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To cite this article: Nazir Ikramov *et al* 2020 *IOP Conf. Ser.: Mater. Sci. Eng.* **869** 072009

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The height of a damless water intake structure threshold

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Abstract. More than 80% of the annual water consumption in Uzbekistan comes from large transboundary rivers such as the Amu Darya and Syr Darya. The rest of the water is formed on the territory of the Republic. Almost all year round, the turbidity of the Amu Darya and Zaravshan rivers is 3÷5 g/l, reaching 15÷18 g/l during flood periods. In most cases, water from the rivers is taken into irrigation channels using damless water intake structures. In order to prevent the ingress of bottom sediments from rivers into channels, thresholds have been constructed at water intake structures, the height of which is set constructively. As a result, bottom sediments pass through thresholds and move along the bottom of channels, reducing their cross-sections, as well as filling the chambers of pumping stations and pressure basins of hydroelectric power plants with sediments. After getting into the flow parts of pipelines and hydraulic machines (pumps and hydraulic turbines), they lead to abrasive wear, as well as other negative consequences. A lot of work has been done to prevent sediment from entering through water intake structures, but so far none of these proposals has provided an effective solution. In the laboratory of the Tashkent Institute of irrigation and agricultural mechanization engineers, a series of experiments were conducted on a glass hydraulic tray to determine the height of bottom sediments, taking into account their heterogeneity. Based on experiments, the dependence on determining the height of the ridge is derived. Based on the obtained dependence, a method for determining the height of the threshold of a damless water intake structure is proposed. This technique was experimentally tested on a laboratory tray. Specifying the threshold height will lead to optimization of capital costs for the construction of the threshold of the water intake structure, as well as reduction of operating costs for cleaning channels from sediment and repair work of hydraulic machines from hydroabrasive wear.

1. Introduction

On average, about 51 billion m³ of water is used annually in Uzbekistan. More than 80% of this volume is formed in neighboring countries and enters the country through such large transboundary rivers as the Amu Darya and Syr Darya [1]. Amu Darya, Syr Darya, Zaravshan, as well as medium and small rivers transport a huge amount of bottom and suspended sediment. Almost all year round, the turbidity of the Amu Darya and Zaravshan rivers is 3÷5 g/l, reaching 15÷18 g/l in flood periods. These sediments enter the irrigation systems of Uzbekistan through a huge number of dams and damless water intakes on rivers and major main canals [2–4]. Numerous laboratory and field studies have proved that the flow rate of bottom sediments moving in the form of bottom ridges in



watercourses is on average 20% of the flow rate of suspended sediments [5,6]. Also, through water intakes, bottom and suspended sediments enter the supply channels of pumping stations and the derivation channels of hydroelectric power plants [7–11]. Passing through the turbines of hydroelectric power plants and pumping units of pumping stations, these sediments lead to abrasive wear of their internal parts and pressure pipelines [12]. This leads to an increase in the operating costs of hydropower facilities [13,14]. In addition, bottom sediments, moving on the bottom of watercourses in the ridge form, fill the channels and the entrance parts of water intake structures [15–17].

The analysis of works [18,19] devoted to free water intake structures showed that the height of the bottom sediment ridges was not taken into account when setting the threshold of the water intake structure. In these works, it is emphasized that the threshold of the water intake structure serves to protect the channel from the ingress of bottom sediments. Various schemes of a water intake structure with thresholds whose height is specified structurally are given. They indicate that the threshold height is set depending on the size and quantity of bottom sediment and often recommend choosing the threshold height before the gateway of the following sizes:

- in the case of sand sediments – $H_{th} = 1,5-2,0$ m;
- in the case of gravel and pebbles sediments – $H_{th} = 1,0-1,5$ m.

This means that the smaller the sediment, the higher the threshold height should be, but the height of the ridge formations is not taken into account when setting the threshold height [18–20].

