Suspension concentration distribution in a stream constructed by spur no. 19 on the Amu Darya river

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Abstract. The concentration of suspended solids is the main indicator of the flow transporting suspended sediments. Knowing its value, it becomes possible to predict channel processes on rivers, the timing of sedimentation tanks and reservoirs. Establishing patterns of the influence of structures on the redistribution of liquid and solid runoff is also a priority task. The main goal of this work is to establish the regularities of the distribution of the concentration of suspended matter in a stream constrained by a transverse spur. The problem is considered for the second time using materials from field studies conducted on spur No. 19 in 2020 on the left bank of the Amu Darya river. The methodology of field studies remained the same as for the first time on dam No. 30 in 2019. The positions of the sections and verticals during sampling to determine the concentration of suspended matter were assigned based on the hydraulic structure of the constrained flow. Considering the presence of homogeneous zones of a weakly perturbed core, intense turbulent mixing and reverse currents, as is customary in the theory of turbulent jets with an admixture propagating in a confined space. On verticals, samples were taken at two points 0.2H and 0.8H, and at shallow depths at a depth of 0.6H. Field observations established that in the zone of the slightly disturbed core of the distribution of the concentration of suspended matter along the depth, it has the shape of a "boot"; however, the length of the toe is much shorter than that of the dam 30 and is observed only in the sections P-P and O-O, and in the other sections there is a leveling in depth. On other sections, they are close to logarithmic. The maximum concentration of suspended matter was observed in the section of confinement O-O at point 0.8H 7.66 kg / m^3, which in the section of confinement under the influence of a new spur occurs deep and lateral erosion of the channel. The distribution in plan in the zone of a weakly disturbed core is close to uniform. Here again, in the zone of intense turbulent mixing, it obeys the theoretical Schlichting-Abramovich dependence for the initial section. With the help of the results obtained, it is possible to predict the siltation of the inter-dam space and the boundaries of the new coastline in the future.

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1 Introduction

Regulation of the channels of large rivers such as the Amu Darya is events on a global scale. Channel processes, especially the erosion of the banks on this river, is intense under the local name "deigish" [1,2,3]. The construction of the Tuyamuyun reservoir on this river, cutting off the peaks of floods, made it possible to regulate the river bed over a length of 185 km from Tuyamuyun to Kipchak. Along with theoretical [4-8], experimental [9-12] and semi-empirical [13,14,15] studies, it is necessary to carry out field studies of the work of the constructed. For this purpose, field studies were carried out in 2019 on dam 30 [16,17], which has been successfully operating since 1989, and in 2020, studies were carried out on spur 19 built in 2019. We studied the velocity field, the distribution of the suspension concentration in depth and in a plan, local erosion, the planned dimensions of the whirlpool zones. The distribution of the suspension concentration plays an important role in predicting the siltation of the inter-dam space. [18, 19].

