Assessment shoreline formation of reservoirs

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Annotation. Article analysis the factors influencing the reduction of reservoir useful volume, including the formation of shores, and proposes and method of their quantitative calculation. The research was provided in the South Surkhandarya reservoir. During the exploitation of the reservoir, were assessed the morphometric index of the basin and changes in bank due to various influences. In article presented mathematical, statistical calculations of changes in erosion conditions due to displacement of the left banks of the South Surkhandarya Reservoir and changes in pressure in the strata and water saturation of the coastal layers. The proposed method of assessment and calculation will allow develop measures to improve the operation of reservoirs based on the determination of morphometric parameters and to prevent the formation of shores.

Keywords: Reservoir, exploitation, shoreline formation, landslides, landslides, mobile mass, useful volume, waterlogged area, coastline.

Introduction and analysis of the current condition of the problem. In the world, one of the most important issues of integrated use of available water resources is regulation of river flow through reservoirs. In this regard, special attention is paid to the reliable and efficient use of existing reservoirs, the provision of water to consumers during the growing season, the development of improved methods for calculating the amount of sediment at the bottom of reservoirs, determining the lost of useful volume during exploitation and shoreline formation due to various impacts.

Due to the fact that the existing reservoirs in the country are filled with mud and sediments from year to year and the useful volume is reduced due to the sedimentation in the flow of rivers which comes to reservoir, erosion of banks, landslides and landmovement. As a result, becomes to some problems with the planned use of reservoirs, ie inconveniences in collecting and delivering the required water, and mitigation of water demand [5, 12, 13]. In this regard, the formation of the banks of reservoirs and their quantitative assessment are relevant in the reliable and efficient use of most reservoirs currently in operation.

Data and methods. Researches were provided in the South Surkhandarya Reservoir and analyzed coastal changes due to various impacts during the exploitation of the reservoir. The total length of the reservoir shoreline is 60 km, of which about 4 km are cliffs. 50% of the coastline is formed from abrasive shores. Scientific research about formation of the reservoir shores found that in the first phase of reservoir filling, the one-meter-long shoreline wash ranged from 100 m3 to 225 m3, while in the second phase it ranged from 50 m3 to 450 m3. Fifteen years later, this size was 5–40 m3. Although coastal washing was accelerated during the initial period of operation, it can be seen that this figure has declined sharply in recent years (Figure 1).

Figure 1. Formation of the shore of the South Surkhandarya Reservoir.

The flow degree generated by transit water discharge in the South Surkhandarya reservoirs does not have a significant impact on coastal erosion. However, the movement of water due to wind-induced ripples creates such a flow velocity that the result is a strong washout in the coastal and adjacent submarine zones, leading to the displacement of large amounts of ground masses [1, 2, 7, 8,].

The chemical and biological processes that happens in the reservoir area, the ripples, the currents in the river flow gradually change the natural relief of the shores and their appearance in the project. Over time, the reservoir becomes shallower as a result of filling with sediments and the coastal areas are covered with vegetation (Fig. 2).

Figure 2. Change of reservoir water surface area.

From these observational data, we can see that the full volume of the reservoir decreases at the normal stagnant water level (NSWL) and the water surface area expands.

In the below were given mathematical statistical calculations of changes in erosion due to the displacement of the left bank of the South Surkhandarya

Reservoir and changes in pressure in the strata, as well as water saturation of the coastal layers and a decrease in pressure there.

Results of coastal deformation brings to formation of a mobile mass, and those mass effects to reduce volume of reservoir and brings to rise of the reservoir water. [1, 2, 7, 11].

The volume weight of the moving mass is expressed as follows:

$$m = \rho W \tag{1}$$

The volume weight of the avalanche mass is written in terms of the coordinates of the displacement limit and is given by the following multiple integral:

$$W = \int_a^b dx \int_c^d \left[Y_1(x,y) - Y_2(x,y) \right] dy \,. \tag{2}$$

Knowing the coordinates of the surfaces bounding the avalanche mass, found the curves of the boundary surface passing through the top and bottom, right and left. These curves were found with using Newton or Lagrange and others approximate formulas (Figure 3).