Some works [17,21] recommend setting these circulation thresholds to reduce the ingress of sediment into the channels. However, even at their optimal installation angle ($\beta = 45^\circ$), the channels cannot be completely protected from bottom sediments. Therefore, determining the optimal height of the threshold of a damless water intake structure is an urgent problem.

2. Materials and methods

The aim of the experimental studies was to assess the effect of various types of heterogeneous sediments of constant size on the height of the ridge. Based on the obtained dependence, the height of the threshold of a damless water intake structure was determined.

The following research objectives were identified:

1. Checking the applicability of the inhomogeneity coefficient of mixtures in the form $\varepsilon = d_{av}/d_i$ with the involvement of the available data on the granulometric composition of heterogeneous bottom sediments.

2. Identification of the relationship between the ridge height and the heterogeneity coefficient of mixtures:

$$h_r = f(\varepsilon = d_{av}/d_i)$$

3. Determining the effect of the average size, sediment composition, and hydraulic flow characteristics on the height of the ridge:

$$h_r = f(H, \mathcal{G}, Q, I, \mathcal{G}_0, d_{av}, d_{max}, d_{av}/d_i)$$

here: d_{av} – the average diameter of the sediment;

d_{max} – the maximum diameter of the sediment;

d_i – particle sizes with the corresponding percentage of security ($i=5, 10, 15, 25, 35, 50, 60, 65, 70, 75, 85, 90, 95$);

\mathcal{G} and \mathcal{G}_0 – average and non-washing flow rate;

H – the average flow depth;

I – slope of the free water surface;

q_s – bottom sediments expense;

ε – coefficient of sediments heterogeneity;

h_r – the ridge height.

Due to the difficulty of assessing the effect of heterogeneity of different types of natural sediments on the formation and movement of bottom ridges in full-scale conditions, the main experiments were performed in the laboratory [22]. Experimental studies were conducted in the laboratory of the Tashkent Institute of irrigation and agricultural mechanization engineers on a hydraulic tray (рис.1).

Artificial mixtures of various types were used as experimental material. Bottom sediments of the Chirchik river in the foothill section of the Gazalkent dam were used as the main experimental material. Types and varieties of manufactured sediments correspond to V.N.Goncharov's classification. Of these varieties of each type, experimental mixtures are taken, which are shown in Table 1, and in Figure 1 in the form of graphs of the granulometric composition of experimental mixtures.

