Effects of water level changes in reservoir basin on coastal erosion

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Abstract. In this article, the Chimkurgan reservoir built in the Kashkadarya basin, located in the Qamashi district of the Kashkadarya region, is selected. Considering the change in the water level of the Chimkurgan reservoir, the level of erosion of the shores in the zone of 14 m of water level change on the left bank of the reservoir was considered. Over time, the forces induced by water weaken the soil aggregates, negatively affecting the soil's stability. The density composition of the reservoir coastal soils was determined at the specified heights. The degree of erosion of the reservoir's banks, depending on the soil type, was also considered. To the bottom of the reservoir, the degree of erosion of coastal soils was determined in the water level change zone at heights of 9 m, 11 m, 13 m, 15 m, 17 m, and 19 m, 22 m, 23 m. It was found that the types of soils obtained from the elevations in the specified place differ from each other. It was determined that the type of soil at these heights is clay, soft soil, and sand, and to a certain extent, the erosion of the banks differs depending on the type of soil.

1 Introduction

The existing water reservoirs in our country are filling up with mud and sediments year by year, which indicates that the useful volume of the water reservoir is decreasing. As a result, the water supply to consumers and the reduction of water supply and water demand will be achieved [1, 2]. The situation worsens when reservoir capacity is significantly reduced due to reservoir subsidence (Alexakis et al. 2013) [19]. In this case, the formation of reservoir banks and their quantitative assessment is an urgent issue for the reliable and efficient use of many currently working reservoirs [3, 7, 11]. Determining coastal erosion areas is very important and is a major priority for conservation efforts (Uddin et al. 2016) [23]. Depending on the size of the surface of the reservoir, we can observe the changes in the water level in the reservoir bowl and the erosion of the shore due to the wind wave. Currently, studies have found that the susceptibility of reservoir coastal soils to water erosion is highly related to the stability of soil aggregates (Barth'es and Roose, 2002; Parsakhoo et al., 2014) [19]. Given these advantages, soil aggregate stability information serves as a key indicator for determining the most vulnerable soil to erosion. As a result of the complete emptying of the reservoir during the vegetation period, we can see the erosion

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of water-saturated coastal soils, the deposition of bottom sediments in the reservoir basin, and the changes in the coast [2,3,5]. Seasonal reservoirs require the development of improved methods for calculating the amount of bottom sediment, determining the loss of useful volume during operation, and studying the processes of bank formation due to various effects [1-3]. Research on the impact of coastal erosion on the water balance and calculation methods in reservoirs, as well as the movement and formation of turbid sediments in rivers and reservoirs, and research on improving their calculation methods, have been carried out [5-7]. Changes in the water level in the reservoir basin can cause bank erosion depending on the characteristics of the coastal soil (Al-Kaisi et al., 2014; Ouattara et al., 2008); determined [18, 22]. The speed of emptying and filling the reservoir can be slowed down. However, this is inevitable because erosion and sedimentation are natural phenomena resulting from the balance of energy elements (LEGOWO et al. 2009) [24]. Found that soil kinetics between onshore and flooded soils yielded different results due to the slow decomposition of submerged riparian soils in the reservoir basin [13, 14].
Therefore, improving the calculation of coastal erosion in the basin of reservoirs is an urgent issue to study the causes of coastal erosion.
It is necessary to study the causes of the erosion of the shores and the dependence of the erosion on the coastal soils.
Studying the processes that take place on the shores during the release and collection of water in the reservoir bowl is of great importance in the use of reservoirs.

2 Method and materials

2.1 Study Area

Chimkurgan reservoir is located in the Kamashi district of Kashkadarya region. It is located 9.5 km from the district center and was built and commissioned in 1957-1963 in the Kashkadarya basin. The reservoir is designed to irrigate an area of 88,000 hectares. The design maximum of the reservoir is 500 million m^3, and its useful volume is 450 m.l.n m^3.