2 Methods

Field studies were carried out on spur 19 on the left bank of the Amu Darya river. It was erected in 2019 on the Khazarasp section of the Khorezm region on the site of the old spur No. 19 (in Fig. 1, the remains of the old spur are shown in the marks at the time of the construction of the new one), the body of which was erected by dredging from sand with a stone head attached. The spur was washed away by the water flow, and there was a threat of erosion of the developed space between the dams with rice crops. The length of the spur at the top is 30 m, at the base is 42 m. The height of the spur, taking into account the depth of erosion, is taken as 12 m. The width along the ridge is 6 m and at the base of 30 m. The establishment of the slope m = 1. The body of the spur and the root part are made of rock fill with a diameter of d = 0.3-1.0 m. An unpaved area with dimensions of 30x15 m was designed for turning the cars. The stone for the spur was brought by dump trucks from the Karatau quarry. The transportation range is 174 km, the volume of the stone is 5625 m3. The angle between the flow direction and the spur axis is taken as 750. The working length at the time of the study (08/23/2020), taking into account the water level and the establishment of the slope, was 34 m
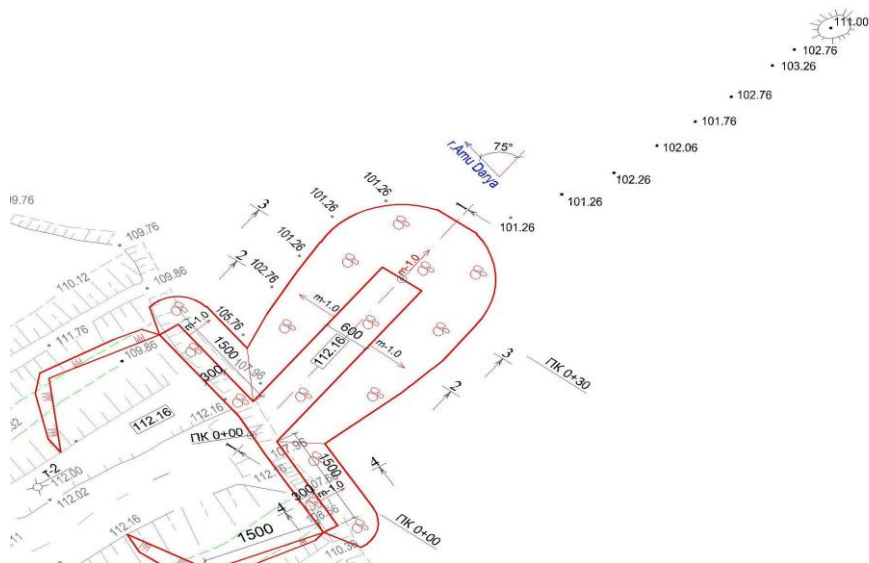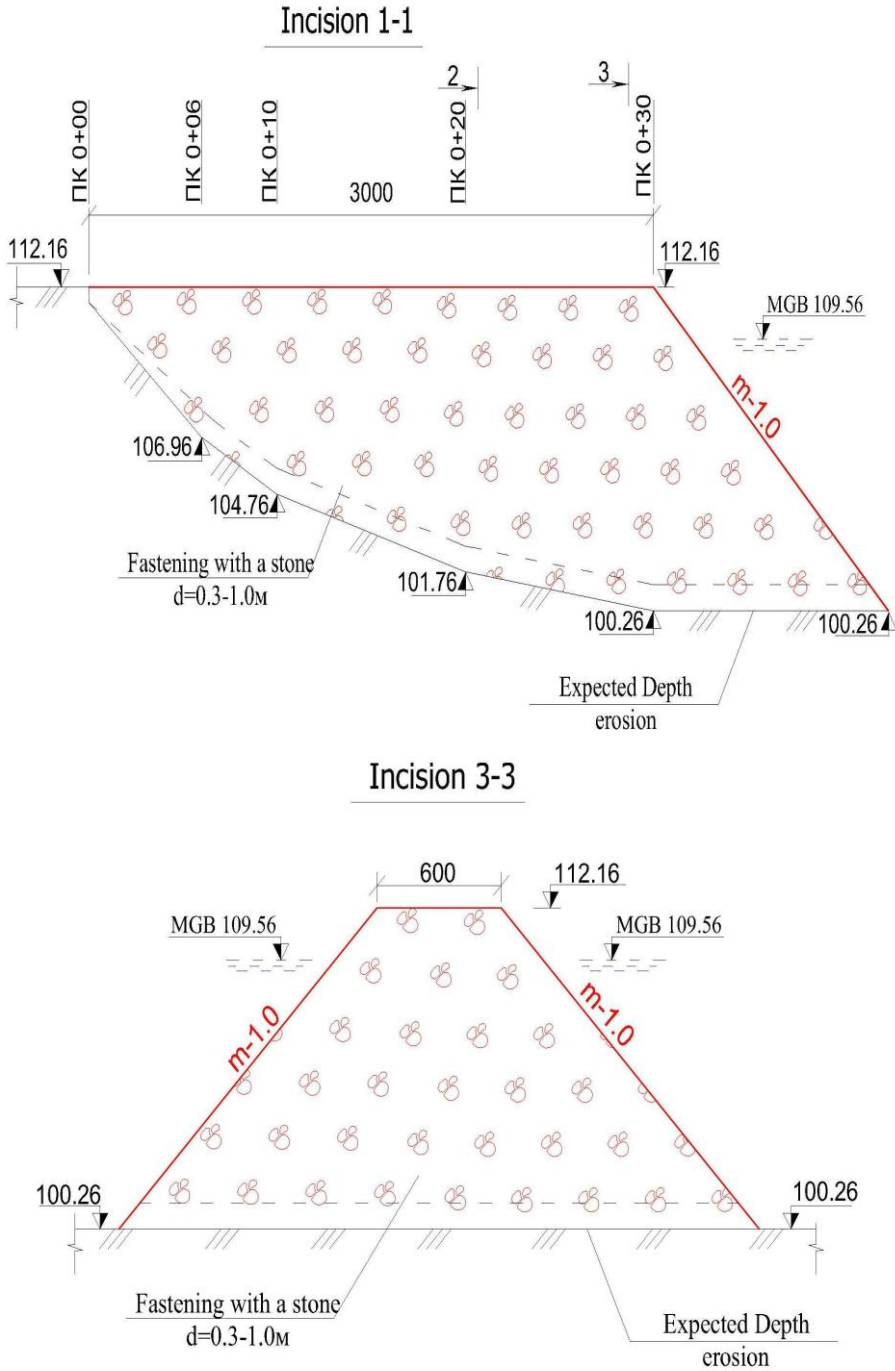
Fig. 1. Construction of spur No. 19 on the Amu Darya river.

