operation mode of the reservoir. In the downstream, drainage systems have been created that reduce the hydraulic level to the calculated level (Fig. 4), and discharge channels for water discharge when it is standing high (Fig. 5.6), shore protection structures, etc.



Figure 4: Systems for lowering the hydraulic level to the calculated mark



Figure 5: Left discharge channel



Figure 6: Right discharge channel

The water level in the reservoir at the time of observation (09/27/2018) was significantly lower than the level of the normal retaining horizon (NRH) and the reservoir mirror area was 32 km² (Fig. 7), the mirror area at the beginning of May 2019, amounted to 36 km², the coast length was 31 km (Fig. 8).



Figure 7: The survey scheme and places of distribution of modern engineering and geological processes and phenomena in the reservoir. Date of shooting September 27, 2018

Legend: 1- view of the downstream; 2- discharge of water by the channel, on the right bank; 3- denudation surfaces of the high slopes of the right bank; 4- discharge of water by the Amuzang canal into the reservoir, the left bank; 5- suffusion funnels, left bank; 6.7 - development of erosion gullies with waste waters after irrigation of rural crops.

Research Article

The observations made by us in October 2018 show that the following processes are observed on the study area:

- weathering of rocks in steep slopes and vertical walls;
- erosion, denudation and suffusion processes that form and develop gullies, suffusion funnels and other landforms. Such landforms are especially developed on the area composed of loess, sandy-loamy rocks on the left bank (Fig. 7-6, 7-7, 9, 10, 11);
- processing of the shores of the reservoir is slower than in 1967–75 (Fig. 12) (Kholmatov et al. 1976) and the current coastal retreat (compared with 1975–80) is approximately 50–65 m (Fig. 13,14).
- subsidence of the surface of loess rocks is observed in the coastal zone of the reservoir with a high standing water level of the reservoir, rising groundwater and flooding area;
- there are old landslides (The technical design 1957), which are sometimes activated (Fig. 15,16);
- mudflows occur in the spring-winter period, and they are common in the left-bank slopes of the foothill plains and others (Fig. 17).



Figure 8: South Surkhan Reservoir. Shooting date 05/05/2019



Figure 9: Development of suffusion and erosion processes on the left bank as a result of water discharge after irrigation



Figure 10: An example of a relatively slow development of a ravine on the left bank



Figure 11: An example of a more intensive development of a ravine on the left bank



Figure 12: The nature of the shallows after the discharge of the water level in 1973 (left bank, dam zone)



Figure 13: The nature of the shallows after the discharge of the water level in 2018, the discharge of water by the Amuzang canal into the reservoir, (left bank, dam zone)



Figure 14: Bank recycling, left bank



Figure 15: Step landslides in slope deposits IV terraces. In the foreground a drawdown crack (photo 1957)



Figure 16: An old landslide in the center, denudated by rainwater, on the right is a suffusion funnel
 The suffusion processes in the years 60-70 were pronounced along the cliff of the third terrace on the right bank of the river. Here, at a distance of $60 \div 80\text{m}$ from the cliff, there are funnels, ponurs,

Research Article

suspension bridges, underground galleries, and caves in the lower part of the cliff. They are observed on the third terrace. All these forms of the karst relief were formed as a result of penetration through cracks or holes of earth moving materials, surface water and their removal of fine earth and sandy soils (Figures 18, 19). At present, suffusion processes are not so pronounced (Fig. 16).



Figure 17: The development of erosion-denudation processes on the left bank as a result of mudflows that occur in the spring-winter period.



Figure 18: Suffocation funnels near the ledge of terrace III. In the background is I terrace and the Surkhan-Darya river



Figure 19. Suffusion funnels near the ledge of terrace III (Photo 1957)

Of the above processes, the most damaging factors, in our opinion, on the territory of the South Surkhan reservoir are the following:

- seismic processes in which earthquakes with an intensity of 8 (eight) points have a repeatability of 1 time in 200-250 years;
- coastal processing and coastline retreat, with the participation of erosion-denudation processes by rainwater;
- suffusion-erosion processes and ravine formation caused by natural and man-made factors;
- washing out and abrasion of river banks in the downstream, collapse of the edge of terraces and slopes.