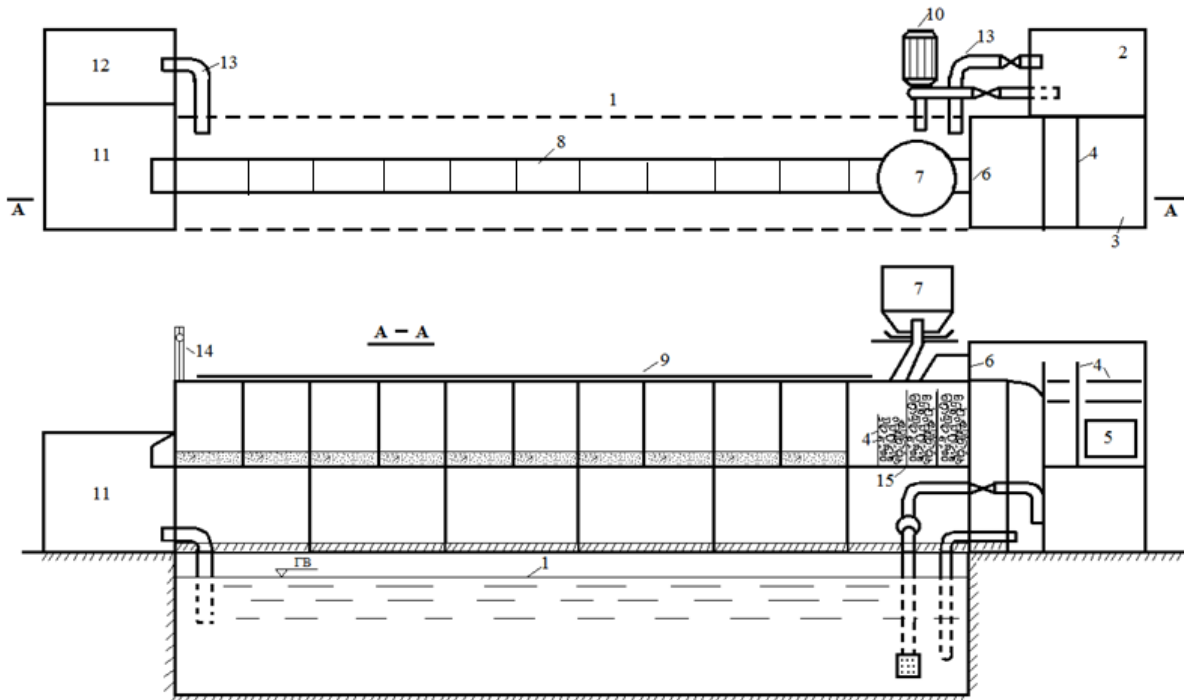


Figure 1. Scheme of a flat glazed experimental unit: 1-main pool; 2-main tank; 3-water intake tank; 4-dampener grids; 5-connecting pipe; 6-spillway; 7-dispenser; 8-tray; 9-rail; 10-centrifugal pump; 11,12-sump pool; 13-return pipes; 14-control panel; 15-chips-dampers.

Table 1. Grain-size distribution of artificially made sediment

No.	Type of sediment	Grain-size distribution in % mass, for particle size in mm								d_{av} (mm)	$\varepsilon = \frac{d_{av}}{d_{50}}$	
		10÷7	7÷5	5÷3	3÷2	2÷1	1÷0,5	0,5÷0,25	0,25÷0,1			<0,1
1	Edge fractioned	-	-	56,75	2,25	2,75	4,5	14,9	14,25	4,6	2,49	0,83
2	Small fractioned	9,5	8,5	8,75	13,75	22,25	14,75	8,75	9,25	4,5	2,51	2,24
3	Large fractioned	-	-	36,5	27	18	11,5	5,07	1,31	0,62	2,53	1,24
4	Evenly fractioned	11,1	10,1	10,1	11,1	11,1	11,1	11,1	12,1	12,2	2,51	2,8
5	Mean fractioned	-	14,4	14,8	15,3	32,7	18,6	2,2	1,25	0,75	2,48	1,88
6	Homogeneous	-	-	-	100	-	-	-	-	-	2,50	1,0

The experimental studies included six series of main experiments. Each series included from ten to fifteen experiments, with water consumption - $Q=5, 10, 15, 20$ l/s. With constant water consumption, only the amount of solid flow rate was changed (from 1 to 6 experiments were conducted). A total of 81 experiments were performed.

