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Backup water impact on the Karshi Main Canal capacity in Uzbekistan

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ABSTRACT: The article presents a study results of impact of the Karshi Main Canal regulation structures on its technical conditions. The field studies carried out using a modern acoustic Doppler profiler - a device for measuring water flow and recording the morphology of deposited sediment on the bottom and slopes of the canal. The Bayesian method has been used for the canal technical state evaluation based on statistical analysis of the data obtained, and the emergency situation probability is assessed as a result of water level increase in upper side of the structures. Recommendations proposed to eliminate the current situation.

KEY WORDS: Irrigation canal, water discharge, flow velocity, regulating structure, sedimentation.

I. INTRODUCTION

Hydraulic structures on irrigation canals play a critical role in the regulation and management of water resources in irrigation systems. The practice peaked internationally in the 1960s and 70s, but in recent years hydropower has faced growing global criticism as its benefits come at a huge environmental cost. But water regulation and turning out structures are an inevitable part of guaranteed water supply to the sectors of economy of Uzbekistan [1, 2, 3].

The impact of hydraulic structures on the environment can be classified according to the different criteria: short-term and long-term, impacts on the surrounding areas, social and environmental impacts on regions, beneficial and negative consequences. In addition to the social and environmental benefits, it is important to minimize the negative impact of the engineering structures on the environment from a sustainable development perspective [4, 5]. One of the negative consequences of the canal structures is that sediment accumulates in the upstream, reducing its capacity. In addition, the sediment deposition in front of the structure leads to increase a downstream erosion, which greatly influences the hydrological processes in earth canals. The lack of sediment leads to a deepening and narrowing of the channel bed over time and a change as well in the groundwater level [6, 7, 8].

In Uzbekistan, comprehensive measures are being widely carried out to improve the efficiency of irrigation systems through modernizing, reconstructing and repairing irrigation canals using modern technologies [9]. The total length of the main irrigation system in the republic is 28 thousand km, inter-farm canals' are 155 thousand km. More than 25 thousand hydraulic structures are located on the main and inter-farm canals [10, 11]. In recent years, about 1,500 km of canals have been reconstructed in the republic. Within this activity 7 km of the Karshi Main Canal (KMC) and 9 km of inter-farm canals, 83 hydraulic structures, 76 gauging stations of this system were repaired in 2023. However, the hydraulic structures risk accidents monitoring and assessment is still limited due to the lack of a unified effective approach to solving such issues.

II. THE RESEARCH OBJECTIVE AND METHOD

The KMC is located in the Kashkadarya region of Uzbekistan. The source of water is the Amudarya River. The canal lifts water to 132 meters using 7 pumping stations and provides water to 402 thousand hectares of agricultural area of the Nishan, Karshi, Kasbi, Mubarak, Kasan districts and the city of Karshi (Fig. 1). The canal length is 105 km. Several water regulating structures are built on the canal, which have been under operation for many years. The maximum water flow rate in the KMC is 350 m3/s at the head of the canal, at the picket (location marker) KP 366 water flow is 320 m3/s, at KP 539 - 270 m3/s, KP 792 flow is 204 m3/s, at the KP 868+74 water flow is 160 m3/s and at the last KP 1121 water flow is 104 m3/s. During the operation period negative situations took place at the regulating structures that affect the safety of the canal and around areas. The issue leads to the KMC efficiency decrease, a reduction in its service life and a deterioration of the surrounding lands reclamation state corresponding an economic damage.

