Regime of deposition of sediments in the head settlement basin of the supply channel of pumping stations

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Abstract. The article presents the results of a study of the mode of inflow and dynamics of sedimentation on the inlet part of the canal. The results of field studies of the state of the channel situation in the supply channels of pumping stations are studied. The process of siltation of the head sump of pumping stations is analyzed. A method for regulating solid runoff into the inlet sections of the canal has been developed. And also by the nature of the change in the hydraulic elements of the flow, the time of siltation of the sump and cleaning the length of the investigated section of the channel were determined. Based on the results of a full-scale study of the supply channel, a recommendation was developed to improve its operation.

1 Introduction

One of the most important issues is the use of water-saving technologies when growing crops on irrigated lands, preventing water losses in irrigation systems, and providing them with guaranteed water.
Of particular importance is ensuring the reliable use of pumping stations and irrigation technologies to supply the required amount of water to the ever-increasing crop areas. One of the important tasks in this direction is to ensure a normal water level in the fore-chamber in order to prevent the operation of pumping units in cavitation mode, to improve the technology of cleaning liquid in water.

The investigated object of the Karshi main canal (KMCh) was put into operation from the river to the canal through the point of the Amu Darya damless water intake, located below Cape Pulizindan. The initial capacity was 80-100 m3/s. On the recommendation of SANIIRI, the water intake point and the head section of the KMCh were moved to the southern rocky part of Pulizindan Cape. In connection with the launch of a new feeding

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channel through hard-to-erode soils, the mode of inflow and the dynamics of sedimentation on the inlet part of the KMCH began to differ from the previously existing ones. Field research shows that in order to improve the conditions for water intake from the Amu Darya in a damless water intake, it is necessary to develop structures leading to a supply channel with the least amount of sediment flowing to the bottom. On the section of the Amudarya River in the zone of the head part of the damless water intake, the river bottom rises and, accordingly, the level of the water surface. The rise of the bottom is formed due to the discharge of pulp into the river during the cleaning of the inlet channel and the head of the water intake by dredgers. The rise of the river bottom leads to the entrapment and entry of a large amount of bottom sediments into the head of the supply channel. After that, it will be necessary to develop a special building structure that will keep alluvial deposits in the head section, and this will make it possible to facilitate the operation of the supply channel. The development of the hydraulic and alluvial regime for the proposed structures on the basis of experimental and field studies is the main goal of scientific work.

2 Methods

The analysis of the results of field studies in the bed of the inlet section of the pumping station of the Karshi Main Channel and the assessment of the throughput capacity of the channel is the research method of this work.

3 Results and Discussion

In order to develop rational methods for regulating sedimentation at the inlet sections of canals that act as a head settling tank, our team conducted field studies during the growing season (March-November) in the area of the damless water intake and the inlet part of the Karshi Main Channel, in 2021-2022.

In field studies, we solved the following problems:

- study of the mode of inflow and dynamics of sedimentation on the inlet part of the canal;

- determination of the nature of the change in the fractional composition of bottom sediments and suspended sediments over time and along the length of the inlet part of the channel;

-determination of the intensity of deep deformation (silting-erosion) of the bed of the inlet part of the channel.

The study of the alluvial regime of the inlet part of the Karshi Main Channel is of great practical and scientific interest. The study of the dynamics of sedimentation under such conditions is almost never found in the literature. Previous studies by A.N. Gostunsky, A.G. Khachaturian and other authors were carried out at depths up to 4.0 m and relatively large slopes $i = 0.0001 - 0.00003$ and average speeds $v = 0.3 - 1.0\ m/s$.

The peculiarity of the head sedimentation basin of the Karshi main canal is the large depths of 5-8 m (in some places up to 9-10 m), the variability of the water level, synchronously reflecting the fluctuation of the water level in the river, small slopes $i = 0.00001 - 0.000008$ at average speeds $v = 0.15 - 0.35\ m/s$. The water flow in the canal ranges from 80 to 200 m3/s.