In this area, when operating the reservoir, it is necessary to take into account the possibility of earthquakes up to 8 points in magnitude. With a high level of reservoir filling to the level of a normal retaining horizon in the coastal zone of the reservoir, where the groundwater level rises to 4 m from the earth's surface, in this zone the earthquake intensity increases to +1.0 points, i.e. with a background seismicity of 8 points, the calculated seismic intensity can reach 9 points. In the lower pool, where the groundwater level is less than 4 m, the intensity of the earthquake increases to +1 point. Historically, many earthquakes were observed in this region with an epicenter close to the object with a magnitude of 7 points, such as the Baysun earthquake on June 5, 1935. The force of concussion in the study area reached 6-7 points (Riznichenko, 1972), fig.20.

Shore processing, suffusion-erosion processes, landslide formation, washing out and abrasion of river banks in the downstream and other processes associated with the activities of surface and groundwaters with the participation of human activities can cause significant damage. They lead to the loss of useful land, premature filling of the dead volume of the reservoir by the removal of loose rocks in the reservoir bowl.

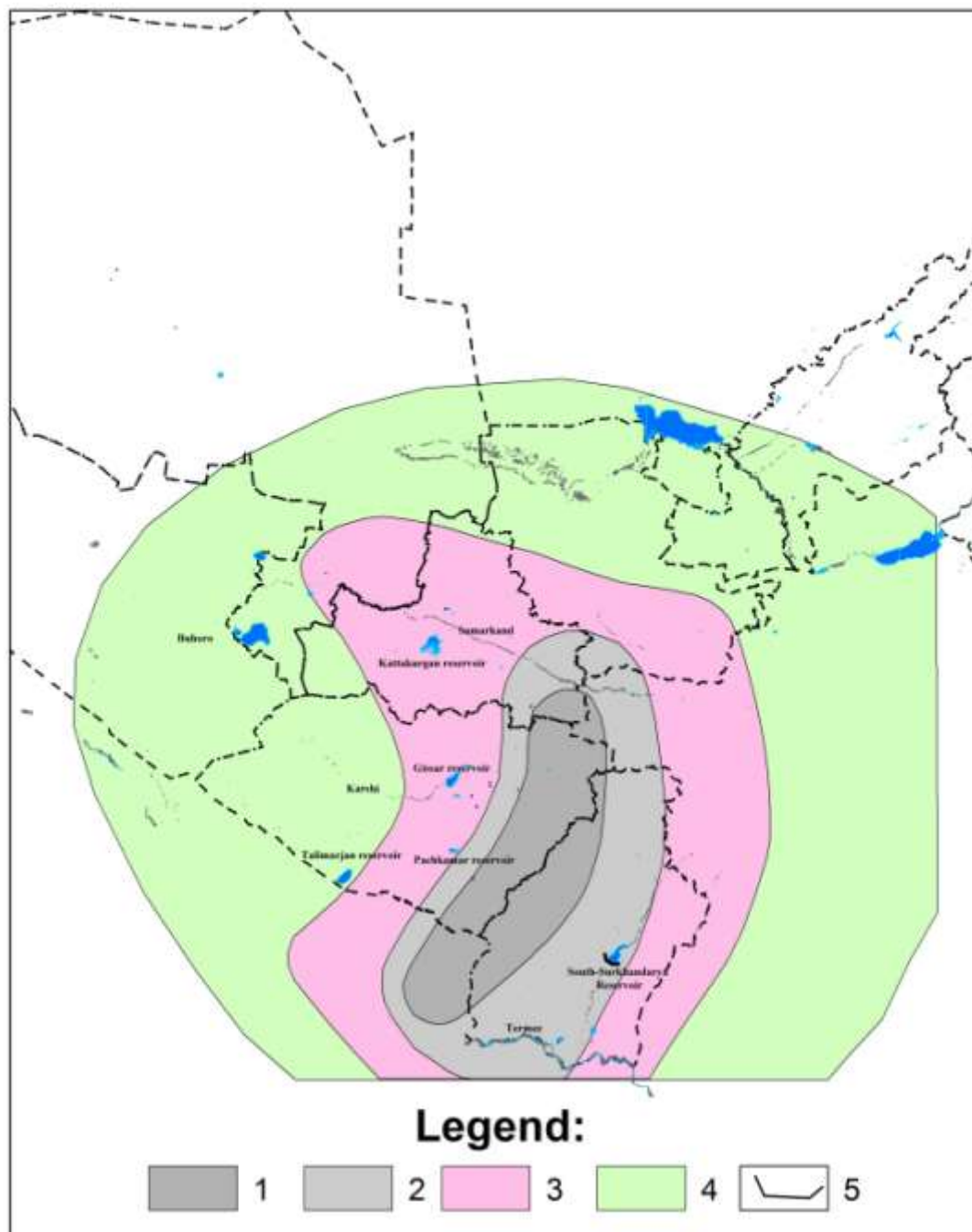


Figure 20: Schematic distribution of scores during the earthquake of July 5, 1935 (Baysunskoye)
 1. 7 points; 2. 6-7; 3. 6; 4. 5-6; 5. South Surkhan Reservoir

In an area where formation or development of damaging factors is possible, it is necessary to take measures to optimally regulate and use surface water and to regularly monitor the state of the reservoir and surrounding areas. In this case, it is necessary to conduct regular monitoring using modern GIS

Research Article

technology, GPS-technologies and materials for remote sensing of the earth. If necessary, appropriate engineering and technical measures should be applied promptly.