Fig. 2. Layout of the investigated area of spur No. 19 (Amu Darya river)

The method for determining the concentration of suspended is stated in the literature for the conditions of gauging sections, stations, relatively stable cross-section without separation flow. In contrast to these existing methods, the designation of sections and verticals for sampling was carried out, taking into account the nature of the flow deformation with a spur. In this case, the formation of upstream and downstream whirlpools, compression and spreading zones, zones of a weakly disturbed core, intense turbulent mixing, and reverse currents were taken into account. [16,17].

Gates for sampling were assigned [16] section where the normal state of the flow P-P is preserved, in the section, there is constraint 0-0, in the section of compression C-C, in the section X-X and V-B within the lower whirlpool.

The assignment of the sections, the establishment of the boundaries of the turbulent mixing zone, and the verticals' location were carried out using a level.

Verticals were assigned at least three at each section and in the zone of intense turbulent mixing, and in the zone of reverse currents, one vertical.

Depth samples were taken at two points 0.2H and 0.8H, and at shallow depths at 0.6H. The samples taken were poured into washed plastic bottles indicating the alignment and vertical number.

The samples taken were passed through filter paper and weighed on an electronic balance, then the filter paper with sediments was placed in a thermostat with a temperature of 180^0. After a certain time, the filter paper with the sediments was weighed, and this was repeated until the last results remained constant without changes. Then the sediment mass GH without filter paper and the concentration of suspended matter flow were determined by the formula

$$\mu = \frac{G_H}{A} \cdot 10^6 \; _{г/м^3} \qquad (1)$$

where is the concentration of suspended matter flow g / m3; - the mass of sediment in the water sample, g; - sample volume, cm^3, 106 - coefficient of conversion from cm^3 to m^3.

$$\mu_c = 0{,}5(\mu_{0,2H} + \mu_{0,8H}) \tag{2}$$

with single point

$$\mu_c = \mu_{0,6H} \tag{3}$$

Diagrams of the distribution of suspension concentration along the width of the sections were plotted using the mean values on the verticals.