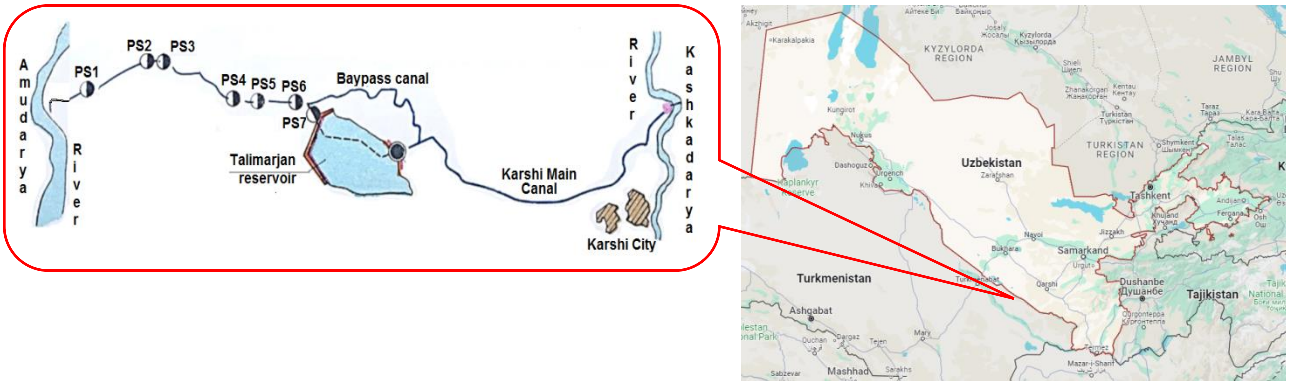

Figure 1. Schematic map of the Karshi Main Canal and its location

The research was carried out on the KMC section from KP258 to KP391. Full-scale measurements were carried out using Acoustic Doppler profiler - River Surveyor S5 model SonTek of XYLEM. Water depth and discharge, flow currents and velocity were measured in front of the cross regulating structure at the KP366, as well as morphological survey of the canal bottom has been conducted to get bathymetric data. The regulation structure at KP366 was built to ensure water supply to the Talimarjan Thrmal Power Plant (TES), which receives water at KP266+50 for cooling of the energy blocks.

Data collection and analysis were carried out related to the technical classifications of the structure. The changed hydrology process due to the structure operation terms, its impact on the upper stream of the canal has been identified. Sediment deposition in the upstream of the structure was studied. The obtained results were processed and the state of the structure was analysed using the method of statistical analysis.

III. RESEARCH RESULTS

The measurement results introduced reduction in the canal's capacity for 30% against water flow 200-220 m3/s indicated by the gauging station at KP178 due to a decrease in flow velocity in the backup water zone and increased sedimentation. When the water flow rate is more than 32 m3/s, the water depth fluctuates within 3-3.4 m, when the flow rate exceeds 50 m3/s the water depth exceeds 3.7 m, with an increase in water flow the flow depth reaches 4.7 m (Table 1). At the same time, the length of the backup water in the canal upstream reaches to 10 km affecting the hydrological regime of the canal.

Table 1. Water depth change depending on flow rate

Flow rate, m^3/s	171	153	125	102	86	21
Water depth, m	4,74	4,62	4,57	4,45	3,98	3,73
Support length, km	0,70	0,84	3,01	5,94	9,12	10,06

Figure 2 shows the changes in water depth in the upper reaches of the structure. Over the past 7 years increase in water depth in the canal has raised from 3.45 m to 3.62 m, and these levels are maintained regardless of changes in water flow in the canal.

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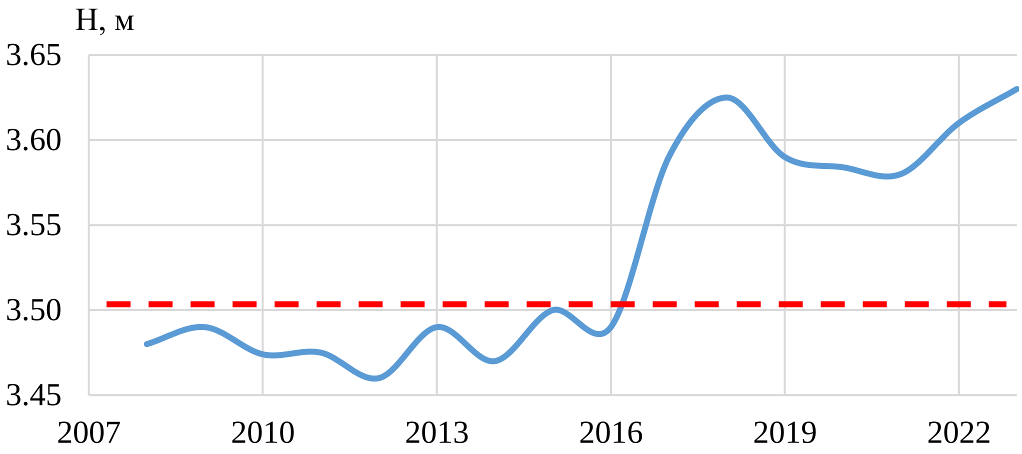

Figure 1. Water depth dynamics in upper side of the structure

Changes in the flow rate and level regime in the canal have a negative impact on the structural elements of the structure at KP366. The concrete covering of the structure is damaged due to process of corrosion, destruction of walls and defects in the valves are observed (Fig. 3).

