A mathematical model for predicting the deformation of the hydraulic model of the dynamics of water flow and morphological parameters of the riverbed in small mountain rivers

Furkat Gapparov[1], *Ilkhomjon* Makhmudov[2], *Mushtariybonu* Gafforova[1*], and *Tursunoy* Apakhodjaeva[1]

[1]Tashkent Institute of Irrigation and Agricultural Mechanization Engineers" National Research University, Department of Department of Hydraulics and Hydroinformatics 39-Kary-Niazev Str., 100000, Tashkent, Uzbekistan

[2]Ministry of Water Resources of the Republic of Uzbekistan, Scientific Research Institute of Irrigation and Water Problems, Tashkent, 100187, Uzbekistan

Abstract. In this article, the changes of the bed of the Govasoy river, which is one of the small mountain rivers, due to the influence of constructions and the formation of the sedimentation layer are studied on the basis of field studies. The mathematical model of predicting the deformation of water flow dynamics and the processes of the bed, and the experimental results are compared with numerical solutions. Information on the territorial division of irrigation networks and water consumers in the Govasay river basin, as well as their digital maps, was created on the basis of geo-information technology. The program was developed to ensure the rapid management of water resources.

1 Introduction

In the world, small mountain riverbeds are a complex natural object related to the formation of fluvial relief and riverbed landscape dynamics-exogenous processes. In the world, special importance is attached to the issues of river flow correction, the processes taking place in the river bed, and the study of problems in getting water from the river. In this regard, special attention is being paid to the improvement of the methods of calculating the bed deformation in these water bodies, the effective management of water resources in small mountain rivers and the application of geo-information technologies in their rational use [1].

On hydraulic and hydrological processes in the riverbed I.V. Egiazarov, K. A. Einstein, G. I. Shamov, I. I. Levi, E. Meyer-Peter, K. F. Artamonov, A. Yu. Umarov, V .F. Talmaza, A.N. Kroshkin, A.B. Kitaev, S.N. Kritsky, Yu.M. Matarzin, M.F. Menkel, D.A. Nikiforova, E.E. Ovcharov, Ya.F. .Pleshkov, Sh.R. Pozdnyakov, L.V. Potapova, M.Ya. Prytkov, A.D.

---

* Corresponding author: ga.furqat@gmail.com

Savarensky, X.A. Ismagilov, VM.R. Bakiev, E.J. Makhmudov, F. Khikmatov, who have conducted research and achieved certain positive results [6].

Despite the conducted research, creating an improved system of rational management and use of water resources in the basins of small mountain rivers, improving hydraulic methods for calculating the deformation parameters of the beds of small mountain rivers, using modern information technologies in water resources management, rapid management of water resources of the river basin based on the territorial division of water consumers scientific and technical issues related to implementation have not been sufficiently studied [4].

2 Methods and materials

Field studies were carried out in order to study the dynamics of water flow and the deformation of riverbed processes in the Ghovasay river. Based on the method of conducting field research, four calculation blocks were determined in the upper part of the Govasoy hydroelectric reservoir. The distance between the dams is 200 meters, and the order number of the dams is numbered from the upper part of the water flow to the hydroelectric station. The values of the water flow and morphological parameters in each of the calculation plots were carried out using a Deeper CHIRP+ echo-doppler with a modern GPS device. Measurements were carried out to determine water consumption and morphological parameters using Deeper CHIRP+ echo-Doppler with GPS device (Figure 1) [4].
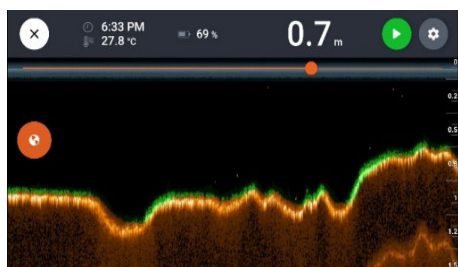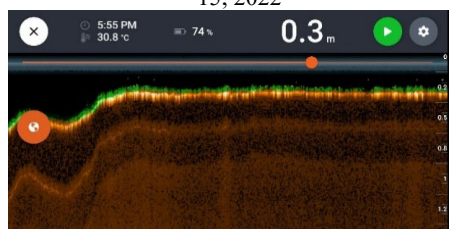