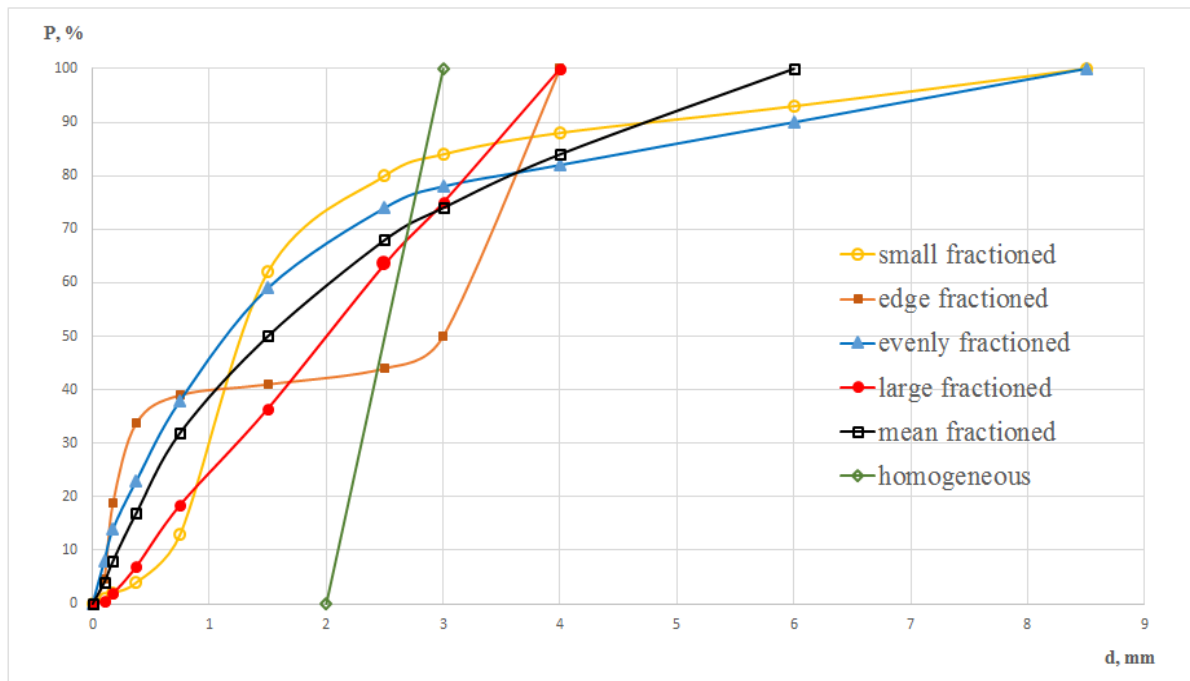


Figure 2. Grain-size distribution of experimented mixtures.

3. Results and Discussion

Determining ridge height in channel flow is necessary for estimating bed roughness in determining channel hydraulic resistance, bedload sediment discharge and channel deformation calculations [22–24], also for setting threshold height in water intake structures, installation depth for pump station exhaust pipes and etc.

In order to set the connection of ridge height of various sediment composition with constant mean particle size and relative flow velocity, from the obtained experimental data we created graphical relationships of $-h_r/d = f(\vartheta/\vartheta_0)$ (Figure 3).

Data analysis of the influence of particle size of sediment on the height of the ridges, depending on ϑ/ϑ_0 $h_r = f(d, \vartheta/\vartheta_0)$ show fine fraction material ($d_i=0,1\div 10,0$ mm; $d_m=2,51$ mm) to experimental data with large fractional material ($d_i=0,1\div 5,0$ mm; $d_m=2,53$ mm), height of ridges with equal values $-\vartheta/\vartheta_0$ tends to decrease. With increasing flow rate, the influence of particle size on the height of the ridges increases. If $\vartheta/\vartheta_0=2,2\div 2,4$ ridges have a maximum height. With a further increase in the ratio of speeds ($\vartheta/\vartheta_0 > 2,4$) ridge height decreases [22]. At the same time, the influence of sediment size also decreases. At values $-\vartheta/\vartheta_0=2,3\div 2,5$ the influence of sediment size on the height of the ridges is insignificant.

The following design formula was obtained on the basis of the analysis of the graphical relationship with accuracy of $0,7\div 0,9$ [22]:

$$\frac{h_r}{d} = -K_g \cdot \left(\frac{\vartheta}{\vartheta_0}\right)^2 + K_H \cdot \left(\frac{\vartheta}{\vartheta_0} - 1,1\right) \quad (1)$$

here: K_g —the proportionality factor for the i -th composition, which, on the basis of the graphical dependence obtained (Figure 4), is determined by the following formula:

$$K_g = 4,38 \cdot e^{0,23 \cdot \varepsilon} \quad (2)$$

K_H —the coefficient depending on the heterogeneity of the ridge, based on the resulting graphical dependence (Figure 5), is determined by the formula:

$$K_H = -9,2\varepsilon^2 + 35,8\varepsilon + 12,7 \quad (3)$$

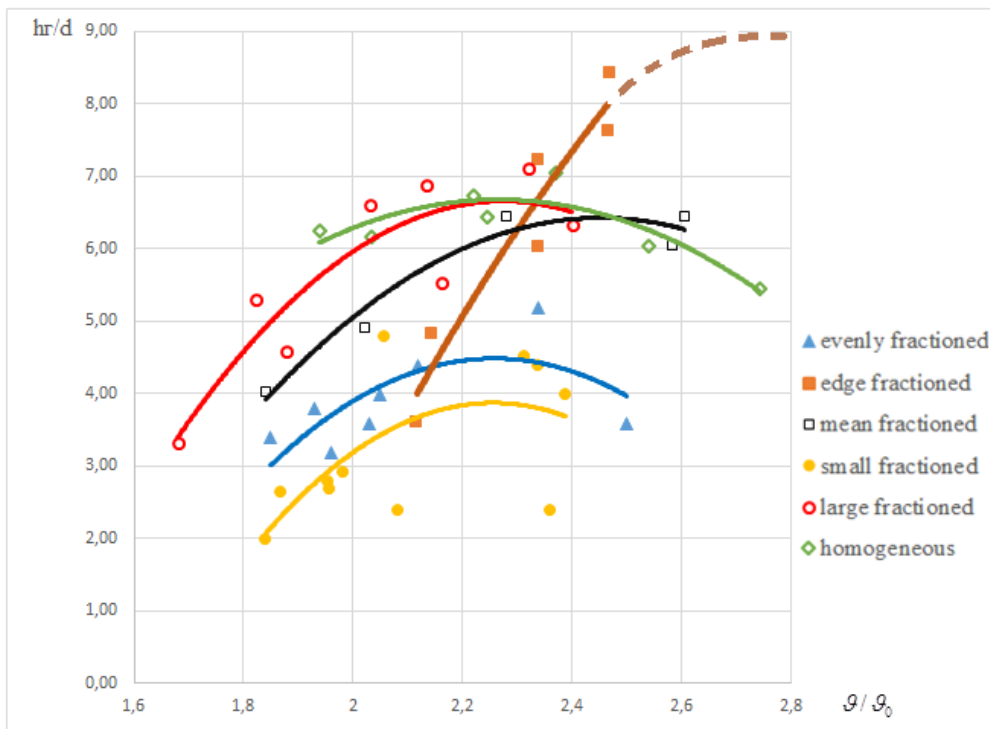


Figure 3. Plot of ridge height and sediment composition to the relative flow velocity.