To solve the set tasks under different regimes, the water flow, the flow of suspended sediments, and the slope of the water surface were measured. Observations were made at the following sites: PC 0+00 (at the entrance to the channel), PC 7+64, PC 13+80, PC19+64, PC 39+00, PC 57+21, PC 200. Two to three times a month the turbidity was measured in detail and the flow velocity was determined. For this, a GR-21 hydrometric

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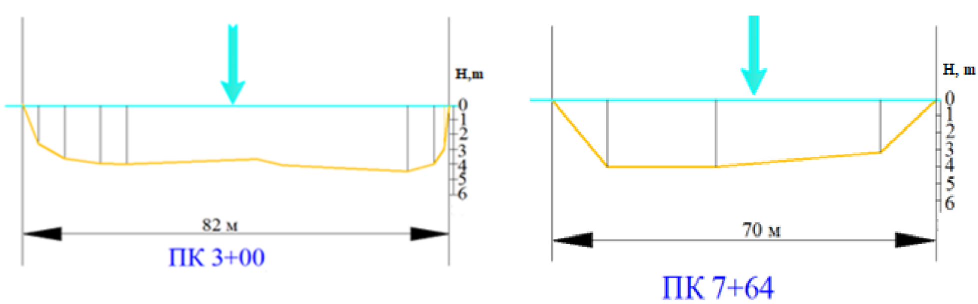
turntable and a 0.5-liter bottle were used, which were attached to a fish-shaped hydrometric weight of 15 kg. At the point of measurement and sampling, the load with the device was lowered using a winch.

Fig. 1. Field studies near the entrance of the Karshi Main Channel at PC 3+00

During the measurements, a cable with special marks was pulled along the alignment every 2.5 m. During the measurement, the boat was fixed on the cable, and the further movement of the boat along the alignment was carried out manually. At the same time, the depth of the flow was measured every 2.5 m. Velocity and turbidity were determined at each section in five (sometimes three) verticals using a five-point method: at the surface; 0.2H; 0.6H; 0.8H and at the bottom.

According to the nature of the change in the hydraulic elements of the flow, silting and cleaning, the length of the studied channel can be divided into 3 sections:

The first rocky section of the canal is located in the area from PC-0+00 (channel entrance) to PC 3+00. The channel width is 50-60 m, the water depth in the channel is 3-5 m, and the average and surface water velocities are 0.46-0.95 m/s and 0.62-1.20 m/s, depending on the flow rate and water horizon in the channel. The speed of water movement along the depth of the stream is distributed evenly with a slight decrease in its value near the bottom. The second section is located in the area from PC-4+00 to PC-39+00 on the widened and deepened part of the canal. The channel width varies from 120 to 170 m; the average water depth is 4.0-7.0 m. The greatest depth is observed in underwater suction dredger faces.



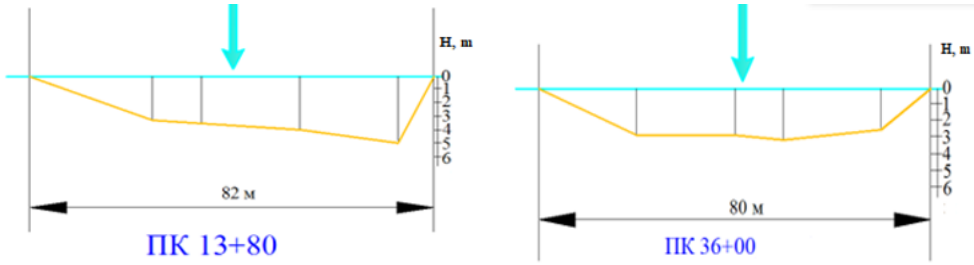


Fig. 2. Change in depths during transverse shear in the bed of the Karshi Main Channel at the PC.