During the operation of the reservoir, a rise in the water level to the mark of the associated gas source and triggering of up to 10 meters or more provokes these processes on the coastal zone of the reservoir's influence, abrasion, collapse of the ledges, processing of coasts and entrainment of loose and loosened materials deep into the reservoir, etc. occur. When the level rises to high marks in the coastal areas there is groundwater abstraction, pinching out in places. In places of development of loess soils as a result of flooding of the territory with ground waters, a subsidence of the earth's surface occurs. These processes take place in the coastal zone - the zone of influence of the reservoir. To clarify the dynamics and intensification of processes, it is advisable to organize monitoring of these zones during a period of prolonged maximum standing of water in the reservoir and during the period of maximum response.

In the territory adjacent to the zone of influence of the reservoir, these processes are also common, and they are associated with natural and technogenic factors. Processes such as erosion-denudation are associated with rainwater and waters discharged after irrigation of crops (Figures 9, 17).

Having studied the nature of the dynamics and the place of distribution of processes, it is possible to predict the loss of usable areas and take measures to combat usherb-forming factors.

To clarify the changes in the engineering-geological conditions after long-term operation of the reservoir, we combined a schematic engineering-geological map with satellite imagery materials (survey date 09/27/2018). The locations of individual processes that cause damage to usable area and affect the reliability of operation of the reservoir are highlighted. The waterfront lines of the reservoir are distinguished at 395 m (08.1971), 440 m (09.1972), 405 m (08.1972) and at 415 m (normal retaining horizon). The territory of the limited processing line 1979 and 2018 was determined (Fig. 21).