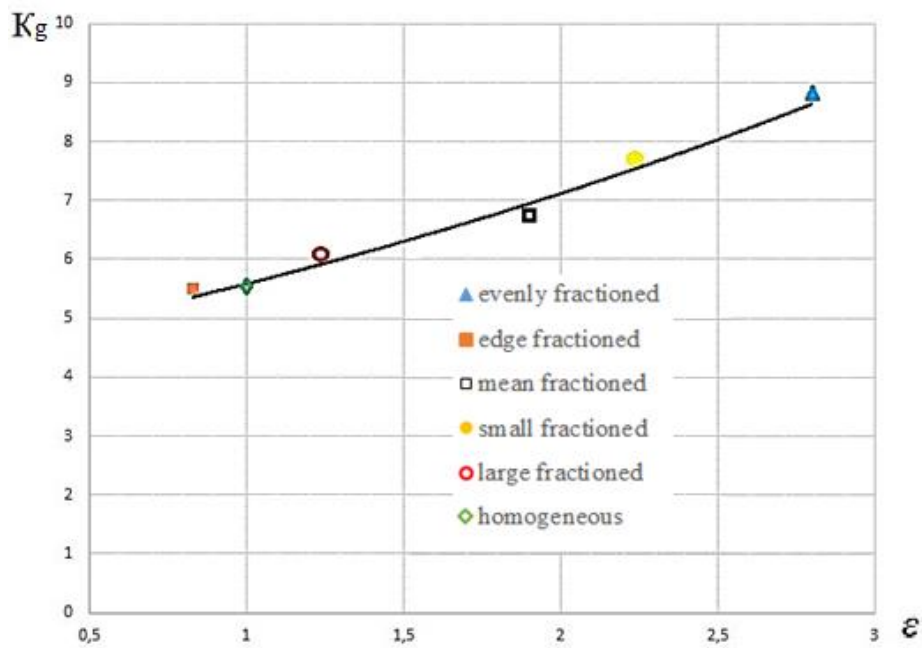


Figure 4. Dependence graph of the coefficient K_g on the heterogeneity of sediment.

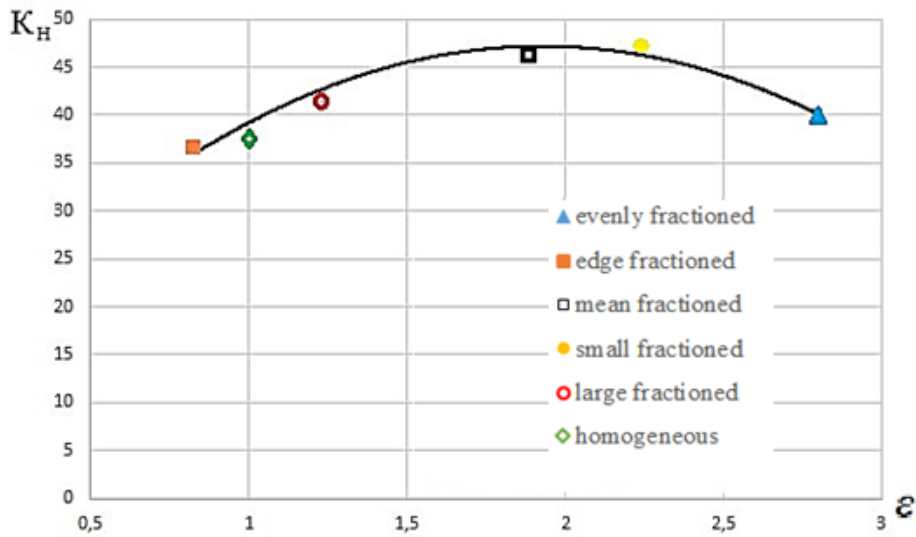


Figure 5. Dependence graph of the coefficient K_H on sediment heterogeneity.

Substituting (2), (3) in (1) we get the following formula:

$$\frac{h_r}{d} = -4,38 \cdot e^{0,23 \cdot \varepsilon} \cdot \left(\frac{\vartheta}{\vartheta_0}\right)^2 - (9,2\varepsilon^2 - 35,8\varepsilon - 12,7) \cdot \left(\frac{\vartheta}{\vartheta_0} - 1,1\right) \quad (4)$$

here:

$$h_r = d \left(-4,38 \cdot e^{0,23 \cdot \varepsilon} \cdot \left(\frac{\vartheta}{\vartheta_0}\right)^2 - (9,2\varepsilon^2 - 35,8\varepsilon - 12,7) \cdot \left(\frac{\vartheta}{\vartheta_0} - 1,1\right) \right) \quad (5)$$

Based on the obtained dependence, a method for determining the threshold height of a damless water intake structure is proposed, since long-term observations of the operation of water intake structures show that the height of the threshold must be taken into account the height of the bottom ridges (Figure 6).