The average speed of water movement is 0.14-0.35 m/s, depending on the flow rate and water level in the canal. In this section of the channel, the velocity and turbidity are unevenly distributed over the depth. At the water surface and up to a depth of 0.2H, the highest values of velocity are observed and, conversely, turbidity has the lowest value. Starting from a depth of 0.6N, the velocity decreases and, conversely, the turbidity increases sharply due to the movement of the bottom sediment layers (in the form of a mud-condensed sediment mass).

The third section is below PC 39+00 to PS-1. The width of the canal along the water's edge varies from 75 to 85 m. The average depth is 4.0-7.0 m, depending on the level and flow of water. The average and surface water velocities, respectively, are 0.23-0.48 m/s and 0.46-0.67 m/s. In this section, the velocity and turbidity are distributed relatively evenly over the depth.

The measurement data for 2021 are plotted in Figure 1, which shows a regular change in the turbidity and fractional composition of sediments both along the length of the inlet part of the KMC and over time due to its silting and falling horizons in the river.

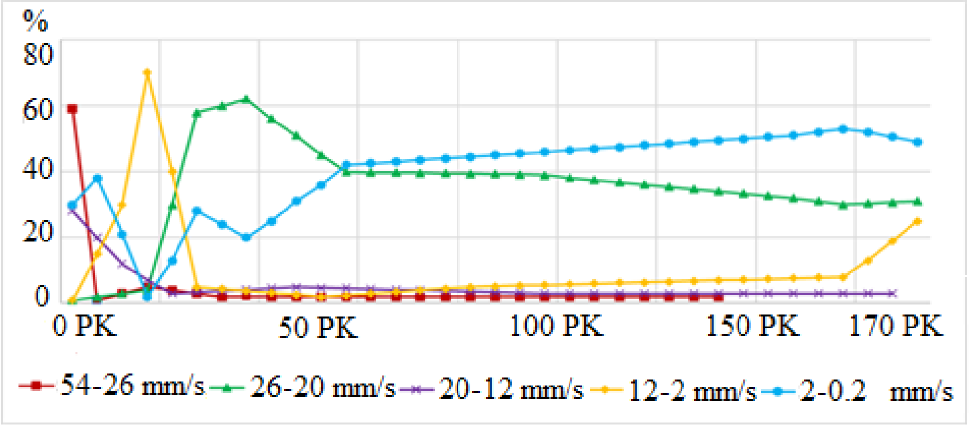


Fig. 3. Changes in the fractional composition of turbid sediments along the length of the main channel

According to the analyzes carried out on May 19, 2021, at a flow rate in the canal of 180 m3/s, the incoming turbidity was 6.20 kg/m3, the outgoing turbidity at PC 39+00 was 3.80 kg/m3, and according to the data on June 21, at a flow rate in the channel of 185 m3/s, the incoming turbidity was 2.98 kg/m3, the outgoing turbidity was 1.50 kg/m3. On June 14, at Q= 135 m3/s, the input turbidity was 2.35 kg/m3, the output was 1.07 kg/m3, and on September 16, 2021, at Q = 130 m3/s, the 0.32 kg/m3.

As seen in Table 1, the content of sand fractions (d>0.25 mm) in the composition of suspended sediments ranges from 0.29% to 2.39%. The content of fine sand fractions (d=0.25-0.05 mm) varies from 19.10% to 50.94%. The content of silty particles (d=0.05-0.015 mm) ranges from 31.38% to 56.81%, and silt particles (d<0.05 mm) from 2.12% to 3.98%. With an increase in the distance from the inlet, the relative content of fine sediment fractions increases.

