# Investigations on determination of changes in inactive volume of water reservoirs (case study of South Surkhan water reservoir)

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**Abstract.** The article develops the change of the reservoir's useable volume under the effect of turbidity-sediments, considering the turbid discharges' hydrological regime into the reservoir, and proposes a computation technique. Field research was conducted in the South Surkhan reservoir. Based on the data collected from the field research, an electronic map of the reservoir bowl was made, and morphometric indicators were evaluated, considering the formation of muddy sediments in the reservoir. When the standard water level of the water reservoir is 415 meters, the designed water surface area is 65 km$^2$, and the full volume is 800 mln. m$^3$, and according to the results of field research, the full volume of the water reservoir at the level of the normal moisture level is 491.2 mln. m$^3$, the water surface was 72.45 km$^2$. It showed that the full volume of the reservoir was reduced by 38.6 percent compared to the design volume during the operation period, and the water surface area increased by 7.45 km$^2$. The research results allow to determine the change in the useful volume of the reservoir under the influence of turbidity and sediments, to determine the morphometric indicators, and to use the water reserve effectively.

## 1 Introduction

Adjusting the flow of rivers with the help of reservoirs is regarded as one of the most critical concerns of integrated water resource utilization worldwide. Special attention is paid to the development of improved methods of reliable and efficient use of existing water reservoirs, scientific justification of the most optimal operating modes, providing consumers with water at the same time during the growing season and increasing the useful volume lost during the operation period [1, 5, 7].

Long-term effective operation of water reservoirs and calculation accuracy of water balance components depends on the number of turbid sediments formed in their bowl. Determining the change in the useful volume of the exploited water reservoir and the formation and size of the turbid liquid that has settled at the bottom of the water reservoir is one of the important problems of today. Today, in our republic, comprehensive scientific research on the creation of new methods of existing hydrological calculations that provide

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*Corresponding author: safarmansurov3@gmail.com opportunities to build water reservoirs, increase the efficiency and service life of structures and ensure their reliable operation, implement effective filling and emptying, identify and improve the factors affecting the effective use of water resources it is important to carry out [1, 3, 6]. The main purpose of this study is to evaluate the change in the useful volume of the Southern Surkhan reservoir under the influence of silt-sediments based on field observations using modern measurement tools to determine the morphometric indicators of the characteristic water levels of the reservoir, and to improve the methods of determining the change in the useful volume of the reservoirs, taking into account the formation of silt-sediments.

The study was carried out on the example of the South Surkhan Reservoir, which is actually functioning. The reservoir is located in the Surkhandarya region and serves to adjust the flow of the Surkhandarya River seasonally for irrigation. When the reservoir was established, it was planned to provide water to 122 thousand hectares of newly irrigated lands. Currently, the reservoir supplies water to more than 154 thousand hectares of irrigated land in Kumkurgan, Zharkurgan, Kyzyriq, Boysun, Sherabad, Angor, Muzrobod, and Termez districts of the Surkhandarya region (Fig. 1).