3 Results

The results of field studies are shown in Table 1 and Fig. 3, 4.

Table 1: Results of field studies of the distribution of suspension concentration in the stream constrained by spur No. 19 (Amu Darya river).

range	Vertical	Positions of verticals in relation to the left bank, m	Water depth m	Sampling depth, m	
			h	0.2h	0.8h
П-П	Π_1	60	4.5	0.9	3.6
	Π_2	107	4.2	0.0.84	3.36
O-O	O_1	78	5.6	1.12	4.48
	O_2	121	6.2	1.24	4.96
C-C	C_1	16	2.5	0.5	2.00
	C_2	48	5.5	1.1	4.4
	C_3	68	5.8	1.16	4.64
	C_4	97	5.5	1.1	4.4
	C_5	138	4.2	0.84	3.36
	C_6	180	2.5	0.5	2.0
X-X	X_1	11	2.2	0.44	1.76
	X_2	37.4	4.2	0.84	3.36
	X_3	68	4.5	0.9	3.6
	X_4	112	3.2	0.64	2.56
	X_5	153	1.8	0.36	1.44
B-B	B_1	7	2.3	0.46	1.84
	B_2	31	3.7	1.11	2.96
	B_3	75	4	0.8	3.2
	B_4	104	2.8	0.56	2.24
	B_5	138	1.92	0.38	1.54

Table 1 continued

range	Sediment weight without filter paper G_H gr		Suspension concentration		Vertical average μ, kg/m3
			$μ$ kg/m^3		
	0.2h	0.8h	0.2h	0.8h	
П-П	1.89	2.13	1.89	2.13	2.01
	2.43	3.45	2.43	3.45	2.94
O-O	4.92	6.71	4.92	6.71	5.815
	5.84	7.66	5.84	7.66	6.75
C-C	1.19	1.21	1.19	1.21	1.205
	2.08	2.18	2.08	2.18	2.13
	2.31	2.69	2.31	2.69	2.50
	2.19	3.05	2.19	3.05	2.62
	2.01	3.09	2.01	3.09	2.55
	1.48	1.51	1.48	1.51	1.495
X-X	1.39	1.47	1.39	1.47	1.43
	1.23	1.97	1.23	1.97	1.60
	1.85	2.15	1.85	2.15	2.0
	2.03	2.21	2.03	2.21	2.12
	1.02	1.13	1.92	2.09	2.05
B-B	1.03	1.16	1.03	1.16	1.095
	1.22	1.42	1.22	1.42	1.32
	1.84	1.87	1.64	1.76	1.71
	1.57	1.71	1.76	1.96	1.86
	1.52	1.76	1.52	1.76	1.64

As can be seen from Table 1 and Figure 3, the value of the suspension concentration increases with depth and obeys the logarithmic distribution law. The maximum measured value of the suspension concentration is located in the confinement section on the verticals 01 and 02 at a depth of 0.8N and, respectively, are equal to 6.71 and 7.66 kg / m^3; the average across the section is 6.28 kg / m^3.

Although the average value of the concentration of suspended matter at the approach site is only 2.475 kg / m^3. Obviously, under the influence of a recently built spur, the flow is saturated with suspended particles due to the erosion of side streams on the left bank and bottom. It should be noted that the nature of the distribution of the suspension concentration along the depth in the form of a "boot" in the area of the weakly disturbed core, established at dam No. 30, is observed here only in the sections P-P and 0-0, and in the rest of the flow in the spreading zone, the concentration distribution is equalized suspension in depth. And the length of the "toe" of the "boot" is much shorter.