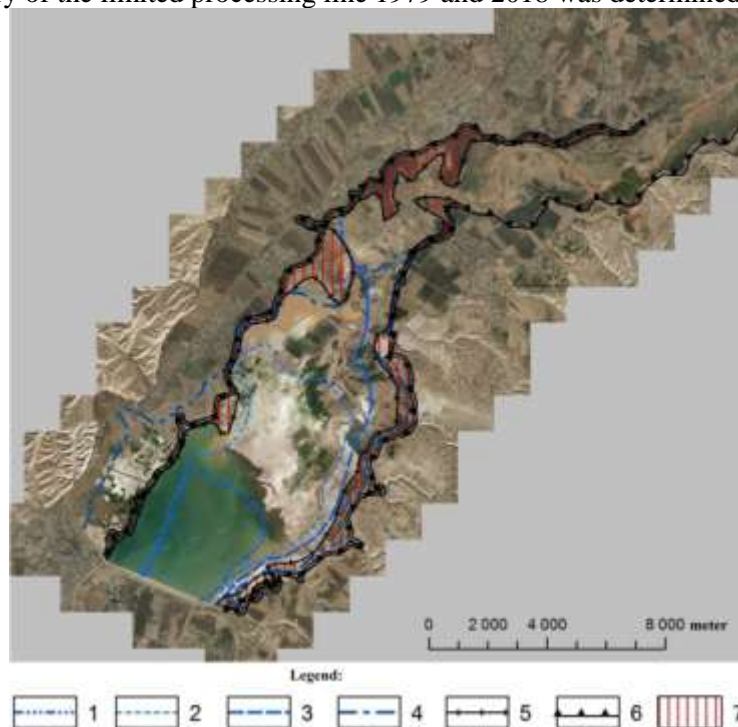


Figure 21: Map-scheme of the lining of the current state of the zones of processing the coast of the reservoir.

The water line of the reservoir, at the marks: 1–395 m (08.1971), 2–440 m (09.1972), 3–405 m (08.1972) and 4 at 415 m (gas); the border of the coastal processing zones: 5-1979, 6- 2018; 7- area of the processed shores of the reservoir 1979 - 2018

Research Article

This strip-like zone extends along both banks of the river. On the left bank, this zone is shallow and wider than on the right bank and ranges from 50-70m with a dam section up to 1-1.5 km. In fig. Figure 22 shows the selected zones according to the degree of processing of coasts in 1976 (Kholmatov et al. 1976): banks with very large processing, large, medium, small processing and banks that are not recyclable. The border of these zones was specified by us in 2018.

