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The hydraulic efficiency of the soil channels

A Fatxulloyev[1]*, A Gafarova[1], M Otakhonov and D Allayorov[1]

[1]Tashkent Institute of Irrigation and Agricultural Mechanization Engineers, Tashkent, Uzbekistan

a.fatxulloyev@tiiame.uz

Abstract. The article is devoted to the improvement of hydraulic efficiency and exploitation reliability by improving the hydraulic parameters of soil irrigation channels, and given the results of the authors' research in theoretical and natural conditions. The article illustrates the analyses of the current problems in the existing soil canals and their negative consequences due to the deformation processes in the channel bed and consequently the increase in flow dynamics and kinematics of hydraulic resistance. Based on the analysis of the results which conducted by Altunin V.S. Zheleznyakov G.V. Karasev I.F. Kosichenko Yu.M. and Mirtshulava Ts.E. in the assessment of hydraulic efficiency and exploitation reliability of the channels, the hydraulic efficiency and operational reliability of the canals have been evaluated. Researchers conducted in Tashkent and Big Fergana canals, which are located in different natural and geographical conditions. The study of deformation processes in soil channel bed provided with the help of XSLEM-Doppler (River Surveyor Live), the formation of flow dynamics and kinematics, and the activation of hydraulic resistance. Based on the study of the kinematic parameters of flow created a velocity diagram expressing the distribution of velocities by the depth of flow in the soil channel in natural conditions. The hydraulic friction coefficients for the Tashkent and Big Fergana canals were determined using the kinematic parameters obtained with the help of River Surveyor Live in natural field conditions, as well as the water permeability of the canals was assessed. Also, the speed diagram, which is one of the most serious problems of hydrodynamics, was built based on data obtained with the help of modern measuring instruments. Also, the study of the formation of kinematic and dynamic parameters in soil-based irrigation canals and the improvement of hydraulic parameters of irrigation canals based on conditions of hydraulic efficiency and operational reliability were concluded. The results of the study are important in the effective use of soil irrigation canals, increasing the reliability of water supply to consumers.

1. Introduction

The deformation processes in the irrigation canals, the sedimentation of the river and the development of the algae in the river, and the exploitation mode and conditions will greatly reduce the water capacity. Changing these parameters to the project-ed parameters will result in a changing of the channel coefficients relative to the projected amount and, as a result, to increase in hydraulic resistance. Therefore, ignoring these factors in the ground channels, first of all, leads to a decrease in the reliability of efficient use of the canals [4, 5, 8, 19, 20].

Although much research has been done on the hydraulic calculation of canals, there are still many issues to be addressed [5, 7]. These include methods for assessing hydraulic efficiency and reliability in the use of canals for many years. At the same time, the regime of changing the channel exploitation in recent years, that is, the operation of major trunk channels throughout the year reduces the possibility of scheduled repair and restoration works. As a consequence, problems such as increased deformation of channels, reduced capacity of canals, and development of algae in the streams affect the reliability of the canals [6, 9, 10, 11].

2. Methods

The above-mentioned problems require the improvement of methods and criteria for evaluating the hydraulic efficiency and efficiency of the soil channels. This research can be traced in the studies of Altunin B.S. [1], Karasev I.F. [21], Kosichenko Yu.M. [22, 23], Mirtshulava Ts.E. [24], and others.

Summarizing these studies and based on studies conducted in the Big Fergana Canal (BFC) and the Tashkent Main Canal (TMC) under natural conditions, we provide the following links [17, 18, 22, 23].

By the capacity of channels:

$$a'Q_p \le Q \le Q_p \tag{1}$$

Allowable speed:

$$\vartheta_m \le \vartheta \le \vartheta_m \tag{2}$$

Relative width:

$$\beta_{a.h.} \le \beta \le \beta_{\max} \tag{3}$$

On the ratio of useful work:

$$\beta'\eta_{ac} \le \eta \le \eta_{ac} \tag{4}$$

By technical condition:

$$\sigma' P_{r.t.c.c.} \le P_{i.o.d} \le P_{r.t.c.c.} \tag{5}$$

Safe operation:

$$P_{ac.nor} \le P_{ac.} \le P_{\max} \tag{6}$$

There: $Q \le Q_p$ is the actual and project water discharge, m^3/sec;

