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Experimental evaluation of the throughput of the supply channel of pumping stations

Dilshod Bazarov[1], *Bekhzod* Norkulov[1*], *Sukhrob* Umarov[1], *Fotima* Artikbekova[1], *Azizali* Kurbanov[2], and *Mirsoxibjon* Salimbayev[1]

[1]"Tashkent Institute of Irrigation and Agricultural Mechanization Engineers" National Research University, Tashkent, Uzbekistan
[2]Karshi Institute of Irrigation and Agrotechnology "TIIAME" National Research University, Karshi, Uzbekistan

Abstract. The article experimentally studied the dynamics of sediment inflow into the fore chambers of pumping stations, revealed the intensity of silting, which affects the reliability and operation of the pumping station, and developed recommendations for improving its efficiency. The hydraulic parameters of the flow were evaluated by increasing the culvert capacity of the canal bed and ensuring a guaranteed flow of water to the pumping station with a minimum amount of sediment. The purpose of this work is to assess the state of its culvert capacity based on the results of field studies, which represent the water supply from the pumping station of the Karshi main canal.

1 Introduction

The object of the study was the supply channel of the pumping stations in the Karshi Main Canal – KMC, where the above-mentioned problems of operation exist [1-5]. Analysis of the results of a field study, the dynamics of changes in morphometric characteristics in the channel of the supply channels of pumping stations and, based on the results obtained, the development of recommendations for improving the conditions of its operation is defined as the main goal of this work.

According to the purpose and nature of the work, the KMC is divided into two parts: machine and work. The machin canal part has a length of 77.6 km, the estimated flow rate is 210 m3/s, flood flow is 230 m3/s. The total geometric height of water rise to the working part of the main canal is 132 m. The cascade consists of six pumping stations, each of which has six pumping units with a capacity of up to 40 m3/s. The machine part of KMC, except for the inlet part of the channel to the first pumping station, has a concrete lining. Water intake into the Karshi Canal is carried out with the help of a damless water intake without a main regulating structure [6-9].

The hydraulic mode in the machine channels, in comparison with gravity ones, has a number of features related to the mode of operation of the pumping station:

water consumption depends only on the operating mode of the pumping station;

the maximum flow in the channel is equal to the productivity of the pumping station;

* Corresponding author: dr.bazarov@mail.ru

the flow rate in the channel changes discretely by the value of the productivity of one pumping unit;

the slope of the water surface and the carrying capacity of the flow increase with the increase in the number.

On the basis of data from field studies on the inlet section of the Karshi main canal, the morphometric characteristics of the channel of the earthen machine canal were determined, depending on a number of factors. According to design features, geological conditions and purpose, the inlet part of the KMC is divided into three sections: rocky which is l = 1.4 km, 1, 2 settling tanks l = 3.6 km and earthen channel l = 15.8 km.

The fractional composition of the bottom sediments of the earth section of the canal changed insignificantly during the study period. An analysis of the longitudinal profile of the KMC inlet channel showed that the condition of the channel and the sump is in an unsatisfactory position. Under such conditions, water intake from the river into the supply channel during the low water period, under unfavorable conditions for water intake from the river into the supply channel, the operational service of the first pumping station very often connects only two units with a flow rate of up to 70 - 75 m^3 / s [10-14]. Connecting the third unit becomes impossible, since in this case the level difference in the fore-chamber of the first pumping station increases sharply and the cavitation phenomenon begins. In this regard, it is necessary to develop priority measures to ensure the required water flow to the KMC water intake. It should be noted that due to the large volume of silting, the sump of the inlet channel has now ceased to function. Due to the influx of a large amount of bottom sediments and large fractions of suspended sediments into the head of the water intake, the entire section of the supply channel to the first pumping station is filled with sediments, some of which are transported in transit to the concrete section of the KMC [15-20].

2 Methods

The study of the results of field and experimental studies in the channel of the inlet sections of the pumping station of the cascade of the Karshi Main Canal and the assessment of the state of the channel's throughput is the research method of this work.

3 Results and discussions

To solve the above problem, an experimental study is recommended that can give a specific forecast of channel deformations of the supply channel.