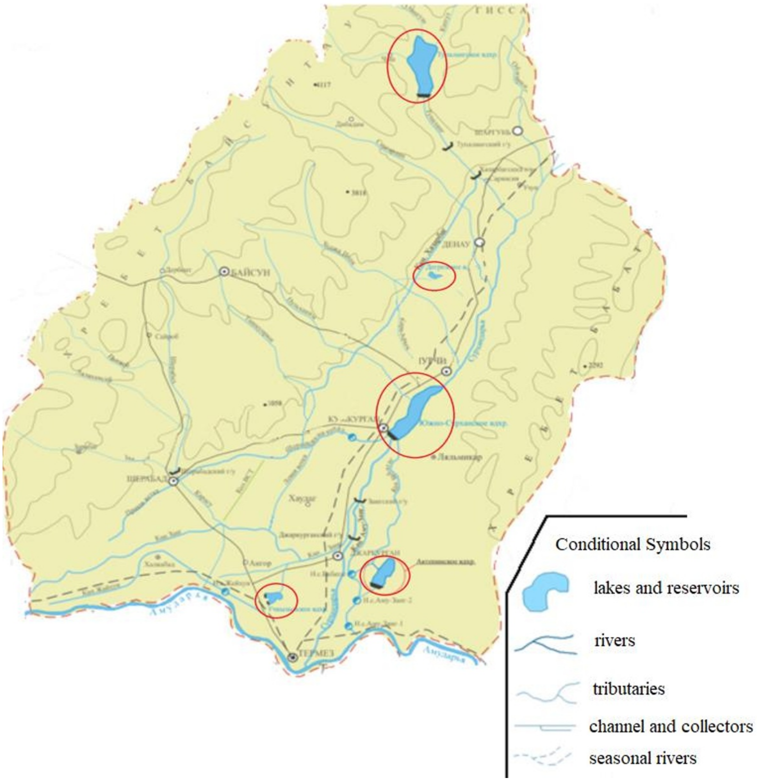

**Fig. 1.** Location scheme of water bodies in Surkhandarya region

Since the Southern Surkhan Reservoir is in the bed of the Surkhandarya River, it is observed that different amounts of discharge from the river come to the reservoir throughout the year. Considering the occurrence of floods in the Surkhandarya basin and its tributaries in April–June, the main turbidity discharges into the reservoir correspond to these months. The amount of suspended discharge begins to increase in March, reaches a maximum value in May, and then decreases until August. In September, the amount of suspended discharge reaches the minimum value. The amount of suspended discharge in April-May is 67.6% of the annual average(Fig. 2).

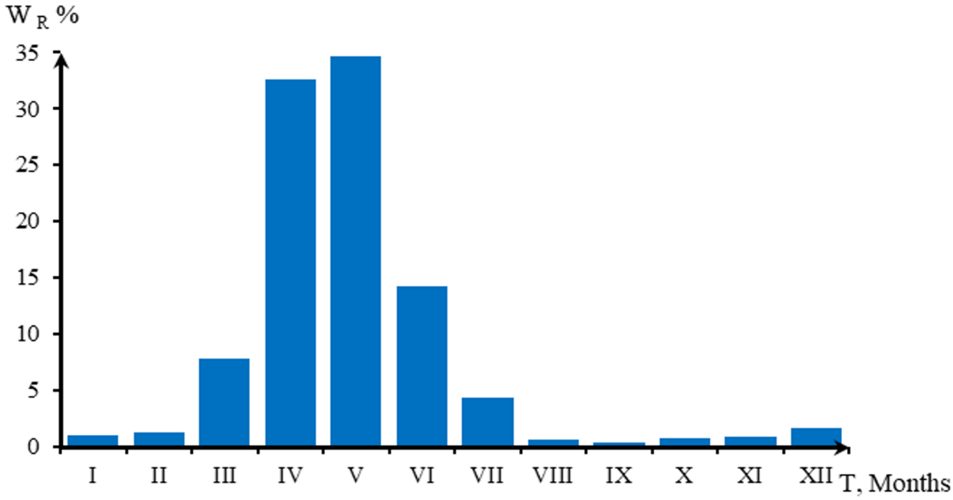

**Fig. 2.** Annual distribution of average multi-year flows in Surkhandarya River

## 2 Solution method

When determining the fractional composition and types of turbid effluents that have settled to the bottom of the reservoir, samples were taken from different points of the reservoir bowl, and the fractional composition and soil type of the obtained samples were determined in laboratory conditions (Fig. 3) [4, 6].

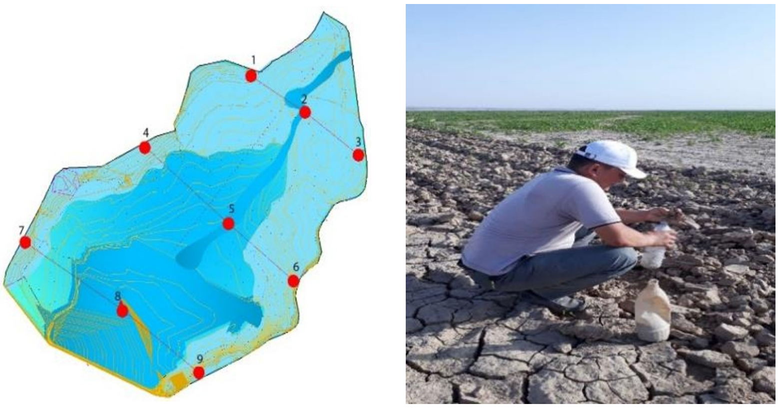

**Fig. 3.** Location of selected reservoirs in bowl of South Surkhan reservoir

According to the analysis of the studied samples, the mechanical composition of the muddy sediments deposited in the reservoir basin has a different composition in the area from the river bed to the dam and mainly consists of medium and heavy sand. The amount of total physical silt is more concentrated at the end of the river near the dam. These changes can also be seen in the diagrams made for each of the section (Figures 4, 5).