α' is the reduction of water capacity due to factors not taken into account when the channel is operating normally;

$\alpha' = \frac{n_p}{n}$ (n_p is the projected coefficient, n- the coefficient of graininess, determined in natural and field conditions;

$\vartheta, \vartheta_m, \vartheta_m$ are permissible mean, muddy and non-washable velocities in the channel;

$\beta = \beta_{a.h.}, \beta_{\max}$ is the maximum relative width of the channel, which corresponds to the available hydraulic cross-section;

$\beta = B / h$, B is the width of the channel by the water level;

η, η_{ac} is the actual and project cost-effectiveness of the channel;

β' is the factor that reduces the efficiency of the channel due to factors not taken into account in the operation $\beta' = \frac{\eta}{\eta_p}$;

$P_{i.o.d}, P_{r.t.c.c.}$ is the indication of design and required technical condition of the channel;

σ' is the coefficient reducing channel technical condition;

$P_{ac.}, P_{ac.nor}, P_{\max}$ are the indications of the actual, normal and maximum safe operation of the channel, (uninterrupted operation);

It should be noted that in order to assess the hydraulic efficiency and operational reliability of the channels α', β', σ', it is necessary to take into account the development of algae in the river, river washout and mudflow, river channel degradation, and other factors.

To assess the hydraulic efficiency and operational reliability of the canals under the existing criteria, it is necessary to determine the coefficients α', β', σ' and on the basis of according to numerous natural field data and design data.

$\alpha' = \frac{n_p}{n}$ is the decrease in water capacity due to factors not taken into account when the channel is operating normally, BFC based on observational data from natural field conditions (PK2105+00÷2174+80) for $\alpha' = \frac{n_p}{n} = 0.86$, Tashkent main channel (PK 38+47÷321+60) for $\alpha' = 0.96g$ was calculated [12, 14, 16].

The main indicator of the hydraulic efficiency of the channels, and the capacity of the canal, we also encounter a number of problematic issues. In particular, the design of canals is used as a condition for the determination of the flow capacity of a stream using a flat-temperature equation, the Shezhi formula:

$$Q = \omega \cdot C \cdot \sqrt{RJ} \tag{7}$$

There: ω is the cross-sectional surface, m^2;

C is the Shezhi coefficient, $m^{0.5}$/sec;

R is the Hydraulic radius, m;

J is the Hydraulic slope.

Although it is possible to determine the parameters of the equation (ω, R, J) to determine the hydraulic efficiency of the channels under natural-field conditions, the Shezhe coefficient C requires separate studies [2, 3, 13, 15]. The results of research on the study of hydraulic resistance (C) in open streams have suggested about 300 empirical connections to determine C. The Manning and Pavlovsky formulas are used to determine C in the hydraulic calculation of channels [CR and R (Construction rules and regulations)].

Studies of hydraulic resistance in soil channels were carried out at the research facilities in the field.

It is known that hydraulic resistance is directly dependent on the type of soil that forms the channel bed and the flow rate. Although the soil type for a particular section of the canal under study is virtually unchanged, the kinematic characteristics of the flow can be drastically changed as a result of deformation processes. Studying kinematic characteristics of flow in natural conditions depends on the modernity of measuring devices, accuracy, and reliability of measurements.

3. Results and Discussion

Field research at the research area was provided with analyses equipment XSLEM-Doppler (River Surveyor Live) device of SonTek, USA (Figures 1-2). The results obtained by River Surveyor Live are shown in (Figure 3-4).