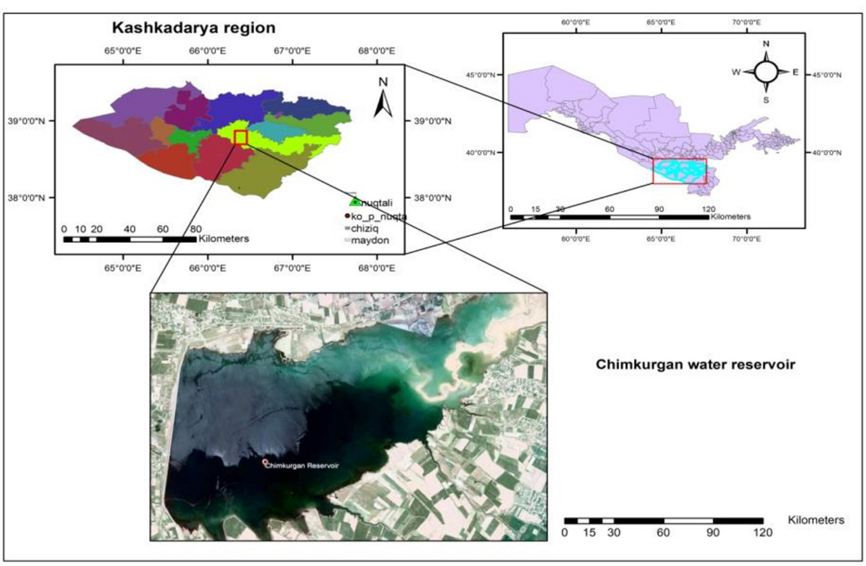

Fig. 1. Chimkurgan reservoir research area

The surface of the reservoir at the normal wetted level is 38,735 km^2. The reservoir has a maximum water discharge capacity of 350 m^3/s. The middle part of this reservoir is located on the left bank (360 68′ 205.66″ N, 660 09′ 536.66″ E.). Regulation of water level changes in the reservoir is carried out for two important purposes. To reduce the demand for water during the vegetation period, the water level is 9 m, and in winter and spring, the water level rise is 23 m to ensure the need for water. It can be seen that a 14 m hydrological disturbance zone of the water level in the reservoir (Fig. 2) appears.

Table 1. Long-term average rainfall from Chimkurgan meteorological station (mm)

Months	**Average by years**						
	2017	**2018**	**2019**	**2020**	**2021**	**2022**	**Average**
I	38.7	36.4	57	57.8	68.8	55.8	52.4
II	67.1	73.2	75.5	37.5	34.4	40.9	54.7
III	67.5	32	65	129.1	84.5	90.4	78.0
IV	43.7	8	41.4	51.2	23.1	39.4	34.4
V	36.4	14	11.7	4.2	26.7	41.5	22.4
VI	2.8	0.4	2.2	0	0	0	0.9
VII	0.6	0	0	0	0	0	0.1
VIII	0	0	0	0	0	0	0
IX	2.7	0	0	0.4	7.6	0.3	1.7
X	7.9	41.4	10.3	12	15	24.5	18.5
XI	7.7	106	32.3	10	83.9	61.1	50.1
XII	8	25.4	28.8	71	20	24.7	29.6
Yearly	23.59	28.07	27.02	31.10	30.33	26.19	28.6

During the research period, the change in the water level in the reservoir bowl depends on several factors. If water is released from the reservoir based on the demand for water alone, it is a process that depends on the amount of irrigation in the area. The water reservoir is estimated depending on the water collection volume and the precipitation amount. Therefore, it is possible to estimate the amount of water collected in the reservoir in which years (1) according to the amount of annual rainfall and how much water is collected in the reservoir during the vegetation period, depending on the water demand of the population.

2.2 Methodology

One of the problems of most of the reservoirs currently in operation is the erosion of coastal soils and the study of the processes taking place in the parts of the coast buried in water. Immediate identification of emerging coastal areas provides an opportunity to develop measures to prevent their erosion.

The dependence of coastal erosion in water reservoirs on coastal soil types and composition was analyzed.

ArcMap 10.8 software was widely used to clearly show the location of the reservoir and the place where the experiment was conducted.

About 80 local and foreign articles on coastal erosion in reservoirs were analyzed. Among them, 15 articles on the properties of coastal soils and 65 articles on the factors influencing coastal erosion processes were analyzed.

In this article, the change in the water level of the reservoir and the type of coastal soil were considered the main factors.