Table 1. The content of the main fractions in the composition of suspended sediments of the Amudarya River

Date	Fractional composition, %				
		0.25-0.05	0.05-0.015	0.05-0.015	0.005
1	3	4	5	6	7
21.05	0.29	19.10	56.81	21.32	2.58
21.05	1.46	30.87	49.91	14.76	3.00
21.05	0.32	27.05	49.32	19.33	3.98
21.05	0.53	24.90	53.59	17.43	3.55
17.06	1.74	35.32	41.45	17.85	3.64
17.06	1.65	31.60	44.16	20.47	2.12
17.06	0.22	29.42	41.03	25.38	3.98
19.06	2.39	34.58	40.85	31.38	3.79
19.06	5.13	46.70	18.39	13.80	2.99

The process of siltation of the sump at the same horizons and turbidity in the river is determined by two main factors: the deposition of sediments that have fallen out of suspension and the volume of excavated soil during the cleaning of the sump.

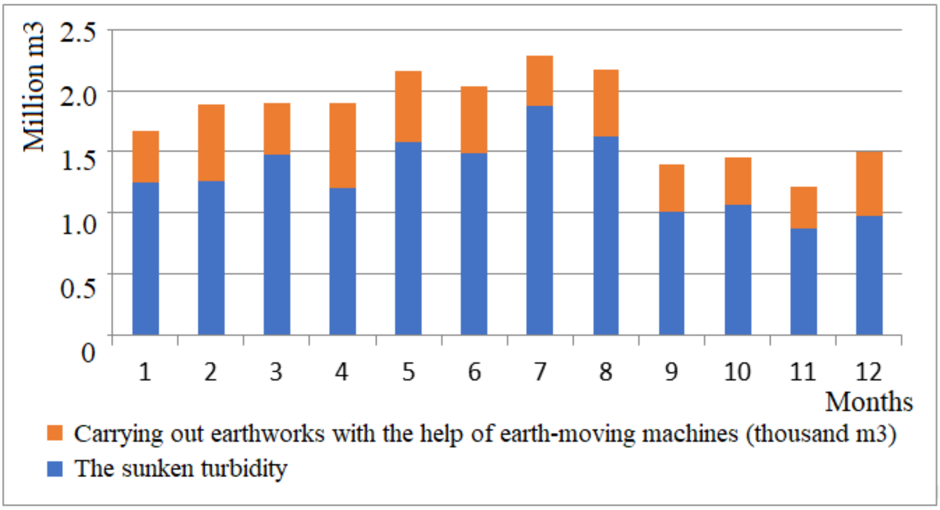


Fig. 4. Sludge volumes and clearing activities along the Karshi Main Channel

The distribution of silting along the length of the supply channel depends on the course of its cleaning. The course of silting leads to a continuous change in living sections, redistribution of the slope of the free water surface and velocities along the length of the head sump.

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When one pump is running $Q_{KMCh.min} = 36\ m^3/s$

$v_{min} = 0.51\ m/s$ $h_{min} = 1.35\ m$ $R_{min} = 1.28m$

When two pumps are running $Q_{KMCh.min} = 72\ m^3/s$

$v_{min} = 0.68\ m/s$ $h_{min} = 2.1\ m$ $R_{min} = 1.95\ m$

When three pumps are running $Q_{KMCh.min} = 108\ m^3/s$

$v_{min} = 0.76\ m/s$ $h_{min} = 2.65\ m$ $R_{min} = 2.42\ m$

When four pumps are running $Q_{KMCh.min} = 144\ m^3/s$

$v_{min} = 0.83\ m/s$ $h_{min} = 3.15\ m$ $R_{min} = 2.84\ m$

When five pumps are running $Q_{KMCh.min} = 180\ m^3/s$

$v_{min} = 0.94\ m/s$ $h_{min} = 3.66\ m$ $R_{min} = 3.2\ m$

The above calculation showed that the lower the water flow in the canal, the greater the sedimentation. As the water flow in the channel increases, the condition for the absence of turbidity in the channel is closer to being fulfilled. During the operation of five pumping units, the maximum water flow in the Karshi Main Channel is observed and the condition of the absence of sedimentation in the channel is fully met.

If we take into account that the sediments moving with the flow in the field have different fractional composition, then it is very difficult and practically impossible to express them in one analytical form, therefore, when developing a new method, it was necessary to use sediment size distribution curves corresponding to a given composition of sediments.