a) (3-3) wall, May 25, 2021 b) (3-3) square, May 15, 2022
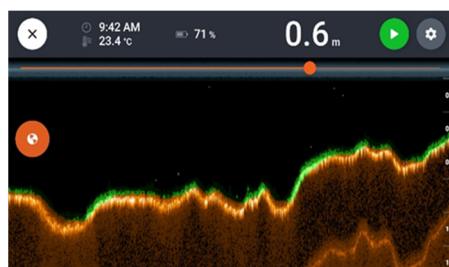
b) (3-3) wall, May 25, 2021 b) (3-3) wall, May 15, 2022
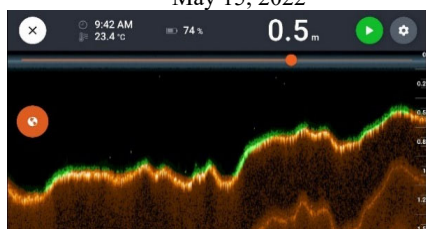
c) (4-4) wall, May 25, 2021 c) (4-4) wall, May 15, 2022

d) (4-4) wall, May 25, 2021 c) (4-4) wall, May 15, 2022

Fig. 1. Dynamics of sedimentation layer formation on walls.

3 Results and discussion

The dynamics of the main parameters of the water flow and the morphology of the channel in the calculation walls in the upper part of the Govasay hydroelectric network are presented in Table 1 [6].

Table 1. Dynamics of water flow depth and sedimentation thickness in the calculated walls.

Walls	Years	The average depth of the water flow, m	Average thickness of sedimentation, m
wall 1	2021	0.93	0.41
	2022	0.65	0.53
wall 2	2021	0.57	0.5
	2022	0.55	0.61
wall 3	2021	0.64	0.55
	2022	0.55	0.79
wall 4	2021	0.47	0.81
	2022	0.26	1.16

The results of the experimental studies of the main parameters of the water flow and the morphology of the river bed in the upper reservoirs of the Ghovasay hydroelectric network show that for two years, the thickness of the mud in the 1st reservoir is 12 cm, 11 cm in the 2nd reservoir, 24 cm in the 3rd reservoir, and 35 cm in the 4th reservoir. increased [4,5].

In order to develop a mathematical model for forecasting the dynamics of water flow and the deformation of riverbed processes in the Govasay River, the special derivative one-dimensional Eksner equation system was written in the following form: [1,3]

$$\left. \begin{array}{c} \frac{\partial h}{\partial t} + S \cdot B \cdot \frac{\partial u}{\partial x} = -K \cdot S \\ \frac{\partial z_{bottom}}{\partial t} = K \cdot S + \frac{1-m}{l} \cdot D \cdot \frac{\partial z_{bottom}}{\partial x} \end{array} \right\} \qquad (1)$$

Here: t – time; x - coordinate axis; h - flow depth; u-water flow rate; K is the coefficient characterizing the intensity of vertical exchange of turbidity in the river bed and stream; m - porosity of rocks with sedimentation at the bottom of the bed; D - diffusion coefficient; ∂z_{bottom} – the mark of the bottom of the riverbed; l - the length of the river section; S is the volumetric concentration of turbidity in the stream; B-flow width. [4,5]

We write the system of equations (1) in the following form:

$$\frac{\partial}{\partial t}(z_{bottom} + h) = \frac{1-m}{l} \cdot D \cdot \frac{\partial z_{bottom}}{\partial x} - S \cdot B \cdot \frac{\partial u}{\partial x} \qquad (2)$$

here: $z = z_{bottom} + h$ - height condition;

$\frac{\partial z_{bottom}}{\partial x} = -i$ - the slope of the river bed;

Then equation (2) becomes:

$$\frac{\partial z}{\partial t} + S \cdot B \cdot \frac{\partial u}{\partial x} = D \cdot \frac{1-m}{l} \cdot i \qquad (3)$$

(3) the parameter S in the equation is found based on Begnold's formula, i.e:

$$S = \frac{\rho_{water}}{2\rho_{mud}} \cdot \frac{u^2}{gh}\left(\frac{0,13}{tg\varphi} + 0,01\right) \qquad (4)$$

here: φ – sonar-Doppler beam angle (7^0), ρ_{water} - density of water; ρ_{mud} – the density of the turbidity; u – average speed of flow; g – free fall acceleration; h - flow depth.