Figure 1. Doppler survey of the large Fergana channel PK 2270+64

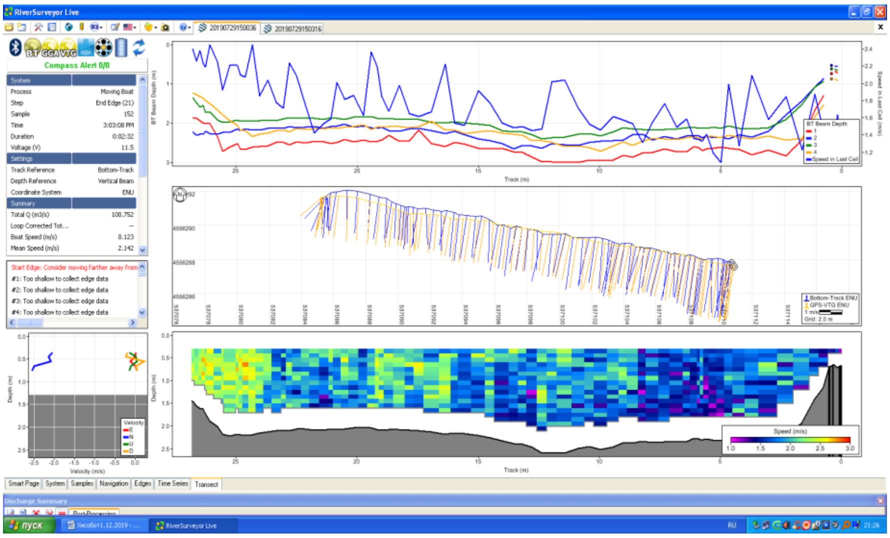

Figure 2. Tashkent main channel PK 1+00

The results of the observations presented in Figures 1-2 show the structure of kinematic parameters of the turbulent flow (1.0 sm^2) in the cross-section of the flow, the formation of flow cross-section in the natural environment, and the flow kinematics to assess the hydraulic resistance.

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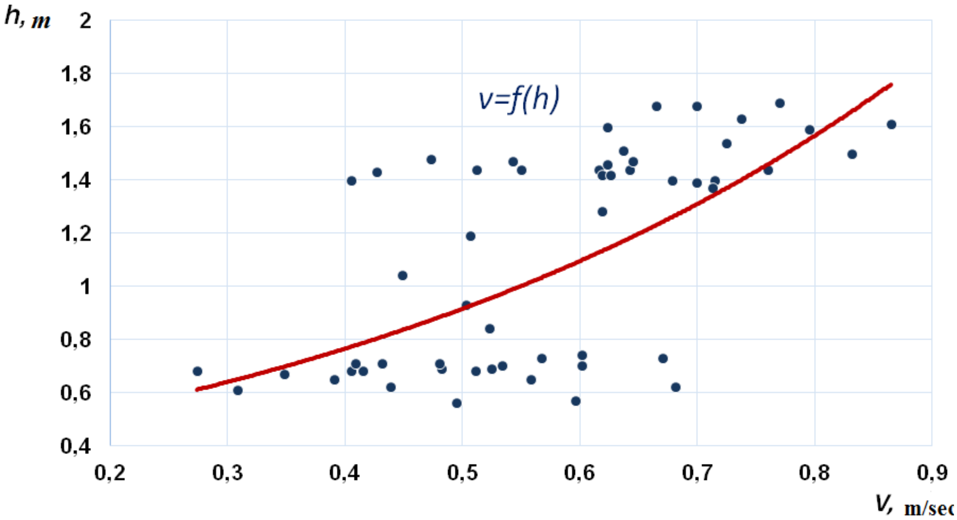