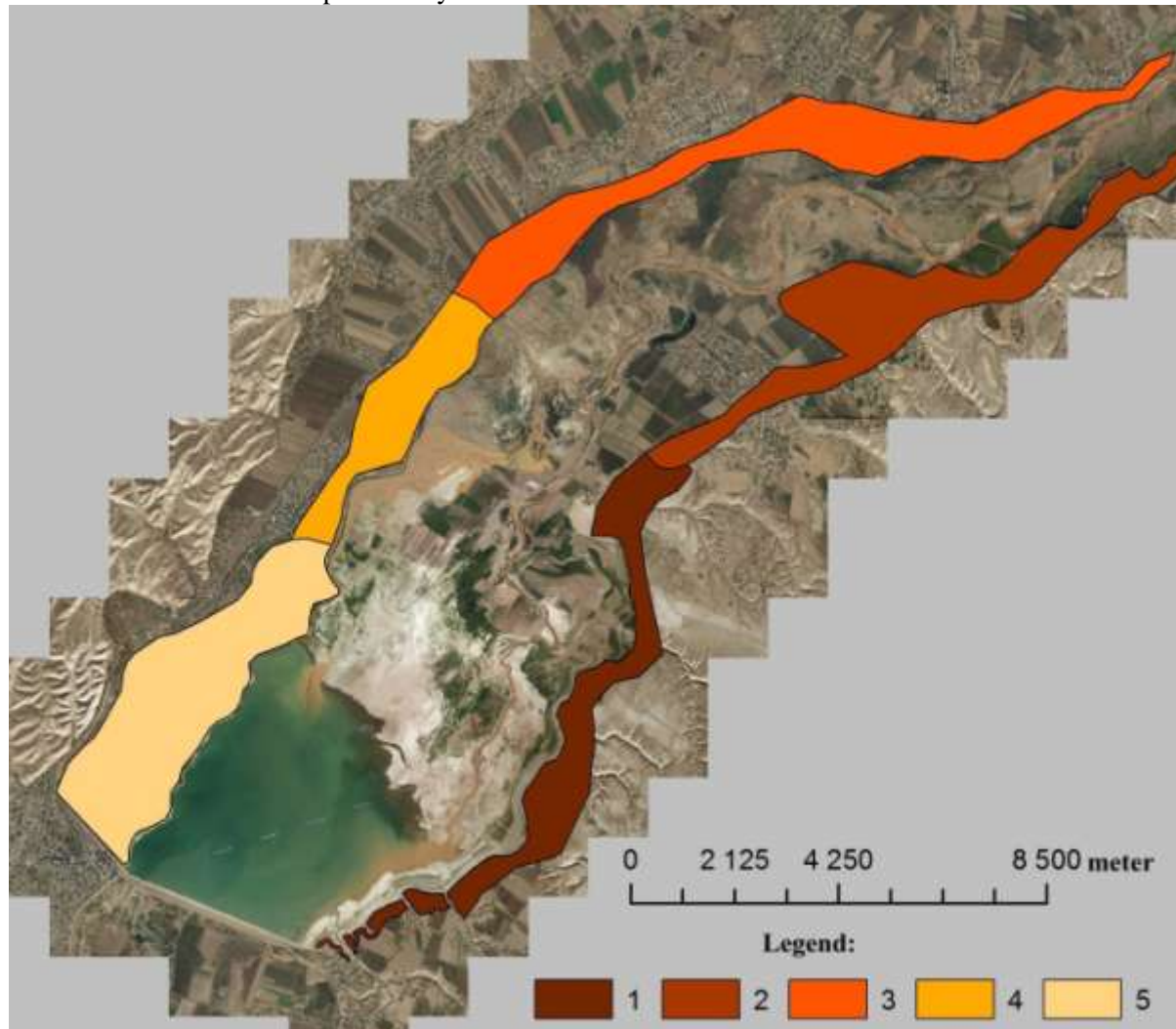


Figure 22: The zoning scheme for the degree of processing of the banks of the reservoir
 Shores: 1- very large processing; 2- large; 3- with medium, 4- low processing, 5- banks not recyclable.

At present, it is advisable to organize geomonitoring of the territory of the reservoir and adjacent territories. Monitoring the dynamics of damaging processes should be carried out using high-resolution remote sensing materials during both high standing water levels in the reservoir and low standing for each year of operation. In order to ensure environmental monitoring and, first of all, farmland by the Decree of the Cabinet of Ministers "Ensuring the implementation of certain provisions of the Decree of the President of the Republic of Uzbekistan dated March 29, 2018 No. PP-3639" On measures for the targeted and effective use of unmanned aerial vehicles of civil aviation in the economy " creation of a joint venture in the form of a limited liability company "BSHARKUZ". It is advisable to use unmanned aerial vehicles to monitor the hydraulic structures and reservoirs of the republic. In the case of a sharp intensification of the processes that cause damage to the usable area and affect the reliability of the

Research Article

reservoir operation of these processes, it is necessary to conduct a thorough examination and study of each damaging factor on the spot.

DISCUSSION

Within the framework of the project "Development of a methodology for assessing the usherb-forming factors of reservoirs located in adyr-plain areas of high seismicity using GIS technology (using the example of the South Surkhan and Pachkamar reservoirs)" (stage I), the following main works were performed:

1. Collected cartographic materials and research materials on the territory of the reservoir for previous years were collected, systematized and analyzed.
2. The engineering and geological conditions of different periods were studied: in the period before construction, at the beginning of the operation of the reservoir and changes in subsequent periods.
3. In 2018, field reconnaissance engineering-seismological and geological works were carried out on the area of the South Surkhansky reservoir, geological and engineering-geological processes were studied and mapped, which significantly damage the usable land area and have a negative impact on the reliability of the reservoir.

The collected materials served as the basis for the development of digital maps of modern processes that damage the reservoir and surrounding areas.

4. A digital map-diagram of the current state of the processing zones of the banks of the reservoir has been developed. Areas with varying degrees of processing of the shores of the reservoir are identified.

It should be noted that the area of the South Surkhan reservoir is located in the plain part of the valley of the river. Surkhandarya. Loess soils of considerable thickness are prevalent here. Therefore, erosion-denudation processes on the slopes of the valley in the coastal zone of the reservoir are developed in this territory. Suffusion funnels, ravines, landslides, processing of the banks of the reservoir, which occupy significant areas, are widespread, and these processes are damaging. We consider it expedient to conduct regular ground-based observations, organize monitoring in the reservoir using modern GIS technologies and high-resolution remote sensing materials.