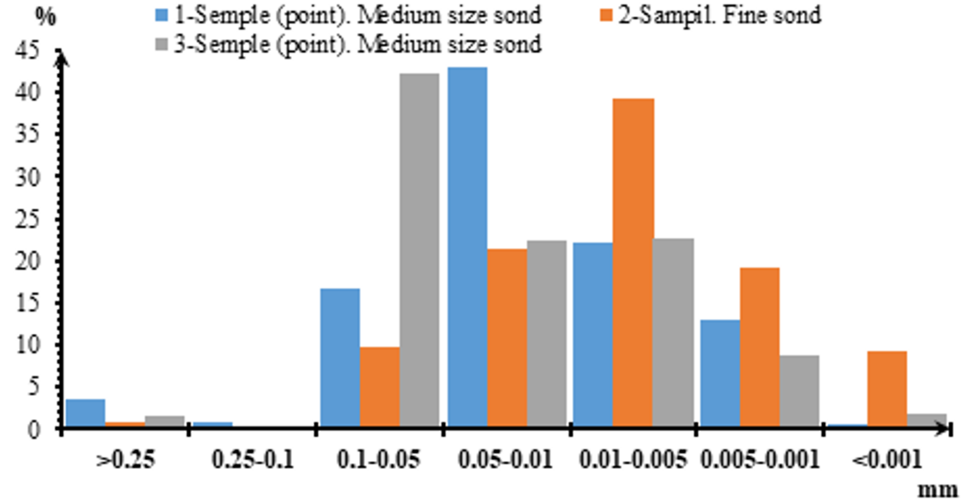

**Fig. 4.** Mechanical composition of turbid fluids that have settled to bottom of water reservoir on first layer.

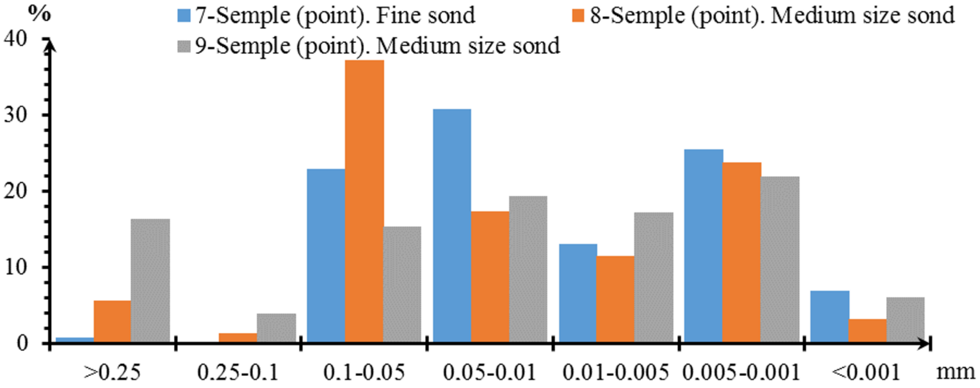

**Fig. 5.** Mechanical composition of turbid fluids that have settled to bottom of water reservoir according to third layer.

It can also be seen from the diagrams made based on the analytical data of the samples taken from the sediments that sank to the bottom of the reservoir that the amount of large dust particles (0.05-0.01mm) is the largest in the composition of the sediments near the dam of the reservoir. In the middle part of the river, it can be seen that the amount of small dust and dirt particles has accumulated. The slope of the bottom of the reservoir bowl and the movement of the water flow cause the distribution of the elements of the mechanical composition of the muddy sediments that have settled to the bottom of the reservoir in this way. The amount of microaggregates is of medium and heavy mechanical composition and mainly consists of skeletal particles (0.25 mm). Fine dust and dirt particles have the property of attaching microaggregates. As a result, the amount of large particles in turbid sediments increases, mainly particles with a size of 0.25-0.05 mm. The main mass of microaggregates consists of 0.1-0.05 and 0.05-0.01 mm particles, which reduce the density of muddy sediments and increase sediment porosity [6, 7].

The following field studies were carried out to determine the change in the useful volume of the reservoir. Initially, the standard water level mark of the reservoir (∇ 415 m) was determined by reference to the dam, and the iBase GNSS data receiving equipment was placed at the standard water level, ∇ 415 m elevation point at the reservoir dam. The value of the absolute height of the reservoir's shoreline at ∇ 415 m was determined every 30 m along the coast (Fig. 6) [1, 4, 6, 7].