In the process under consideration, used Lagrange's interpolation formula. The same can be said for Newton's formula, one can use it too. To do this, need to write Newton's interpolation formula for the curves delimiting the avalanche mass and for C_1B_1A and CBA:

$$Y(x) = y_0 + (x - x_0)\frac{y_1 - y_0}{x_1 - x_0} + (x - x_0)(x - x_1)\frac{\frac{y_2 - y_1}{x_2 - x_1} - \frac{y_1 - y_0}{x_1 - x_0}}{(x_2 - x_0)} + \ldots,$$

$$Y(x) = 0 + (x - 0)\frac{y_1 - y_0}{x_1 - x_0} + (x - x_0)(x - x_1)\frac{\frac{y_2 - y_1}{x_2 - x_1} - \frac{y_1 - y_0}{x_1 - x_0}}{(x_2 - x_0)} + \ldots$$

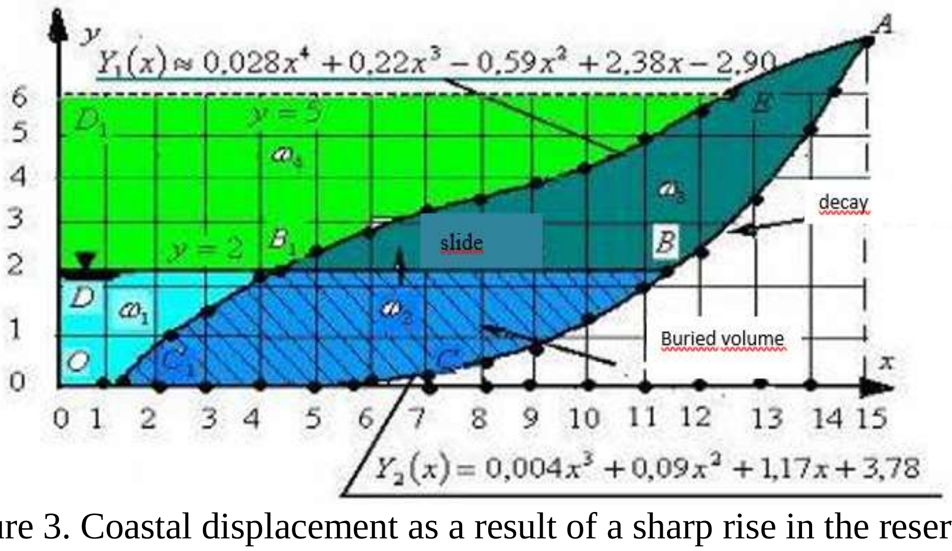

Figure 3. Coastal displacement as a result of a sharp rise in the reservoir level

The Lagrange interpolation formula is selected by selecting the curves C_1B_1A and CBA abscissa delimiting the avalanche mass as shown in Figure 3:

$$x_0 = 1{,}2, x_1 = 3, x_2 = 6, x_3 = 9, x_4 = 12, x_5 = 15.$$

We get the corresponding ordinates from the ordinates in Figure 3:

$$y_0 = 0, y_1 = 1{,}5, y_2 = 2{,}8, y_3 = 4, y_4 = 5{,}5, y_5 = 7.$$

Lagrange's interpolation formula is:

$$Y(x) = \frac{(x-x_0)(x-x_2)(x-x_3).(x-x_4)}{(x_1-x_0)(x_1-x_2)(x_1-x_3)(x_1-x_4)} y_1 + \frac{(x-x_0)(x-x_1)(x-x_3)(x-x_4)}{(x_2-x_0)(x_2-x_1)(x_2-x_3)(x_2-x_4)} y_2 + \frac{(x-x_0)(x-x_1)(x-x_2)(x-x_4)}{(x_3-x_0)(x_3-x_1)(x_3-x_2)(x_3-x_4)} y_3 + \frac{(x-x_0)(x-x_1)(x-x_2)(x-x_4)}{(x_4-x_0)(x_4-x_1)(x_4-x_2)(x_4-x_3)} y_4 + \qquad (3)$$

We put the given coordinates in Lagrange's interpolation formula:

$$Y_1(x) = \frac{(x-1{,}2)(x-6)(x-9).(x-12)}{(1{,}8)(-3)(-6)(-9)} 1{,}5 + \frac{(x-1{,}2)(x-3)(x-9)(x-12)}{(4{,}8)(3)(-3)(-6)} 2{,}8 + \frac{(x-1{,}2)(x-3)(x-6)(x-12)}{(7{,}8)(6)(3)(-3)} 4 + \frac{(x-1{,}2)(x-3)(x-6)(x-12)}{10{,}8(9)(6)(3)} 5{,}5 \approx$$

$$Y_1(x) = \frac{(x-1{,}2)(x-6)(x-9).(x-12)}{197{,}6} + \frac{(x-1{,}2)(x-3)(x-9)(x-12)}{92{,}5} + \frac{(x-1{,}2)(x-3)(x-6)(x-12)}{105{,}3} + \frac{(x-1{,}2)(x-3)(x-6)(x-12)}{318{,}1}.$$