To conduct experimental studies on a hydraulic model and obtain reliable results, it was necessary to perform work in the following sequence:

- familiarization with the project of the head structure of the damless water intake in KMC;

- modeling studies, and materials used in substantiating the engineering solution (problem to be solved in the project and substantiation of options for design solutions, cartographic and topographic materials, regime hydrological data, aerospace surveys, geological survey materials, field research materials and the degree of their sufficiency, results processing and analysis of all the collected material as a result of the field studies carried out in the supply channel of the KMC);

- statement of the problem, determination of the place and role in the problem of modeling studies being solved on the channel in combination with other methods (field studies, hydromorphological analysis, hydraulic calculations, laboratory experiment, mathematical modeling);

- selection of the type of physical model (rigid, deformable, undistorted, distorted) and its dimensions;
- substantiation of the modeling technique for the selected type and size of the model, formulation of the conditions for geometric, dynamic and kinematic similarity, selection of the size and density of the experimental material in the case of a deformable model;
- design, construction and equipment of the model;
- calibration (calibration) of the model based on data obtained in kind specifically for this purpose;
- performance of experiments and their interpretation, analysis of experimental data and conversion to nature for natural and design conditions, careful study of design options, including additional options that arise in the course of scientific research work;
-formulation of conclusions and recommendations based on the results of model studies.

Studying the channel processes in the laboratory through experimental studies, one can obtain not only qualitative but also quantitative similarity of nature and model, which is determined by the similarity of the hydraulics of the flow and the shape of the channel, subject to the condition of sediment mobility. Modeling of channel processes and the hydraulic structure of the flow in lowland rivers with respect to geometric similarity has always given quite satisfactory results, which are in good agreement with nature. To ensure the similarity of the occurring phenomena of the model with nature, the researchers modeled the depth on a larger scale compared to the width, i.e. distorted the scale of the model.

In the experimental model, measurements were taken to determine the hydraulic parameters of the sump. The water level, water flow rate, velocity distribution over the sump and other parameters were determined in experimental studies directly related to the accuracy of measuring work and measuring instruments. It has been recognized that adopting a scale of 1:70 with the proposed simulation formula gives effective results for modeling unsteady and steady motions.

The admissibility of scale distortion can be explained by the fact that the ratio of the depth of the flow to its width H / W under the conditions of the Amudarya River for large water flows is much less than for small ones. Consequently, a small stream creates relatively large depths (H/D), as if distorting its vertical scale. This means that the morphometric relationship in the form of $\frac{\sqrt{B}}{H}$can remain constant, but it can change.

Amu Darya sand cannot be modeled on a geometric scale, since the model sediments turn out to be too small (powder) and lose the property of loose bodies. In such cases, a material with a reduction in specific gravity without a reduction in diameter is used as a substitute for sand. Since the sediment diameter cannot be reduced, the actual scale of the model remains distorted. Therefore, when the bottom of the river bank is composed of sand that is not amenable to geometric modeling, regardless of the change in the specific gravity of natural material, it is necessary to distort the vertical scale in order to ensure sand mobility in the model.

Similar processes should be represented by differential equations in analog form to fulfill the similarity laws underlying the construction of models and recalculation of experimental results for a real object. In this case, the uniformity condition must be satisfied, which includes the geometric dimensions of the channel, boundary and initial conditions, and the physical properties of the water flow moving in a real object and in a model.

To ensure that the forces in the real object and the experimental device were the same, the forces were scaled:

$$M_G = \frac{G_H}{G_M} = \frac{(ma)_H}{(ma)_M} = \frac{(\rho WLT^2)_H}{(\rho WLT^2)_M} = \frac{(\rho L^2 V^2)_H}{(\rho L^2 V^2)_M} \quad (1)$$

where $G_н$ and $G_м$ are similar forces in a real object and in a model, respectively; tn and tm are similar masses in the real object and in the model, respectively; an and am are similar accelerations in the real object and in the model, respectively; ρ is the density of the liquid, W is the volume of the liquid; L ~ - characteristic length, it should be noted that in the physical modeling of open watercourses, the depth can be taken as a linear dimension, i.e. L=H. T - time; Indexes "n" and "m", respectively, are the designations of "full-scale" and "model" structures.