**Fig. 6.** State of connecting AUPNT equipment receiving information to satellite.

To determine the change of the water surface area and water volume, determination of the absolute height points in each meter in the intervals from the normal moisture water level mark ∇ 415 m to the minimum water level mark ∇ 392 m i73 - iBase GNSS equipment, which determines the points of absolute height in one meter and receives the information, was transferred to the database via satellite. During field research, the water level in the reservoir was ∇ 401 m, and the water volume of the reservoir was 35.3 million. m$^3$, and the water surface area was 7.10 km$^2$. Using the sonar device (LUCKY FF718LiC) of the water-covered part of the reservoir, the depths of each selected wall were determined, and daily cross-sectional drawings were made (Fig. 7).

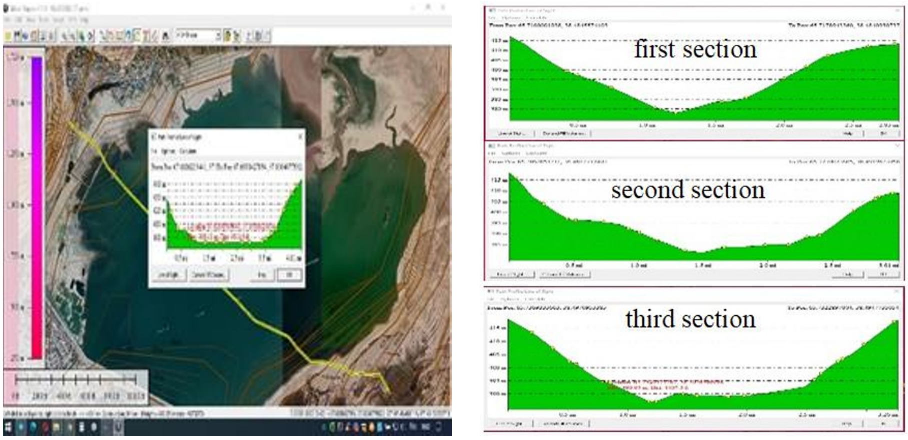

**Fig. 7.** Daily cross-sections of water reservoir on selected streams.

Within the framework of the research, determining the change of the useful volume of the South Surkhan reservoir under the influence of turbidity-sediments was carried out based on field observations using modern measurement tools, and the morphometric indicators of the reservoir were clarified. An electronic map of the South Surkhan reservoir basin was created based on the use of modern geographic information system technologies in the assessment of hydrological and hydraulic processes in the reservoir (Fig. 8).

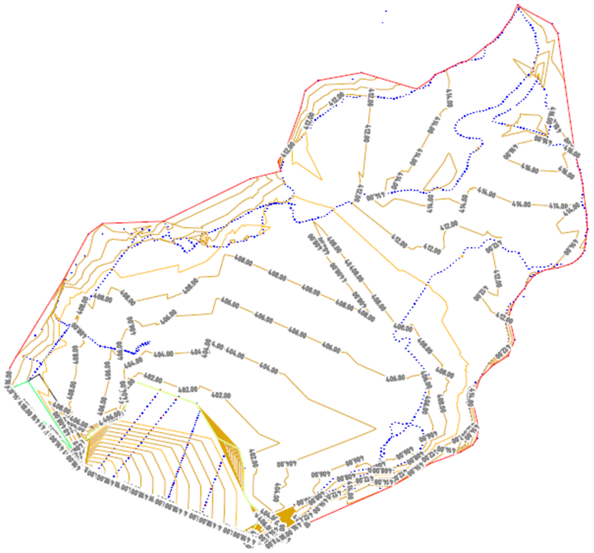

**Fig. 8.** Electronic map of South Surkhan reservoir basin

Special attention is paid to the influence of turbidity processes on the change in the useful volume of reservoirs. When determining the amount of turbidity, studies were conducted to consider the water reservoir's main parameters: the water volume and the change in the water level. In this direction, I.A. Shneer, A.V. Karaushev, V.S. Lapshenkov, K.Sh. Latipov, V.A. Skrylnikov, A.Arifzhanov, F.A. Gapparov, and other scientists developed the research from the beginning of the exploitation of reservoirs to the financial year. The decrease in volume over time can be determined by the following relationship [3, 5, 6, 7]:

$$\Delta V = [(V_{max} - V_{min}) - (\sum \Pi - \sum \mathrm{P})] \tag{1}$$

where: $V_{max}$ and $V_{max}$ are reservoir volumes obtained from the design curve corresponding to the maximum and minimum water levels at the end of the month: $\sum \Pi$ *and* $\sum \mathrm{P}$) are the sum of water balance constituents of the water reservoir for the months of the accounting year from the month following the month with the maximum water level to the month with the minimum water level.