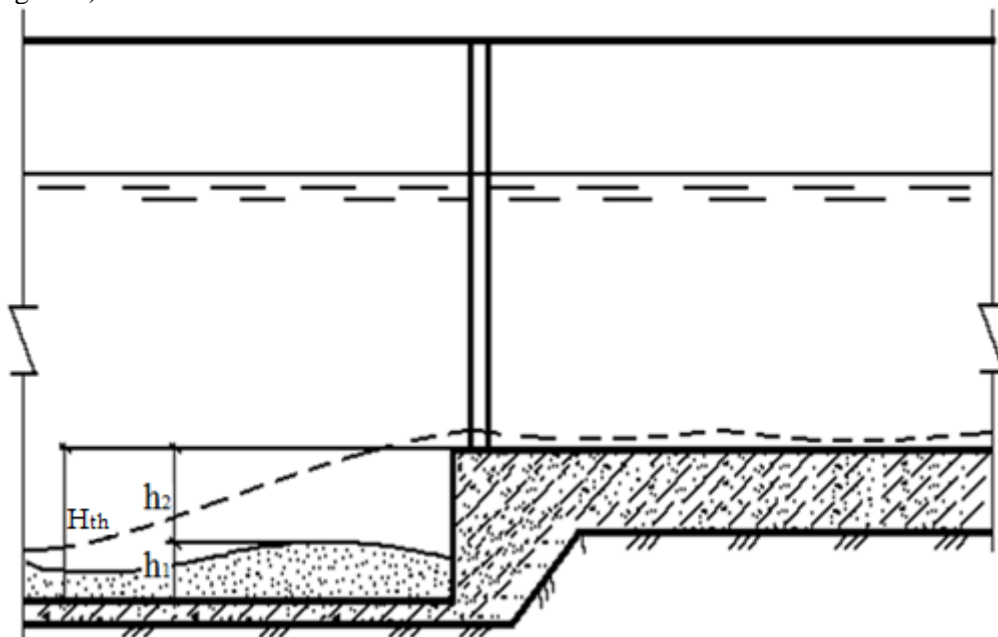


Figure 6. Scheme for determining the height of the threshold, taking into account the bottom ridges.

According to the proposed method, it is recommended to determine the height of the threshold with a ridge bottom using the following formula:

$$H_{th} = h_1 + h_2 \quad (6)$$

here: $h_1 = h_r$ – the height of the bottom ridges, determined by the formula (5).

h_2 – the value that takes into account the ripple (size) of the ridge height, which is recommended to be taken equal based on the conducted experiments:

- for sand sediments - $h_2 = 0,5 \cdot h_r$;
- for gravel and pebble sediments - $h_2 = 0,3 \cdot h_r$.

Application of the recommended method will lead to optimization of capital expenditures for construction of the water intake structure threshold, reduction of silting of irrigation channels, supply channels of pumping stations and derivation channels of hydropower plants, as well as reduction of abrasive wear of hydraulic machines (pumps and hydraulic turbines). As a result, capital expenditures for the construction of a damless water intake threshold will be optimized, and operating costs for cleaning channels from sediment will be reduced, as well as repairs of pumps and hydraulic turbines from hydroabrasive wear and tear.

4. Conclusions

1. The altitude of the ridge sediment will give the opportunity to more optimally determine the height of the threshold of damless intake structures of irrigation canals, supply channels of pumping stations and derivation channels of hydropower plants.
2. Specifying the threshold height will lead to optimization of capital costs for the construction of the water intake structure threshold.
3. Reducing the ingress of bottom sediment into the supply channels will reduce the operating costs of cleaning the channels from sediment, as well as repair work of pumps and hydraulic turbines from hydroabrasive wear.