According to formula (2) we have:

$$П_к = \frac{\alpha Q^2 B}{g\omega^3} = \frac{\alpha \upsilon^2 \omega^2 B}{g\omega^3} = \frac{\alpha \upsilon^2}{1} \cdot \frac{B}{gBH} = \frac{\alpha \upsilon^2}{1} \cdot \frac{1}{gH} = \frac{2(СКЭ)}{СПЭ} = Fr = \frac{V_н^2}{g_н L_н} = \frac{V_м^2}{g_м L_м} \quad (2)$$

It should be noted that the kinetic parameter, which indicates the state of flow movement and is determined by the ratio of the doubled amount of the kinetic energy of the flow to the potential energy, and the Froude number, which is the ratio of half the kinetic energy to the potential energy characterizing the gravity of the flow, are assumed to be equal when modeling hydraulic processes each other.

Based on the above condition, the similarity of the hydrodynamic and kinematic characteristics of the water flow moving in the model and in the real object is performed by fulfilling the condition of geometric similarity.

In addition, when modeling a hydraulic process based on the results of research

$$Fr_м = Fr_н = idem \quad (3)$$

$$\mathrm{Re}_м = \mathrm{Re}_н = idem \quad (4)$$

Recognizing that the simultaneous fulfillment of conditions is a complex issue,

$$Fr_м = Fr_н = idem \quad (5)$$

$$\mathrm{Re}_м > \mathrm{Re}_н \quad (6)$$

it is substantiated that even if the condition is met, a result sufficiently reliable for practice is obtained.

The experimental setup was built in the interdepartmental educational and scientific laboratory of the Tashkent Institute of Irrigation and Agricultural Mechanization Engineers of the National Research University and consists of a metal tray. It has a slope of 0.0002, a width of 38 cm, a length of 655 cm and is connected to a tank with overall dimensions of 60 cm x 180 cm x 100 cm.

Scientific research was carried out in laboratory conditions. In this case, a rectangular flume (Fig. 1) was observed when the water level was not in the backwater mode and there were no sediments in the water.

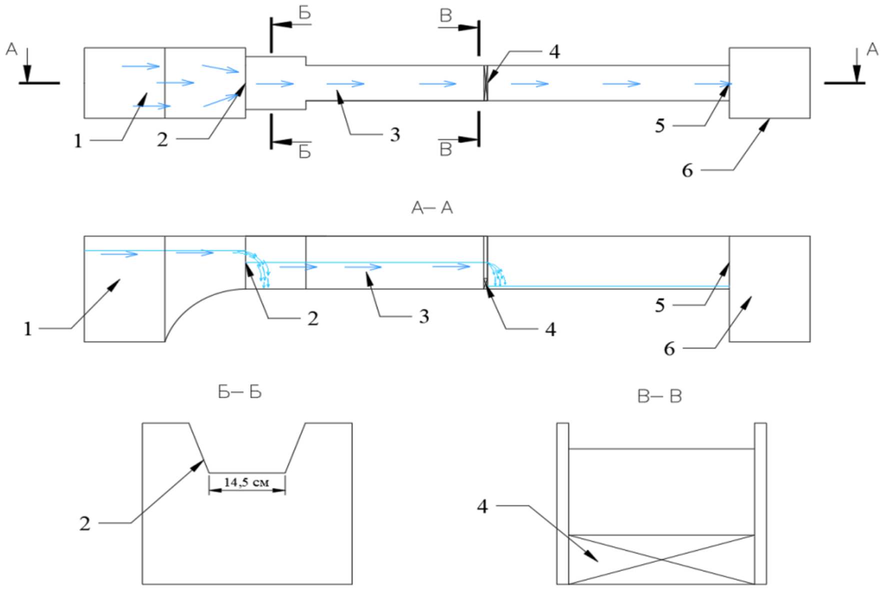

Fig. 1. Pressure tank, 2. Cipoletti water meter, 3. Channel, 4. Gate, 5. Gate (blind), 6. outlet channel

At the same time, the flow rate of water entering the flume (m^3/s) was measured with a Cipoletti water meter and calculated using this formula

$$Q = 1.9 \cdot b \cdot H\sqrt{H}$$

here: b is the width of the threshold, (m); The water level is above the H-threshold, (m). Based on the formula, the flow rate of water flowing through the Chipoletti was 3.5 l / s. At the second stage of the work, the ability of the water flow was studied, containing deposits.