The reduction of the water volume calculated by the difference between the maximum and minimum levels can be attributed to the reduction of the useful volume of the reservoir by calculating the difference between the determined standard damped level (SDL) and the dead water level (DWL):

$$\Delta V_{effective} = \Delta \mathrm{V} \, \frac{\nabla SDL - \nabla DWL}{H_{max} - H_{min}} \tag{2}$$

where: ∇SDL is the standard damped level of the water reservoir; ∇DWL is dead water level of the water reservoir; $H_{max}$ is maximum water level (in the accounting year); $H_{min}$ is the minimum water level (in the accounting year). To determine the decrease in the full volume of the reservoir, the following relationship is used [6, 7]:

$$\Delta V_{full} = \Delta V_{effective}\frac{\Delta V_{FWL}}{\Delta V_{FWL}-\Delta V_{AWL}} = \Delta V_{effective}\frac{1}{1-\frac{\Delta V_{AWL}}{\Delta V_{FWL}}} \quad (3)$$

The following expression was obtained by putting (2, 3) into (1) to change the amount of turbidity:

$$\frac{V_i}{V_{FWL}} = K\left(\frac{H_i}{H_{FWL}}\right)^{n_1} \quad (4)$$

where: $V_i$ and $V_{FWL}$ are the volumes of sediments accumulated from the bottom of the reservoirs to the depth H and to the standard wetted level;
k and $n_1$ are coefficients determined based on research in field conditions.

As a result of the analysis of the data collected from the conducted field research based on mathematical statistics methods (correlation coefficient 0.92), the following expression was obtained, which expresses the dependence of the relative turbidity volume in the reservoir on its relative depth (Fig. 9):

$$\frac{\Delta V_N}{\Delta V_{MWL}} = 0.92\left(\frac{H}{H_{MWL}}\right)^{1.23} \quad (5)$$

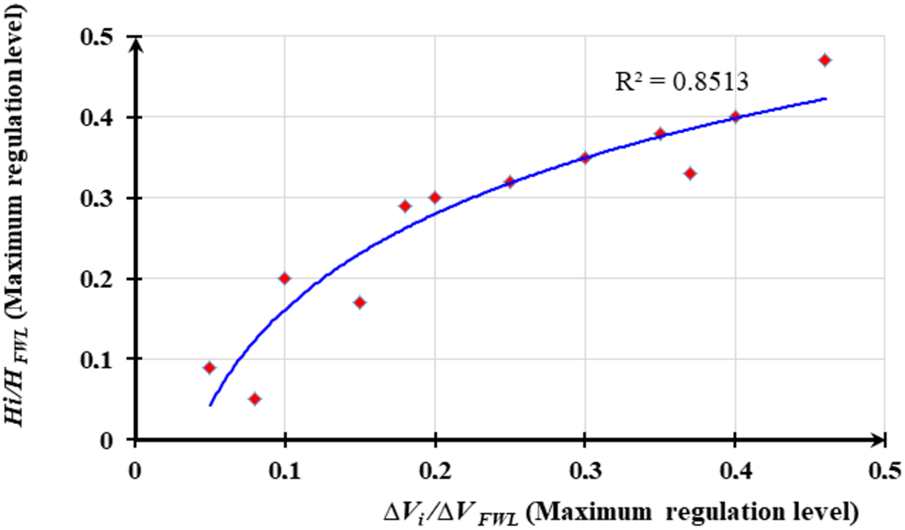

**Fig. 9.** Reservoir relative turbidity volume versus relative depth graph.

A comparison of the calculated magnitude of the decrease in the useful volume of South Surkhan reservoirs and the data obtained as a result of field observations conducted in the reservoir basin shows that the calculation method gives reliable results, that is, the difference in the decrease of useful volume is less than (+3 -4%), that is, South Surkhan water and in the warehouse, this indicator is 0.97 (Table 1).