We express the u-function in equation (3) in the following form based on the expression proposed by V.N. Goncharov-Ts.E. Mirtskhulova:

$$u = \sqrt{\frac{2}{3.5} \cdot g \cdot d} \cdot lg\left(\frac{8.8}{d} \cdot x\right) \qquad (5)$$

Considering expressions (4) and (5), equation (3) becomes as follows:

$$\frac{\partial z}{\partial t} + \frac{B}{2} \cdot \frac{\rho_{water}}{\rho_{mud}} \cdot \sqrt{\left(\frac{2}{3.5} \cdot g \cdot d\right)^3} \cdot lg^2\left(\frac{8.8}{d} \cdot x\right) \cdot \frac{\left[\frac{0.13}{tg\varphi} + 0.01\right]}{g \cdot h \frac{8.8}{d} \cdot x \cdot ln10} = D \cdot \frac{1-m}{l} \cdot i \qquad (6)$$

$\frac{\partial z}{\partial t} \approx \frac{dz}{dt}$ taking into account, the integral of equation (2) will have the following form:

$$z = \int \left[D \cdot \frac{1-m}{l} \cdot i - \left(\frac{B}{2} \cdot \frac{\rho_{water}}{\rho_{mud}} \cdot \sqrt{\left(\frac{2}{3.5} \cdot g \cdot d\right)^3} \cdot lg^2 \left(\frac{8.8}{d} \cdot x\right) \cdot \frac{\left[\frac{0.13}{tg\varphi}+0.01\right]}{g \cdot h \cdot \frac{8.8}{d} x \cdot ln10} \right) \right] dt + c$$

or

$$z = \frac{D \cdot \frac{1-m}{l} \cdot i - \left(\frac{B}{2} \cdot \frac{\rho_{water}}{\rho_{mud}} \cdot \sqrt{\left(\frac{2}{3,5} g \cdot d\right)^3 \cdot lg^2 \left(\frac{8.8}{d} x\right) \cdot \left(\frac{0.13}{tg\varphi}+0.01\right)} \right)}{\frac{8.8}{d} \cdot g \cdot h \cdot x \cdot ln10} \cdot t + C \qquad (7)$$

As a result, we got the expression (7) expressing the height condition.

$Z_{bottom}=z-h$ if we take into account, then we will have the following equation representing the dynamics of turbid sediments formed in the river bed:

$$z_{mud} = \frac{D \cdot \frac{1-m}{l} \cdot i - \left(\frac{B}{2} \cdot \frac{\rho_{water}}{\rho_{mud}} \cdot \sqrt{\left(\frac{2}{3,5} g \cdot d\right)^3 \cdot lg^2 \left(\frac{8.8}{d} x\right) \cdot \left(\frac{0.13}{tg\varphi}+0.01\right)} \right)}{\frac{8.8}{d} \cdot g \cdot h \cdot x \cdot ln_{10}} - h + C \qquad (8)$$

Based on the experimental values of the hydraulic parameters of the flow and the morphological parameters of the riverbed in the upper part of the Govasoy hydrogrid, we will carry out the numerical experiment of equation (8). The error of comparing numerical and experimental results was 4% (Figure 2) [3].
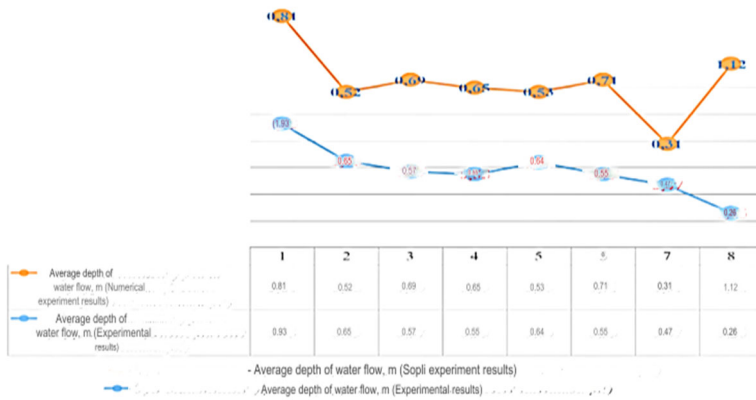