References

- [1] Ministry of Water Resources Report 2019 Tashkent, Uzbekistan
- [2] Ergashev R, Artikbekova F, Jumabayeva G, and Uljayev F 2019 Problems of water lifting machine systems control in the republic of Uzbekistan with new innovation technology *E3S Web of Conferences* 97
- [3] Shaazizov F, Badalov A, Ergashev A, and Shukurov D 2019 Studies of rational methods of water selection in water intake areas of hydroelectric power plants *E3S Web of Conferences* 97
- [4] Shaazizov F, Uralov B, Shukurov E, and Nasrulin A 2019 Development of the computerized decision-making support system for the prevention and revealing of dangerous zones of flooding *E3S Web of Conferences* 97
- [5] Yan Y and Koplik J 2009 Transport and sedimentation of suspended particles in inertial pressure-driven flow *Phys. Fluids* 21(1)
- [6] Omid M H, Karbasi M, and Farhoudi J 2010 Effects of bed-load movement on flow resistance over bed forms *Sadhana - Acad. Proc. Eng. Sci.* 35(6) pp 681–691
- [7] Yang C T and Marsooli R 2010 Recovery factor for non-equilibrium sedimentation processes *J. Hydraul. Res.* 48(3) pp 409–413
- [8] Castillo L G, Carrillo J M, and García J T 2013 Flow and sediment transport through bottom racks, CFD application and verification with experimental measurements *Proceedings of 2013 IAHR Congress. Tsinghua University Press, Beijing*
- [9] Ruijsscher T V, Hoitink A J, Naqshband S, Paarlberg A J 2019 Bed morphodynamics at the intake of a side channel controlled by sill geometry *Adv. Water Resour.* 134
- [10] Philip H 2004 Alternating bar instabilities in unsteady channel flows over erodible beds *Mechanics* 499 pp 49–73
- [11] Knox E M, Latrubesse R L 2016 A geomorphic approach to the analysis of bedload and bed morphology of the Lower Mississippi River near the Old River Control Structure

- Geomorphology* 268 pp 4–35
- [12] Mamajonov M, Bazarov D R, Uralov B R, Djumabaeva G U, and Rahmatov N 2020 The impact of hydro-wear parts of pumps for operational efficiency of the pumping station *J. Phys. Conf. Ser.* 1425
- [13] Ikramov N, Kan E, Mirzoev M, and Majidov T 2019 Effect of parallel connection of pumping units on operating costs of pumping station *E3S Web of Conferences* 97
- [14] Kan E, Ikramov N, and Mukhammadiev M 2019 The change in the efficiency factor of the pumping unit with a frequency converter *E3S Web of Conferences* 97
- [15] Bazarov D R and Mavlyanova D A 2019 Numerical studies of long-wave processes in the reaches of hydrosystems and reservoirs *Mag. Civ. Eng.* 87(3) pp 123–135
- [16] Bazarov D, Shodiev B, Norkulov B, Kurbanova U, and Ashirov B 2019 Aspects of the extension of forty exploitation of bulk reservoirs for irrigation and hydropower purposes *E3S Web of Conferences* 97
- [17] Khidirov S, Berdiev M, Norkulov B, Rakhimov N, and Raimova I 2019 Management exploitation condition of Amu-Bukhara machine channel *E3S Web of Conferences* 97
- [18] Rasskazov L N, etc 2011 *Hydrotechnical constructions (on rivers)* Associations of construction universities Moscow p 537
- [19] Nesterov M V 2018 *Hydrotechnical constructions* Infra-M Moscow p 601
- [20] Khetsuriani E D, Kostyukov V P, Ugrovatova E G 2016 Hydrological Studies on the River Don around the Alexandrovsky OSV Water-Intake Facilities *Procedia Eng.* 150
- [21] Kloovsky A V, Rumyantsev I S, Kozlov D V 2015 Some ways to improve the hydraulic working conditions of damless intake waterworks with bottom circulation thresholds *Environ. Manage.* 3 pp 45–52
- [22] Ikramov N 2018 *Dissertation of the doctor of philosophy (PhD) on technical sciences.* TIIAME Tashkent p 116
- [23] Samokhvalova O A 2011 Calculation of the height of sand ridges in large and small plain rivers *Bull. St. Petersburg. State Univ.* 4(7) pp 135–148
- [24] Khodzinskaya A G and Verbitskii V S 2019 Determination of the Discharge of Bottom Sediments in River Beds Composed of Soil of Varying Grain Size *Power Technol. Eng.* 52(6) pp 669–674