REFERENCES

- Dzhuraev NM, Yodgorov ShI, Khusomiddinov AS, Kurbanov BT, Tuychiev MA (2018).** The use of modern ArcGIS geographic information technologies in assessing the geo-ecological conditions of reservoirs located in different physical and geographical conditions. Collection of reports of the International Scientific Conference "Geophysical Methods for Solving Actual Problems of Modern Seismology" dedicated to the 150th anniversary of the Tashkent Scientific and Research Geophysical Observatory. Tashkent, October 15-16, 2018 Publishing house "Complex print", 444-450.
- Kholmatov ZKh, Rashidov A, Kholmatova RN (1976).** Report on the topic "Study of changes in engineering and geological conditions under the influence of the flat reservoirs of Central Asia and the development of methods for their prediction" (1973-1976). Funds State Committee of the Republic of Uzbekistan on Geology and Mineral Resources, Tashkent -
- Khudaibergenov AM (2001).** Problems of geoecology and protection of the geological environment of the cities of intermountain and foothill depressions of Uzbekistan. "Geoecology and geoecological problems of mountain and intermountain systems." Mater. Int. Conf., March 26-28, - Tashkent, 2001, 133-135.
- Kurbanov BT, Dzhuraev NM, Yodgorov ShI, Khusomiddinov AS, Mavrotalasiti F (2018).** Analysis of geoecological and seismic ecological conditions of hydraulic structures located in a highly seismic zone. Materials of the international conference "The influence of natural global changes and technological conditions on hydraulic engineering, geotechnical and geoecological processes: analysis of results and development forecasting". Tashkent October 12, 132-138.

Research Article

Magdiev HN, BB Kurbanov, BT Kurbanov (2016). Application of the three-dimensional modeling methods for problems solution to elaborate a salt drain basis. *Bulletin of the Kyrgyz State University of Construction, Transport and Architecture named after N.Isanov, Bishkek, Education-Printing Centre "Avangard"* - №2(52), 161-168.

Sergeev EM (1985). Theoretical foundations of engineering geology. *Geological Foundations M*: Nedra, 332 p.

Yodgorov ShI, NM Dzhurayev, BT Kurbanov, HM Magdiev (2016). Analysis of change of engineering-geological conditions of the Chartak territory with using GIS and GPS-technologies//Bulletin of the Kyrgyz State University of Construction, Transport and Architecture named after N.Isanov, Bishkek, Education-Printing Centre "Avangard" 2(52), 122-130.

Yodgorov ShI, NM Dzhurayev, BT Kurbanov, HM Magdiev (2016). Research of the engineering and geological conditions of the area for construction of hydro-technical structures with application of GIS-tehnologies//Bulletin of the Kyrgyz State University of Construction, Transport and Architecture named after N.Isanov, Bishkek, Education-Printing Centre "Avangard", 2(52), 115-122.

Yodgorov ShI, Tuychieva IA (2018). Features of modern geodynamic processes around the Hissarak reservoir. *International Scientific Conference "Geophysical Methods for Solving Actual Problems of Modern Seismology" dedicated to the 150th anniversary of the Tashkent Scientific and Research Geophysical Observatory. Tashkent, October 15-16, "Complex print"*, 444-450.

Yu V Riznichenko (1972). Seismicity of Western Uzbekistan. Repl. ed. Corr. USSR Academy of Sciences Yu. V. Riznichenko, Publishing House "Fan" of the Uzbek SSR, Tashkent, 152 p.

Zolotarev GS, Piotrovskaya TYu (1973). Layouts of engineering-geological maps of mountain-folded areas for underground and surface (urban and road) construction and recommendations for their compilation. - M, 22p.

Zolotareva GS, DS Sokolova and EG Chapovsky (1961). Edited by Experience and methods of studying the hydrogeological and engineering-geological conditions of large reservoirs. Parts two and three. Publishing House of Moscow University,. 360p.