	1	2	3	4	5	6	7	8
Average depth of water flow, m (Numerical experiment results)	0.81	0.52	0.69	0.65	0.53	0.71	0.31	1.12
Average depth of water flow, m (Experimental results)	0.93	0.65	0.57	0.55	0.64	0.55	0.47	0.26

- Average depth of water flow, m (Sopli experiment results)
- Average depth of water flow, m (Experimental results)

Fig. 2. A graph comparing the results of the experiment with numerical solutions to determine the average depth of the water flow.

	1	2	3	4	5	6	7	8
Average thickness of sedimentation, m (Experimental results)		0.53		0.85		0.79		1.16
Average thickness of sedimentation, m (Numerical experiment results)		0.47		0.49		0.86		0.97

- Average thickness of sedimentation, m (Experimental results)
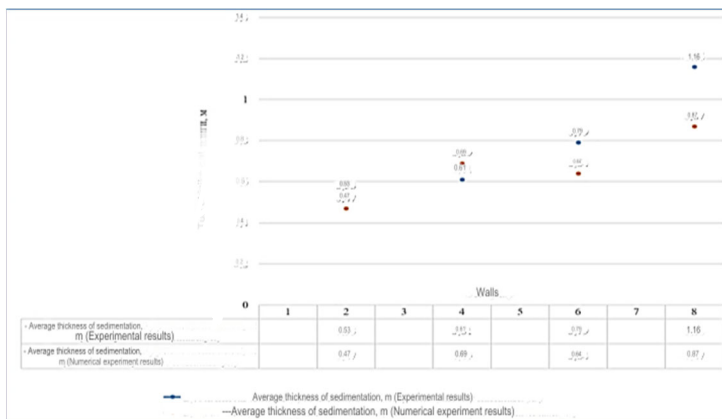- Average thickness of sedimentation, m (Numerical experiment results)

Fig. 3. Comparison graph of the results of the experiment conducted on the study of the dynamics of sedimentation in Uzan with the results of the numerical experiment.

The Govasay small river basin is formed from the flow of erosive waters, and the main part of the river water is used to irrigate the lands of Chust district. There are 98 water intake structures, 89 hydroposts, 8 main canal structures and other structures in the Govasay river basin. A digital map of the scheme of irrigation networks and territorial division of water consumers in the Ghovasay river basin was developed (Figure 4) [2].
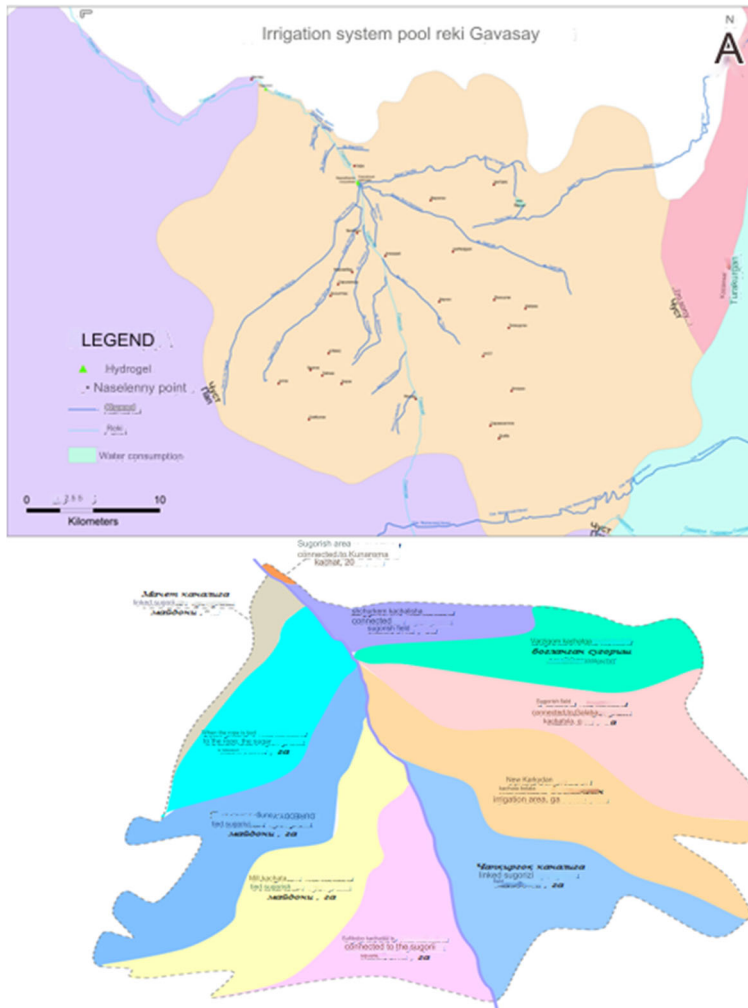