One of the most important characteristics in terms of operation is the operating time of the sump. Taking into account the average turbidity of the water entering the sump, as well as the need for continuous water supply to pumping station 1, it is possible to determine the duration of silting of the sump.

Based on the results of field-measuring work, a hydraulic calculation of a three-chamber sump in the KMCh water supply channel was performed. It is argued that the width of the chamber in the proposed three-chamber settling tank must be reduced depending on the flow rate, otherwise sedimentation will occur in the front of the chamber. It is possible to wash one chamber when two chambers are operating in the sump operation mode.

$$Q_{sump} = q_{work} + Q_{flush} \qquad (1)$$

where q_{work} - work is the operating water flow, Q_{flush} - is the flush water flow

According to the conditions for ensuring flushing, the specified depth must fulfill H conditions.

$$H < Z + \frac{Q_{flush}}{v_{flush}} \qquad (2)$$

$$H + i_o \cdot S_p \leq Z + \frac{Q_{flush}}{v_{flush}} \qquad (3)$$

We have determined the recommended working width of the sump using the following formula.

$$B = \frac{Q}{H_{work} \cdot v_{av}} \tag{4}$$

Taking into account the approximation of the calculation method, it is recommended to determine the length of the sump chambers:

$$S = \frac{(1.2-1.5)h_1 v}{w'} \tag{5}$$

As for the average speed of water movement in the sump, we obtain (when settling fractions with a particle size of $d = 0.25 - 0.005\ mm$):

$$v = 0.1 \div 0.25$$

Water depth at the beginning of the sump:

$$h_1 = \frac{q_{work}}{v \cdot B}$$

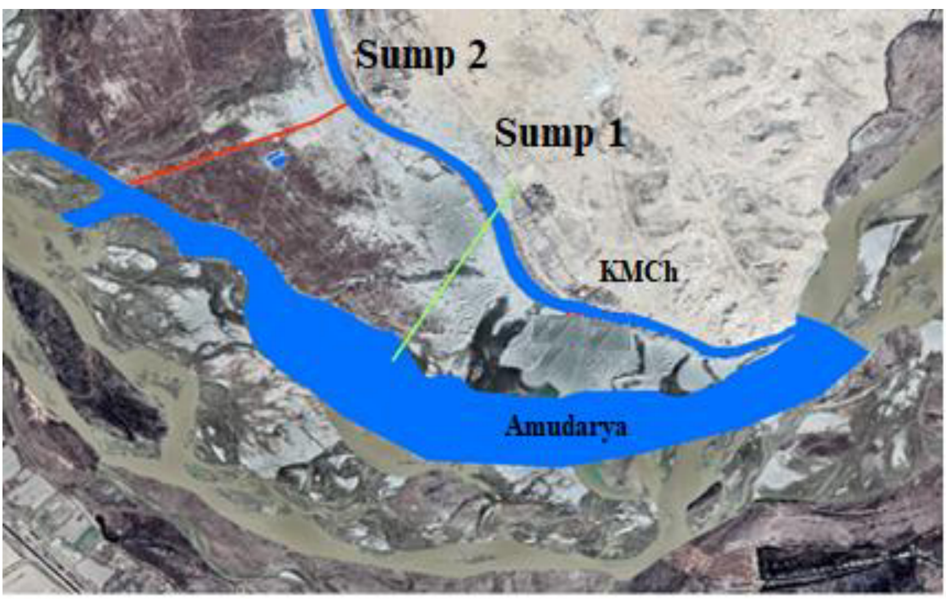

Fig. 5. Space view of the location of the proposed sediment basin on the Karshi Main Channel