The nature of the distribution of suspended matter concentration in depth in the zone of reverse currents on the verticals C1, X1, B1 keeping the general appearance, the difference between and does not exceed 1.1 and 1.15. It should be taken into account that the shallow depths on the X1 and B1 verticals indicate that some sediment deposition has already occurred in the whirlpool zone due to intensive mass exchange (liquid and solid) through the zones of intense turbulent mixing.
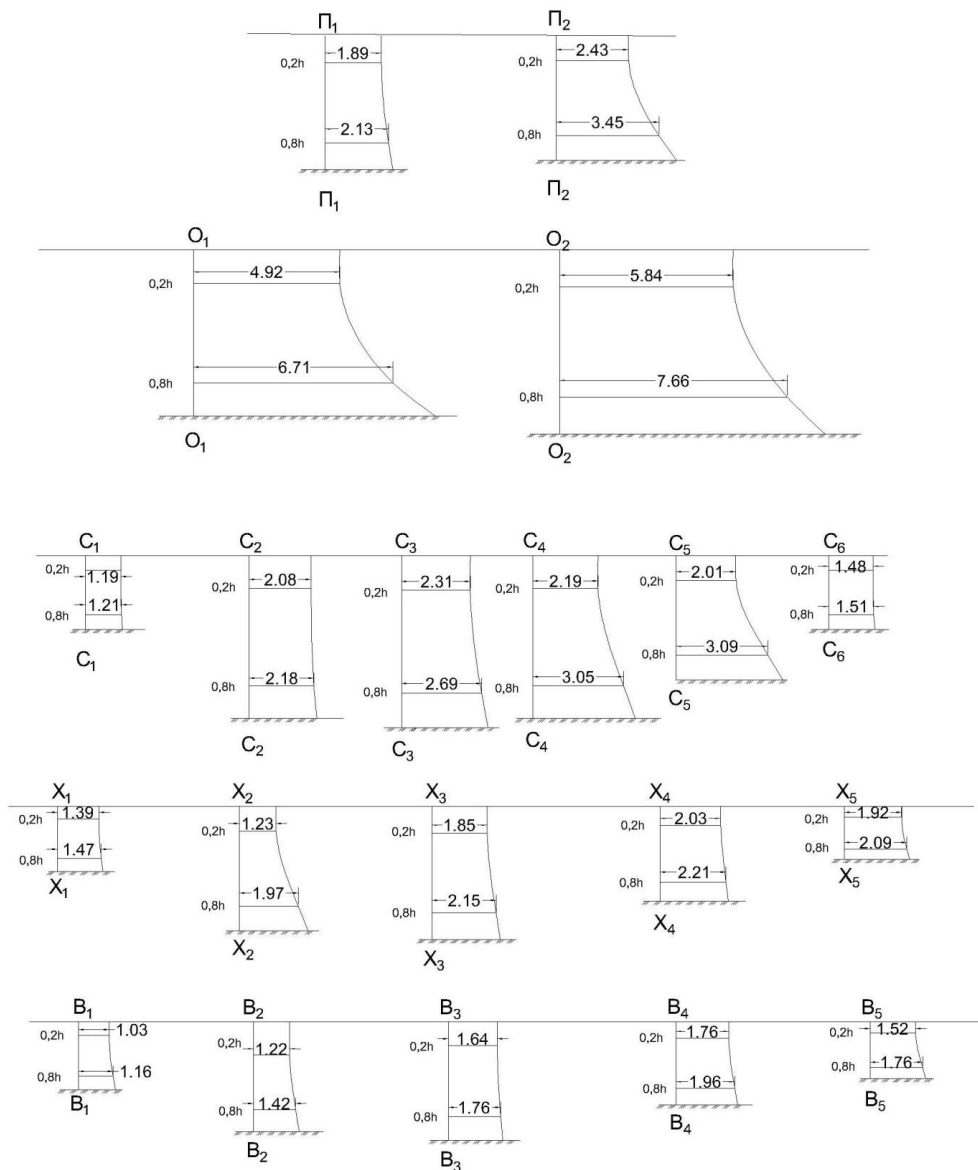
Fig. 3 Distribution of suspended matter concentration along the flow depth in sections П-П, 0-0, C-C, X-X, B-B.