**Table 1.** Comparison of data obtained from observations of decrease in full volume of water reservoirs with calculation results

| **№** | **Years of monitoring** | **1975** | **2002** | **2021** |
|---|---|---|---|---|
| 1 | Amount of turbid sediments determined based on observations, mln.$m^3$ (FWL). | 139 | 297 | 310.3 |
| 2 | Calculated amount of turbid sediments, mln.$m^3$ (FWL). | 136 | 294.5 | 308.2 |
| 3 | Difference, % | 0.97 | 0.97 | 0.96 |

The volume of the reservoir for any year can be calculated by the following formula depending on the water level in it:

$$V = V_{clay} - \Delta V_{MWL} \left(\frac{\Delta V_N}{\Delta V_{MWL}}\right) \tag{6}$$

where: V clay is the volume of the reservoir determined by the design curve; $\frac{\Delta V_N}{\Delta V_{MWL}}$ is value taken from Figure 7.

Based on the conducted studies, bathymetric graphs were developed with the clarification of morphometric indicators of the South Surkhan reservoir (Figures 10, 11).

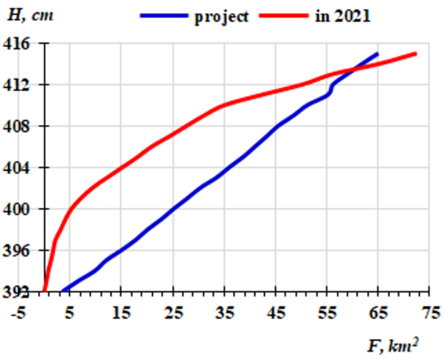

**Fig. 10.** Dependence of reservoir water surface on water level

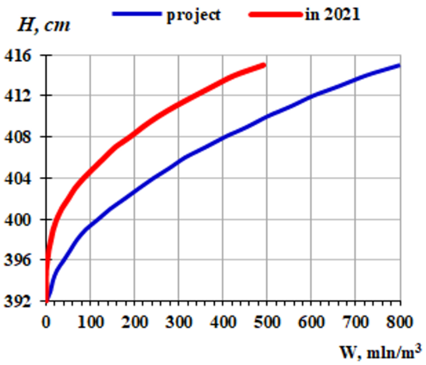

**Fig. 11.** Dependence of reservoir water volume on water level

The total length of the reservoir coastline is 60 km, of which about 4 km are cliffs. Abrasion beaches cover 50% of the coastline. According to the scientific research conducted to study the formation of reservoir shores, in the first stage of filling the reservoir, the washing of one meter-long shore was from 100 $m^3$ to 225 $m^3$, while in the second stage, it was from 50 $m^3$ to 450 $m^3$.

After 15 years, this size was 5-40 $m^3$. It can be shown that during the initial period of exploitation, the coastal washing was carried out intensively, but in the following years, this indicator decreased sharply. The design water surface area is 65 $km^2$, and the design volume is 800 million $m^3$; according to the results of the research conducted in 2021, the water surface area of the water reservoir was 72.45 $km^2$, and the water volume was 491.21 million $m^3$. The water surface area has expanded by 7.45 $km^2$, whereas the amount of water has reduced by 308.8 million $m^3$.

## 3 Conclusions

According to the study's findings, the amount of discharge from the sources that fill the South Surkhan reservoir was investigated, the mechanical composition of the turbid discharge that sank to the reservoir's bottom was investigated, and the discharge's location in the reservoir basin was justified. Determining the change in the useful volume of the reservoir under the influence of turbidity and sediments was carried out based on field observations using modern measurement tools, and the morphometric indicators of the characteristic water levels of the reservoir were determined. An electronic map of the reservoir basin was created based on geoinformation system technologies. This makes it possible to quickly identify and predict hydrological processes occurring in the reservoir. According to the results of the field research conducted in the water reservoir, the surface area of the water at the standard humidity level was 72.45 km$^2$, and the volume of water was 491.21 million m$^3$. As a result, it was determined that the surface area of the water surface increased by 11.5%, and the water volume decreased by 38.6%. Based on the analysis of the results of field research and the water balance model, the method of determining the useful volume of the reservoir, considering the change in the water level, was improved, and bathygraphy was developed. The difference between the calculation results of the recommended method and the data obtained based on natural field research was 3-4%. Applying the research results in water management creates opportunities for improving the hydrological regime of water reservoirs, increasing the accuracy of calculations of water balance elements, and ensuring the safe and efficient use of water reservoirs.

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