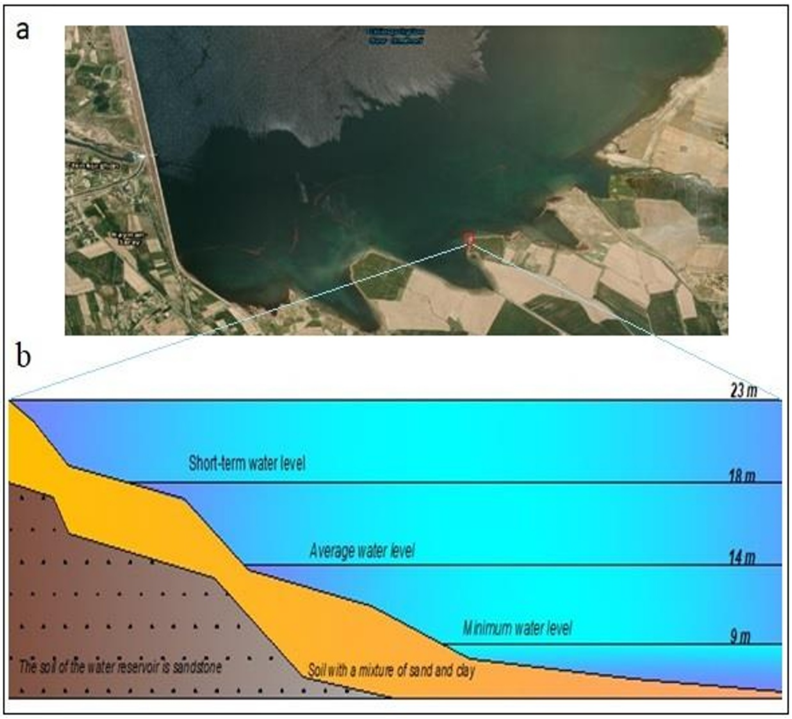

Fig. 2. Place of research on shore of reservoir a) Place of research b) Changes in water level

2.3 Formulas

To evaluate the stability of the coastal soil, first of all, it is necessary to determine the diameter of the coastal soil in the formula (1) (Niewczas and Witkowska-Walczak, 2005). took into account [15,18]. (a) Average soil diameter (d_o)

$$d_o = \left[\frac{\sum_{i=1}^{n} W_i \cdot \ln X_i}{\sum_{i=1}^{n} W_i}\right] \tag{1}$$

where Xi is the average diameter of the soil fraction, and Wi is the soil mass fraction. Using the coastal soil stability level (d_o), it is necessary to determine the rate of decomposition of coastal soil from formula (2) [12,17,18]. (b) Soil stability index (b)

$$\beta(\%) = \left(\frac{WDS - WP25}{WDS}\right) \cdot 100 \tag{2}$$

where WDS is the total weight of the dry sample used, and WP25 is the weight of the soil size that passed the sieve diameter d <0.25 mm.

Degradation of soils (b), as these soils oscillate under a constant wet state, the degradation rate over time through g (Al-Kaisi et al., 2014; Ouattara et al., 2008); expressed by formula (3) as follows [16,20].

$$\gamma(\%) = yt^{x} \tag{3}$$

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Here y is the intercept indicating the initial stability, x is the slope indicating the decay rate, and t is time.

The degree of erosion of the coastal soil k is calculated by the following formula (4) [16, 17, 21].

$$k = \left\{0.2 + 0.3exp\left[-0.0256 \cdot Q \cdot \frac{1-M}{100}\right]\right\} \cdot \left(\frac{M}{G+M}\right)^{0.3}$$

$$\left(1.0 - \frac{0.25C}{C+\exp(3.72-2.95C)}\right) \cdot \left(1.0 - \frac{0.7SN1}{SN1+\exp(-5.51+22.9SN1)}\right) \quad (4)$$

where k is the approximate erosion of the soil, Q, M, and G are the content of sand, fine soil, and clay (%), C is the amount of organic carbon in the soil (%), and SN1 is equal to 1 - Q/100. G=Clay, Q= Sand, M= Soft.

3 Results

Table 1 shows the distribution of the physico-chemical properties of the soil on the shore along the heights in the reservoir bowl. The results presented showed that lower altitudes showed lower and higher and control altitudes showed higher. (Table 2). Observed nitrogen (N) and potassium (K) concentrations were higher at higher elevations and lower at lower elevations with N content of 0.13%, 0.17%, 0.13%, and 0.11% for 15m, 17m, and 19m. was. and 0.11%, 0.10%, and 0.09% were recorded for 23 m, 9 m, 11 m, and 13 m, respectively. K was found to range from 20098.87 (mg/kg) at lower altitudes to 18172.13 (mg/kg) and at higher altitudes from 17959.51 (mg/kg) to 24779.12 (mg/kg). In general, the mechanical composition of coastal soil showed an intensive part of sand particles; the content of fine soil is from 58.02% to 87.54%, the content of sandy soil is from 2.35% to 39.64%, the content of clay is We can see from the figure (3) that it ranges from 2.26% to 9.99%. Table (2) shows that the coastal erosion (k) level varies significantly depending on the composition of coastal soils in the range of 9 m to 23 m of the reservoir shore level.

Table 2. General ground characteristics of coast for selected heights.

Height (m)	Soil density (g/sm^3)	Sand soil (%)	Soft soil (%)	Clay soil (%)	N (%)	C (%)	k
9	1.34	2.35	87.54	9.99	0.11	0.13	0.21577
11	1.30	4.75	87.01	8.25	0.10	0.12	0.21799
13	1.41	6.22	87.6	6.18	0.09	0.12	0.21992
15	1.47	8.78	86.01	5.22	0.13	0.12	0.22109
17	1.45	27.6	68.01	4.39	0.17	0.11	0.22214
19	1.40	30.5	66.02	3.94	0.13	0.12	0.22257
22	1.31	35.39	60.58	3.62	0.11	0.12	0.22266
23	1.32	39.64	58.02	2.26	0.11	0.11	0.2241

Using Table (2), we have described the distribution of coastal soils at this (38°55'47.2"N, 66°23'54.2"E) latitude in the area of the reservoir bowl by the depth of the reservoir.