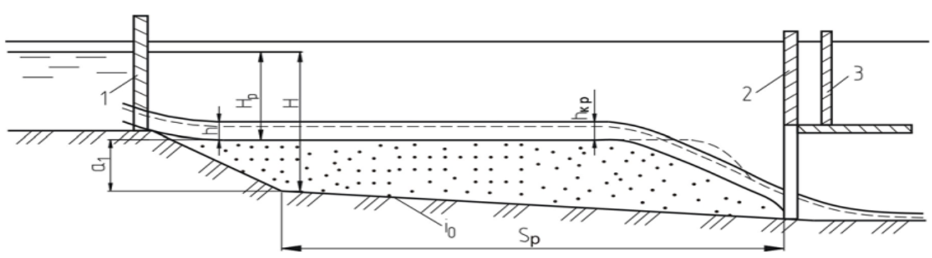

Fig. 2. Scheme of flushing turbid deposits from the sedimentation tank 1 - inlet gate (Cipoletti), 2 - flushing

In this case, the slope of the lower part of the flume was set to 0. In this case, the gate installed in front of the flume was closed, and the water flow of 3.5 l/s flowing through the Cipoletti rose to the water backwater level (0.5 m) for 7 minutes.

Fig. 3. The process of humidifying the water flow on the laboratory bench

After that, the shutter, installed at the bottom of the retaining section, was opened at different heights and the transport ability of the turbid particles settled on the bottom of the flow channel was studied. For each case, the velocities were measured using a micro vane in each section [17, 19, 20].

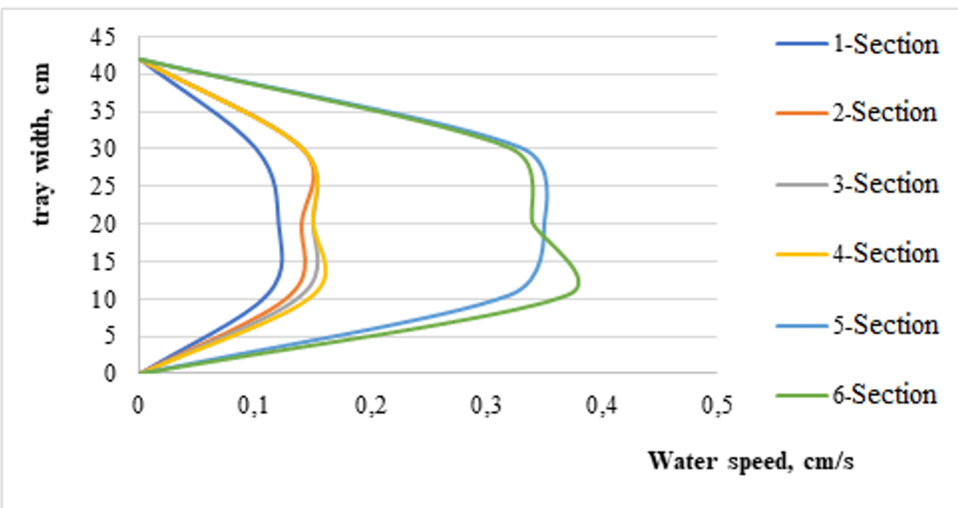

Fig. 4. Graph of the speed in each plot

The average speed on the tray is determined by the following formula:

$$v_{av} = \frac{\sum v_i + \frac{m}{4} v_n}{n + \frac{m}{4}} \tag{7}$$

Where $\sum v_i$ is the sum of the velocities on the curve, m is the height of the last region divided into residuals, in mm, v_n the speed in the middle of the last region divided into residuals, n is the total number of regions

We determined the thickness of the deposited sediments using the Zamarin method.

$$\delta = \frac{q \mu t 60 \cdot 60}{1000L} \cdot 100 \tag{8}$$

Here q is the relative water consumption, m^3/s running m
t-time interval μ - volume of settled sediments
L- length of settled sediments
Here *L*- is found by the Zamarin formula

$$L = \frac{H(v_1 + v_2)}{2w} \tag{9}$$

The consumption of flushing water is determined by the following formula.

$$Q = \varepsilon ba\sqrt{2g(H_0 - \varepsilon a)} \tag{10}$$

After the tray was completely empty of water, the position of the turbid particles remaining at the bottom was studied and their height was measured in each section (Fig. 5).