Figure 2. The regulation structure damages

Measurements along the section carried out in the upper reaches of the structure for the period May 15-26, 2023 showed that the size of this section is 44.2 m, which is 4-5 m less than the design indicator. The bottom elevation of the canal rose by 0.85-1.35 m due to sediment deposition. At the time of the field measurements the maximum depth was 4.5 m, the average flow velocity was 1.1 m/s, and the water flow was 159.4 m^3/s (Fig. 4).

The canal efficiency analyse identified that at low water period the efficiency coefficient is 0.70-0.79 because of the structure was built at a long distance from the TES. The flow rate dynamics and upstream water level in the structure were analysed considering the operation terms of the structure considering water supply to the TES, and the negative impact of this process on the canal was identified.

The Bayesian method is used for calculation the reliability of the canal with a three-stage probability assessment of the structure impact on the canal operation. The probability of an accident occurring because of a rise in the water level the structure upper side was considered using the Bayes probability formula [12,13].

$$P(A_j \mid B) = \frac{P(B \mid A_j)P(A_j)}{\sum_{i=1}^{n} P(B \mid A_i)P(A_i)} \quad (1)$$

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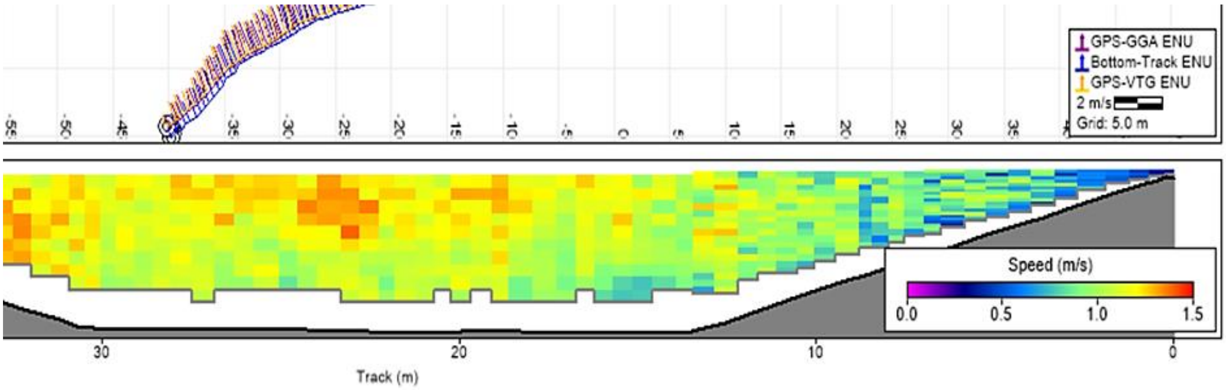
here - $P(A_j) - A_j$ - initial probability associated with the backup water in the structure upper side; $P(A_к)$ - the probability of an accident occurring at a structure, which is determined by the formula:

$$P(A_к) = \frac{K_i}{N} \quad (2)$$

$\sum_{i=1}^{n} P(B\,|A_i)P(A_i)$ – the sum of the probability processes that can occur.



Track (m)	DMG (m)	Width (m)	Area (m2)	Mean Speed (m/s)	Boat Speed (m/s)	Left Q (m3/s)	Right Q (m3/s)	Total Q (m3/s)	Corrected To (m3/s)	% Measured (%)
43.76	41.97	43.970	157.362	1.007	0.387	0.07	0.00	158.482	--	73.2
45.24	42.43	44.426	159.598	1.003	0.415	0.05	0.04	160.132	--	74.3
44.50	42.20	44.198	158.480	1.005	0.401	0.06	0.02	159.307	--	73.8