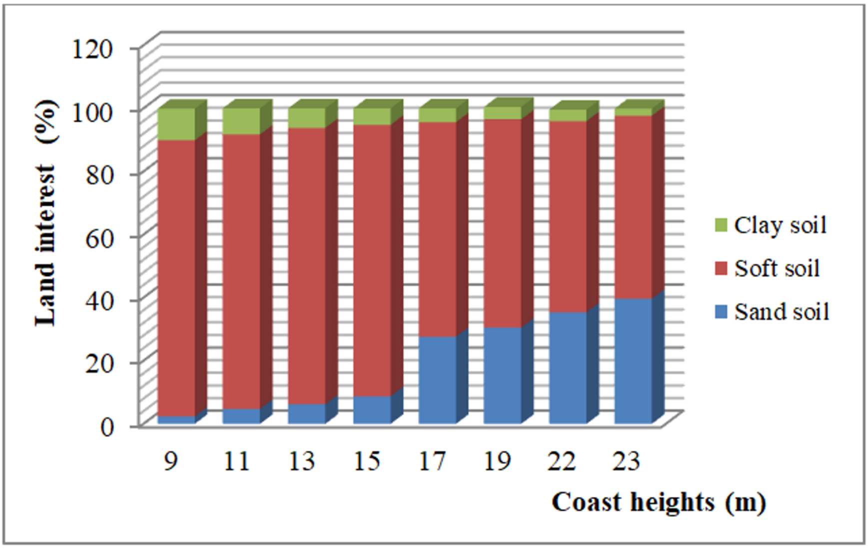

Fig. 3. Percentage of coastal soils at the specified heights of the reservoir bowl (%)

We can see from Figure 3 that the degree of erosion of the coastal soil (**k**) depends on the water level ($\Delta H/H_{max}$) at different levels of the reservoir bowl. We found out that the decay rate k=0.2241 at the height of the water level h=23 m at the normal wet level and that this indicator decreases slightly as the level decreases; for example, the decay rate k=0.21577 when the lower level is h=9 m high. So we can see that in water reservoirs, it is necessary to pay great attention to the filling and emptying water.

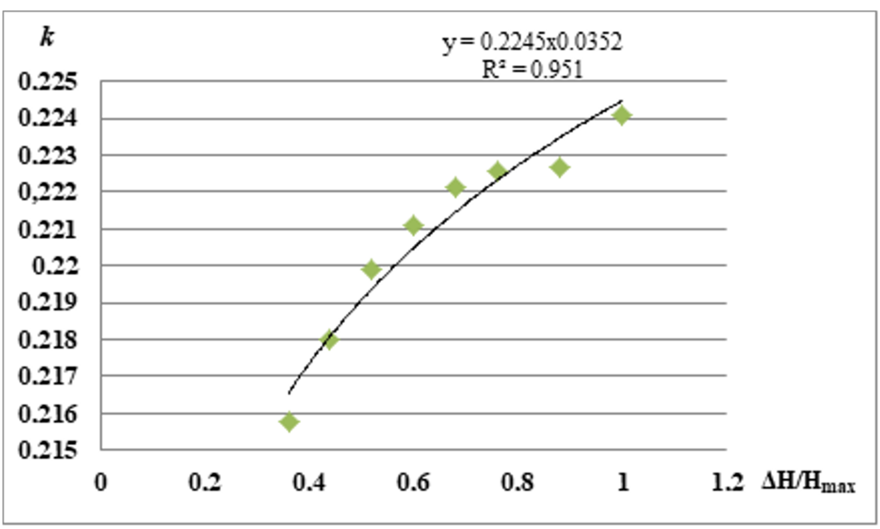

Fig. 4. Coastal erosion in reservoir basin depends on reservoir levels

4 Conclusions

In the zone of 14-meter change of the reservoir's water level, we can see the erosion of the coastal soils of the reservoir. We can determine the degree of erosion by concluding that the degree of decay of coastal soils decreases when the water level decreases and increases when the water level rises, and the correlation $R^2 = 0.9382$.

It was found that erosion of the shores depends on the type of soil on the shore. It was determined that the decay rate for loamy soil is $R^2 = 0.8887$, $R^2 = 0.9281$ for loose soil, and $R^2 = 0.9009$ for clayey soil.

Generally, we can see that the degree of degradation and stability of coastal soils depends on the soil type.

In this study, we can see the process of water level change in the reservoir bowl, its influence on coastal soil kinetics, and its relation to soil erosion.

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