Analysis of the distribution of suspended matter in the plan according to the data in Table 1 and Figure 4 shows that in the zone of the slightly disturbed core behind the section, the O-O constraints decrease from 6.25 to 1.75 kg / m^3.
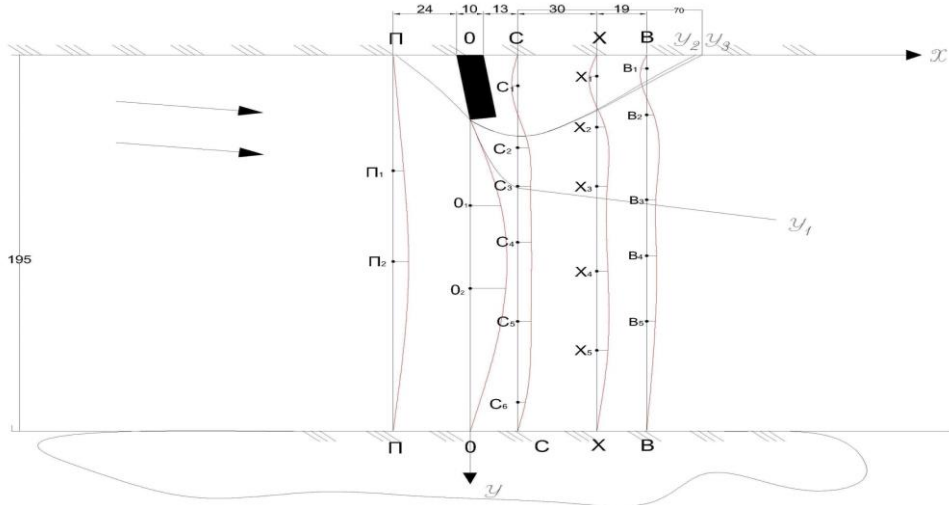
Fig. 4. The distribution of the suspension concentration in the plan

Field studies on dam 30 have substantiated [16] that the distribution of suspension concentration in the zone of intense turbulent mixing obeys the theoretical Schlichting-Abramovich relationship [20,21]

$$\frac{\mu_{\text{я}} - \mu}{\mu_{\text{я}} - \mu_{\text{н}}} = 1 - \eta \qquad (4)$$

where $\mu_{\text{я}}, \mu_{\text{н}}, \mu$ are the concentration of the suspension in the core, in reverse currents

and the zone of intense turbulent mixing; $\eta = \dfrac{y - y}{y_1 - y_2}$ is point relative ordinate, where is