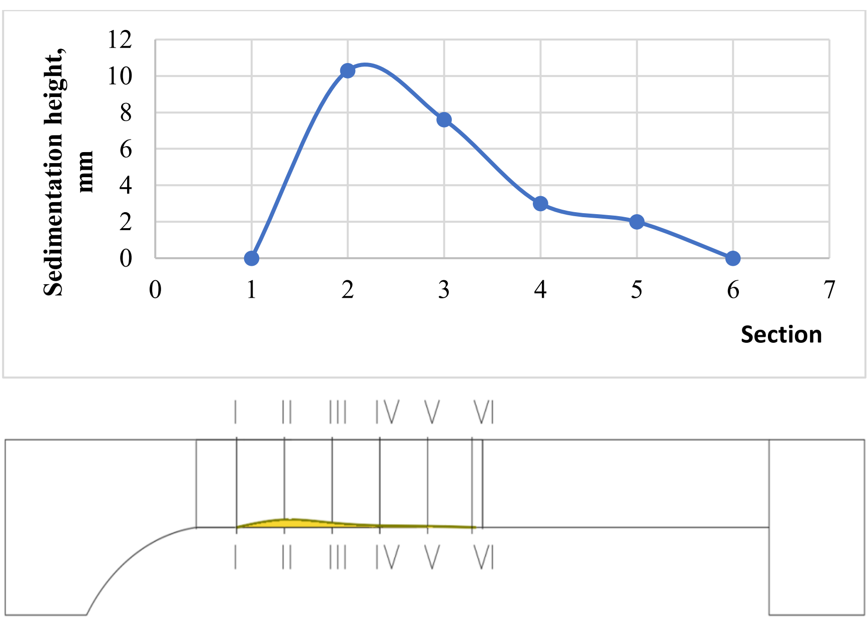

Fig. 5. The state of the remaining turbid particles after complete emptying at slope i=0.

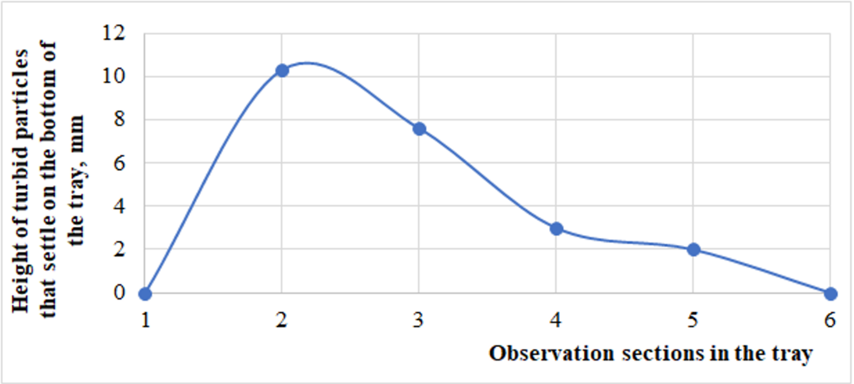

Fig. 6. Location of cloudy particles remaining at the bottom along the length of the tray

At the second stage of work, the flume bottom slope was changed from 0 to 0.02 and observational work was carried out. Even in this case, the shutter installed in front of the tray was closed, and when the water reached the backwater level, it was observed that the turbid particles contained in the water settled on the bottom of the tray at each given gate along its length.

Fig. 7. The process of sedimentation of turbid particles to the bottom of the tray when the water flow reaches the backwater level

After that, the shutter, installed at the bottom of the retaining section, was opened at different heights and the ability to transport turbid particles settled at the bottom of the flow channel was studied. At the same time, for each case, the velocities were measured using a microrotator in each of these sections (Fig. 8).

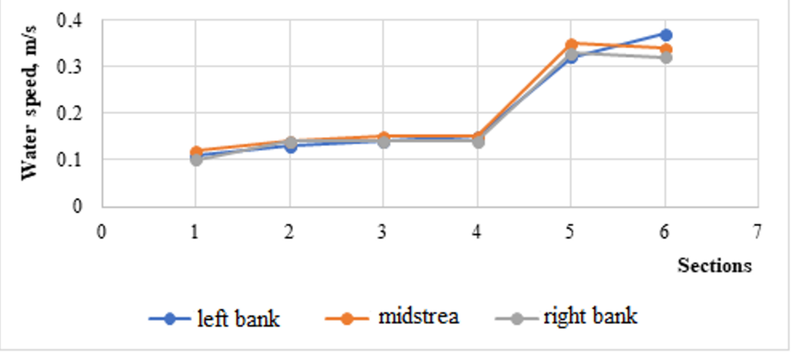

Fig. 8. Flow velocities for the case when the shutter opening height $a = 8\ cm$ with a channel slope $i = 0.02$