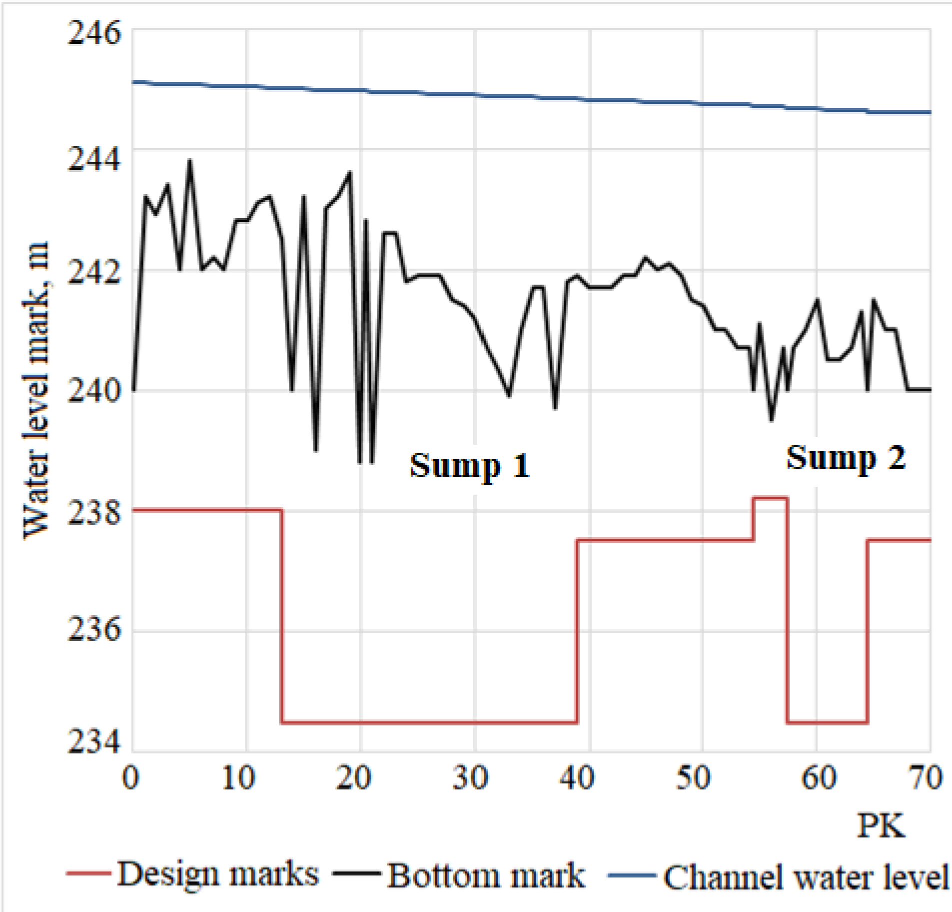

Fig. 6. Level changes in the bed of the sediment basins, located on the Karshi Main Channel

The obtained quantitative parameters of the dynamics of changes in the flow turbidity and its fractional composition along the length of the inlet part of the channel can be used to determine the amount of sediment remaining in suspension after settling, as well as the category of soils. Further research should be aimed at developing a rational technology for cleaning the inlet sections of channels.

4 Conclusions

Based on the results of field studies conducted in the Karshi main canal, based on an assessment of its passability, 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. According to the collected data and conducted field studies, channel formation processes occur in the area of the mouth of the main channel, especially in the main channel with a length from PC 13+80 to PC 39+00, recommendations for improvement have been developed.
2. 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.

Due to the development of improved parameters of the KMK head sump, the efficiency of pumping units increased by 12%.

3. Based on field studies, the dynamics of the hydraulic parameters of the flow in the channel was analyzed. According to these data, it was found that large-scale erosion processes will occur in the canal section within a short time. This indicates that the hydraulic regime of the channel significantly redistributes the speed, depth, and width of the flow. That is, an increase in sediment inflow into the riverbed causes a decrease in the depth of water runoff and an increase in the width of the riverbed.
4. The design parameters of the settling tank have been improved, taking into account the transporting capacity of the flow and the fractional composition of sediments in the supply channel. The place and time of placing the dredgers in the sump and the points of pulp discharge were also determined.

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