Figure 3. Speed area at the Big Fergana channel PK 2270+64

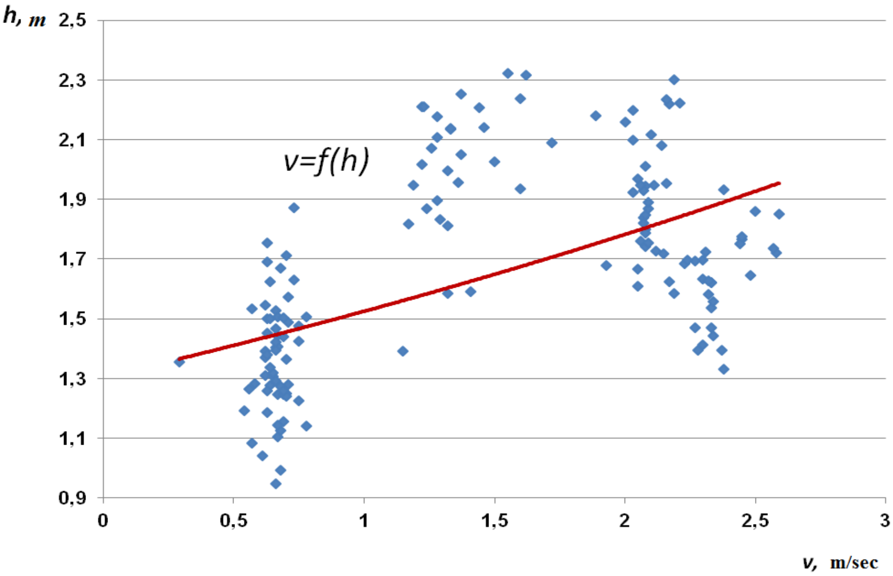

Figure 4. Speed area at PK1+00 Tashkent Main Channel

Figures 3-4 represent the open-stream distribution of flow speed through channels. Using the velocity data we determine the hydraulic resistance coefficient C. We perform the calculations in Table 1 below.

Table 1. Results of the calculation of hydraulic resistance

Channel title	Project information			Measured data		
	ϑ_{Med} m/sec	R, m	C	ϑ_{Med} m/sec	R, m	C
Big Fergana Channel PK 2270+64	0.95	0.9	72.6	0.57	1.26	36.8
Big Fergana Channel PK 2000+30	0.99	1.01	80.4	0.59	1.48	42.9
Tashkent Main Channel PK 1+000	1.14	1.22	118.7	1.66	1.81	104.2

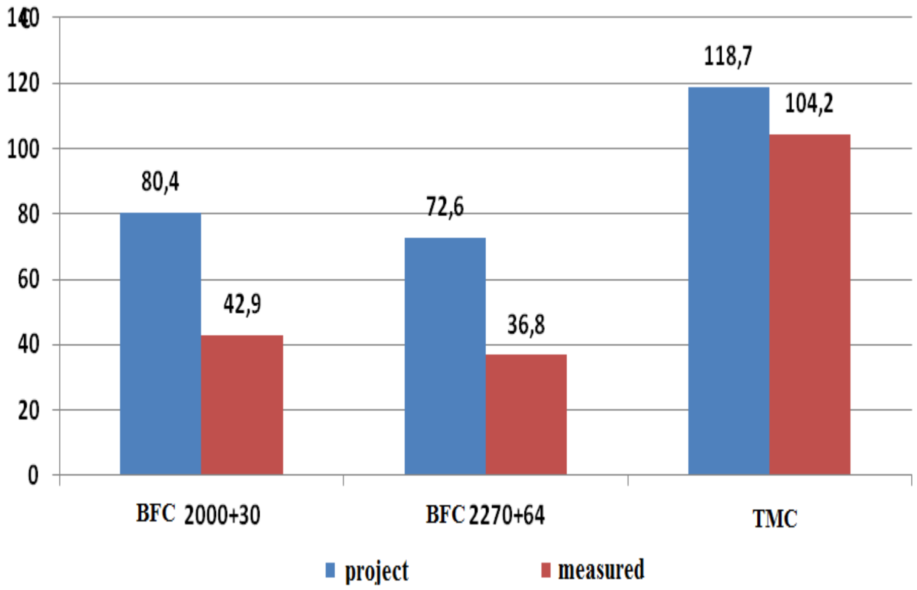

Figure 5. Study of hydraulic resistance in research area

4. Conclusions

Studies of hydraulic resistance in irrigation channels show that in all cases we can see that the hydraulic resistance is lower than the projected value. There results to decrease the capacity of the canals.

The aforementioned facts are also evident through the reduction of the channel's exploitation coefficient as the main criterion for evaluating the hydraulic efficiency and operational reliability of the channels. Increased hydraulic resistance in the river accelerates the filtration process, resulting in increased water losses. Therefore, the loss of canal water can be evaluated directly by the channel's exploitation coefficient, as well as deformation processes such as the development, muddiness, and washing of algae in the river also increase hydraulic resistance.

Therefore, if we accept the channel's coefficient of efficiency (C.O.E.) as a condition for ensuring the hydraulic efficiency and operational reliability of the channels, a sufficient basis for the evaluation of hydraulic efficiency and operational reliability will be established.

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