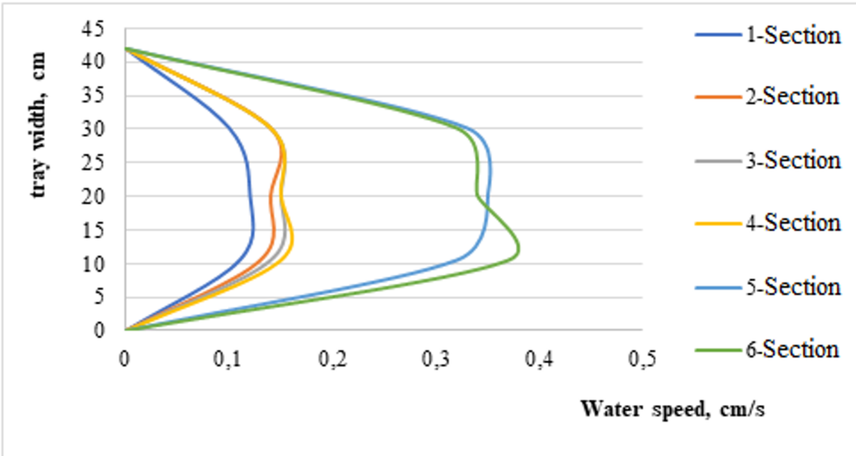

Fig. 9. Graph of the speed on the diagram

After the well was completely emptied of water, the position of the turbid particles remaining at the bottom was studied and their height was measured in each section.

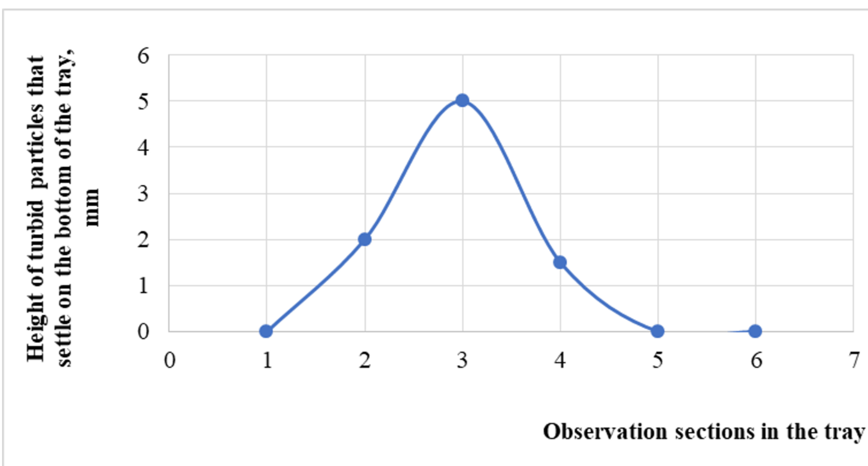

Fig. 10. Location of cloudy particles remaining at the bottom along the length of the tray

4 Conclusions

During the experiment, it was clear that, along with an increase in the volume of water intake, the volume of turbidity entering with water also increased. This is due to the fact that a large amount of suspended and bottom sediments, which naturally enter from the river runoff into the canal bed, lead to a decrease in the moving cross section of the canal and water permeability.

Based on the results of field and experimental studies carried out in the channel of the supply channel of pumping stations, based on an assessment of its throughput, the following conclusions can be drawn:

1. During the year, control work was carried out on the practice of using dredgers, determining the scope of work performed, measuring factors affecting the efficiency of pumping stations.

2. On the basis of the collected data and conducted field studies, a scientific study of the processes of channel formation in the area of the mouth of the main canal was carried out and recommendations were developed to improve the efficiency of the use of pumping station units.

3. A method has been developed to achieve, by changing the parameters of the channel, an increase in the efficiency of the units of the pumping station of the Karshi main canal.

4. On the basis of experimental studies, the efficiency of pumping units increased by 12% when developing new design parameters for the Karshi main canal sump.

5. On the basis of experimental studies, the optimal design solutions for settling tanks are presented to reduce the flow of turbid deposits into the antechamber of pumping stations and retain nanoparticles, as well as the place and time of placement of dredgers in the settling tank, and the pulp discharge points are determined.

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