defined μ; y_1, y_2, y are ray ordinates $0^1 - y_1; 0^1 - y_2; 0^1 - y$. Field data on spur 19 from Table 1 were plotted on a graph (Figure 4.) from which it also follows that the distribution of the suspension concentration in the zone of intense turbulent mixing obeys the theoretical Schlichting-Abramovich dependence proposed for the initial section of the jet. The degree of constriction of the flow of spurs 19 is equal to 0.174, which means the flow spreading occurs within the specified area. The maximum deviation from the theoretical one is 15.2%.
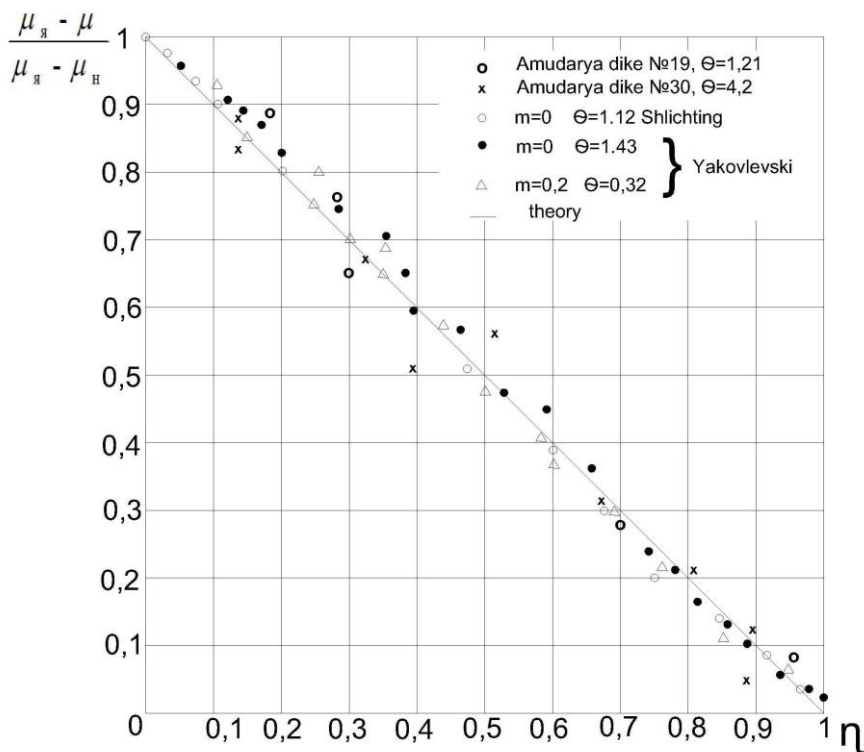
Fig. 4. Distribution of turbidity in the zone of intense turbulent mixing.

4 Discussion

In SANIIRI, a plan has been developed for regulating the Amu Darya river channel from the Tuyamuyun reservoir hydroelectric complex to Cape Kipchak at a length of 185 km. The scheme provides for two-way regulation of the river bed by transverse blind dams, and it is implemented. The dams' body is built of sand, and the head is protected from erosion by rock fill. Due to the increased saturation of the Amu Darya water with suspended sediments reaching up to 12 kg/m^3, intensive siltation of the space between the dams occurs. An acute shortage of water and land resources in the region will lead to developing the space between the dams.

In 2019, we carried out field measurements of the distribution of suspension concentration in the area of dam 30 in the Turtkul section of the river. And in 2020, on the newly built spur 19 on the left bank in the Khazarasp area. Sampling in both cases was performed from a hydrometric boat using a bathometer bottle. Samples were analyzed in the building materials laboratory of the Tashkent Institute of Irrigation and Agricultural Mechanization Engineers. In both studies, the main provisions of the theory of turbulent jets were used, the scheme of dividing the flow into hydraulic homogeneous zones: weakly perturbed core, intense turbulent mixing, and reverse currents. Regularities of the distribution of suspension concentration in the vertical and the plan were obtained.

Both studies confirmed that the distribution of the suspension concentration in the zone of the weakly disturbed core in the plan remains more or less uniform. The zone of intense turbulent mixing is universal and obeys the Schlichting-Abramovich dependence in the initial section.

5 Conclusions

1. Field studies were carried out to establish the regularity of the distribution of suspended matter concentration in a stream deformed by a newly built blind spur 19 on the Amu Darya River.

2. The sampling points were assigned based on the nature of the deformed flow in the headwater at the backwater section, in the confinement and compression sections and the spreading area. The number of verticals was assigned at least two in the zone of intense turbulent mixing.

3. The maximum concentration of suspended matter was observed in the confinement section at a depth of 0.8 N and, respectively, are equal to 6.71 and 7.66 kg / m3. Such saturation of the flow occurred due to erosion of the bottom and lateral side streams resulting from the destruction of the old dam 19.

4. The universality of the distribution of the suspension concentration in the zone of intense turbulent displacement is confirmed and obeys the theoretical dependence of Schlichting Abramovich for the initial section of the jet.

5. Comparing the results of both studies with the results of theoretical and experimental studies gives satisfactory results; the deviation does not exceed 15.2%. It makes it possible to predict the silting up of the space between the dams and organize the protection of a new coastline.

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