Fig. 4. Scheme of irrigation networks in the Ghovasay river basin and regional distribution map of water consumers in the basin.

Implementation of rapid management of water resources and improvement of accounting of water transported through irrigation networks play an important role in improving the use of water resources in the Govasay river basin.

MS Access was chosen as the subject of the software and database, and Delphi programming language was chosen as the programming language [7].

The developed software automatically calculates the water distribution. If there is an excess of water in the distribution, it will be directed to the Vorzik reservoir, and on the contrary, if the amount of water is less than the need, it will be warned about it.

4 Conclusion

In 2021-2022, according to the results of the experimental studies of the hydraulic and morphological parameters of the flow in the upper part of the Govasoy hydroelectric system, the thickness of the mud in the upper part of the upper part of the Govasoy hydroelectric system was 12 cm on average, 11 cm in the 2nd part, and 24 cm in the 3rd part. and in the 4th stage it increased by 35 cm.

Based on the system of Eksner equations, a mathematical model for forecasting the dynamics of water flow and the deformation of riverbed processes in the Govasoy river was developed [8].

The water balance of the Ghovasay river basin was developed. Based on the improved models, the models that can ensure the rational and efficient use of water resources in various situations were improved, and the Visual Basic computer program was developed. The software serves as a practical development in the implementation of the rapid management of water resources of the river basin, the organization of reliable monitoring of the river flow, and the improvement of the accuracy of the calculation of water balance indicators.

References

1. F.A. Gapparov, J. Abdullaev, *Organization of safe use of Tudakul reservoir*, Proceedings of the republican scientific and practical conference dedicated to the year of youth (Tashkent, 2008), p. 76-78

2. I. Ruziev, L. Samiev, D. Mustafoyeva, S. Nortaev, S. Yakhshiev, E3S Web of Conferences **371** 01013 (2023).

3. Y.S. Sheralievich, Journal of engineering, mechanics and modern architecture **2(6)**, 85-89 (2023)

4. M.F. G'affarova, Sh. Yaxshiyev, D. Yoshiyeva, International journal of agrobiotechnology and veterinary medicine **1** (2023).
   https://doi.org/10.5281/zenodo.7676372

5. Sh.Sh. Yaxshiyev, Models and methods for increasing the efficiency of innovative research **2(22)**, 29-35 (2023)

6. F. Gapparov, A. Khaydarov, L. Kogutenko, M. Gafforova, E3S Web of Conferences **401** 03074 (2023).

7. A. Khaydarov, T. Apakxujayeva, D. Atakulov, E3S Web of Conferences **401** 01013 (2023)

8. F. Gapparov, A. Khaidarov, S. Yakhshiev, M. Gafforova, D. Atakulov, Journal of Advanced Zoology **44(S-3)**, 955-967 (2023).