Figure 3. The measurements results carried out on KP366

At the research three main indicators (criteria) were considered that influence the reliable and efficient operation of the regulation structure: A_1 - change in water level relative to the crest of the structure; A_2 - is closing/opening rate of the gates; A_3 - filtration through the canal bottom and slopes. For the above probabilistic parameters the following criteria indicators were identified: $K_1 = 0{,}65$, $K_2 = 0{,}12$, $K_3 = 0{,}03$. In this case: $N = K_1 + K_2 + K_3 = 0{,}80$.
Based on the expressions above the following results were obtained:

$$P(A_1) = \frac{K_1}{N} = \frac{0{,}65}{0{,}80} \qquad P(D/A_1) = P_1 = 0{,}20$$

$$P(A_2) = \frac{K_2}{N} = \frac{0{,}15}{0{,}80} \qquad P(D/A_2) = P_2 = 0{,}55$$

$$P(A_3) = \frac{K_3}{N} = \frac{0{,}04}{0{,}80} \qquad P(D/A_3) = P_3 = 0{,}10$$

Based on the canal state study results according to the above indicators the following accident rates were determined: P1 = 0.20 - the probability of an accident that could occur as a result of water level rise in the canal; P2 = 0.55 - probability of an accident due to destruction of canal slopes; P3 = 0.10 – accident probability due to increased filtration through the bottom and slopes of the canal.

Using the formula (1) the probability of an accident arising as a result of the first criterion was determined, i.e. rising water level in front of the structure $P(A_1|B) = 0{,}6$. As a result of a long-term backup of water in the KMC, the

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probability of destruction of the canal and structure equal to 0.6, which means a fairly high probability of negative events and there is a need for an urgent solution of the issue.

For efficient operation of the canal, taking into account the water supply to the TES, it is recommended to construct an additional control cross structure at KP275, which will reduce the length of water backup zone and reduce the level of water level rise in the canal, removing the negative impacts (Table 2).

Table 2. Change in water level and head length depending on the flow rate in the Canal

Flow rate, m^3/s	171	153	125	102	86	21
Water depth at present time, m	4,72	4,60	4,37	4,05	3,88	3,53
Water depth after the construction of the proposed structure, m	3,50/ 1,22	3,25/ 1,35	3,10/ 1,27	2,75/ 1,75	2,02/ 1,86	1,2/ 2,33
Backup water length, km	0,69	0,84	0,87	1,01	1,55	1,70

While constructing an additional control structure at KP275+50 the maximum water level rise can reach up to 1.2 m, depending on the flow rate in the canal, the length of the backup will not exceed 1.7 km, i.e. the impact of the structure on the operating mode of the canal and its technical condition will be minimal (Fig.5). Also recommended urgent cleaning of the upper side of the regulating structure from deposited sediments in order to reduce the negative impact on the reclamation state of the lands.

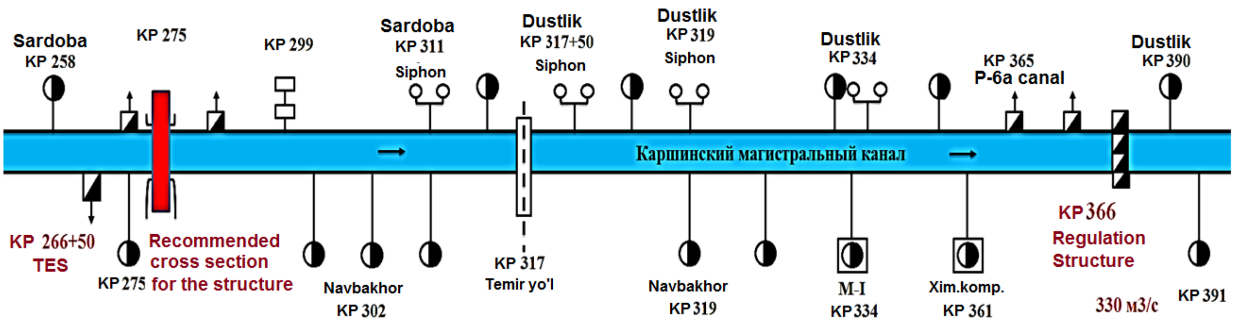

Figure 5. The canal section with regulation and recommended structures

IV. CONCLUSION

Studies have shown that water backup at high levels in upper side structures on large canals can lead to deterioration in canal performance and the possibility of accidents. On the Karshi Main Canal the probability of an accident that can occur as a result of a failure of the structure is quite high. While constructing an additional control structure at picket KP275+50 the emergency probability will be minimal. In order to ensure efficient operation of the canal, taking into account the reduction in available water resources in the region and in order to save it, it is recommended strictly following the established discharge limit of 20-30 m^3/s for the Talimarjan Power Plant.

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