Performing some simplifications, found the equation of the C_1B_1A line which delimiting the avalanche from above:

$$Y_1(x) \approx -0{,}005x^4 + 0{,}14x^3 - 1{,}35x^2 + 4{,}70x - 4{,}70 + +0{,}010x^4 - 0{,}27x^3 + 2{,}16x^2 - 5{,}72x + 4{,}20 + -0{,}010x^4 + 0{,}21x^3 - 1{,}44x^2 + 3{,}49x - 2{,}46 + 0{,}003x^4 - 0{,}06x^3 + 0{,}04x^2 - 0{,}09x + 0{,}06 \approx \approx 0{,}028x^4 + 0{,}22x^3 - 0{,}59x^2 + 2{,}38x - 2{,}90.$$

the equation of the C_1B_1A line looked like this:

$$Y_1(x) \approx 0{,}028x^4 + 0{,}22x^3 - 0{,}59x^2 + 2{,}38x - 2{,}90. \qquad (4)$$

With the same way were found the equation of the CBA curve bounding the avalanche section from the bottom. To do this, given the appropriate coordinates**:**

$$x_0 = 6, x_1 = 9, x_2 = 12, x_3 = 15.$$

$$y_0 = 0, y_1 = 0{,}8, y_2 = 2{,}5, y_3 = 7,$$

We put the given coordinates in Lagrange's interpolation formula:

$$Y_2(x) = \frac{(x-6)(x-12)(x-15)}{54} 0{,}8 - \frac{(x-6)(x-9)(x-15)}{54} 2{,}5 + \frac{(x-6)(x-9)(x-12)}{162} 7 \approx$$

$$Y_2(x) = 0{,}01\frac{(x-6)(x-12)(x-15)}{1} - \frac{(x-6)(x-9)(x-15)}{1} 0{,}05 + \frac{(x-6)(x-9)(x-12)}{1} 0{,}04 \approx$$

$$Y_2(x) = 0{,}0141x^3 - 0{,}33x^2 + 3{,}42x - 10{,}8 - 0{,}05x^3 + 1{,}5x^2 - 13{,}95x + 40{,}5 + + 0{,}04x^3 - 1{,}08x^2 + 9{,}36x - 25{,}92 = 0{,}004x^3 + 0{,}09x^2 + 1{,}17x + 3{,}78$$

The equation of the CBA curve looks like this:

$$Y_2(x) = 0{,}004x^3 + 0{,}09x^2 + 1{,}17x + 3{,}78. \qquad (5)$$

Using the coordinates of the avalanche in motion and the equations of the ODB_1C_1 curves found by the Lagrange formula and the equations of the C_1B_1A and CBA curves, were written as:

$$\omega_1 = \int_0^{1,2} dx \int_0^2 dy + \int_{1,2}^{4,2} dx \int_0^{Y_1(x)} dy = 2,4 + \int_{1,2}^{4,2} Y_1(x)dx = 2,4 + \int_{1,2}^{4,2} \left(0,028x^4 + 0,22x^3 - 0,59x^2 + 2,38x - 2,9\right)dx$$

$$\omega_1 = 2,4 + 20,44 = 22,84 кв.б \quad (6)$$

Avalanche cross-sectional area of C_1CBB_1 were found with using the coordinates in Figure 3 and the equation of the C_1B_1A and CBA curves which found by the Lagrange formula:

$$\omega_2 = \int_{1,2}^{4,2} dx \int_0^{Y_1(x)} dy + \int_{4,2}^{11,5} dx \int_{Y_2(x)}^{y=2} dy = \int_{1,2}^{4,2} Y_1(x)dx + \int_{4,2}^{11,5} \left(2 - Y_2(x)\right)dx = 55,11 кв.б \quad (7)$$

By the following integral were found the moving cutten surface B_1BA (Fig. 3).

$$\omega_3 = \int_{4,2}^{11,5} dx \int_2^{Y_1(x)} dy + \int_{11,5}^{15} dx \int_{Y_2(x)}^{Y_1(x)} dy = 71,5 кв.б \,. \quad (8)$$

By the following integral were found moving cutting surface DD_1EB_1 (Fig. 3):

$$\omega_4 = \int_0^{4,2} dx \int_2^5 dy + \int_{4,2}^{11} dx \int_{Y_1(x)}^5 dy = 117,5 кв.б. \quad (9)$$

Conclusion. As a result of the research, it was found that on the left bank of the South Surkhandarya reservoir there are cases of landslides, migration of soil, and on the right bank there is a process of shallowing due to the accumulation of debris.

One of the problems of most reservoirs currently in operation is that the reservoir can be identified using the proposed calculation method for small landslides, soil erosion and degradation, subsidence, washing, and shoreline displacement on water-buried coastal slopes. Immediate detection of emerging coastal areas provides an opportunity to develop measures to prevent them.

If the reservoirs will project and explotate on the basis of the above measures, they will be prevented from malfunctions and accidents, the operation of the reservoir will be further improved, and the efficient use of water from the reservoir will be achieved.

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