ANALYSIS OF STUDIES ON BED DEFORMATIONS AND FLOW PARAMETER CALCULATIONS IN DIVIDING CHANNELS

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Abstract: This article analyzes one of the complex problems of open-channel hydraulics: channel deformations caused by turbulent flows at the entrance to a consumer channel in the flow bifurcation zone, and the resulting changes in flow kinematics. It emphasizes the need to improve effective hydraulic calculation methods for predicting flow parameters and associated deformations in the channel bifurcation zone. Research conducted by several scientists in this area is reviewed. The results show that ignoring turbulent motion significantly reduces the accuracy and effectiveness of hydraulic calculation methods related to deformation processes.

Keywords: low, channel, fluid, confluence angle, channel, canal, channel deformation.

Entrance

The bedrock of rivers and subsoil channels in nature is constantly influenced by their flows, causing them to change and, accordingly, their cross-section. The formation of the bedrock in this state often leads to conditions that are inconvenient for users of irrigation channels, namely, the deterioration of the natural conditions of rivers and subsoil channels and a decrease in their water-conducting capacity.

It is known that rivers and underground channels are characterized by the cross-sectional area of the bed and the water permeability index. This situation looks more complicated in plan. Centrifugal forces act on the curvature of the bed in question. These forces, in turn, affect the formation of bed cross-sections and secondary flows that occur during a number of local processes.

Style and materials

In practice, cases of water flow separation from the side bank and the occurrence of vortex areas are observed. This vortex area can also be called a stagnation zone. Due to the decrease in the speed of the fluid flow in the stagnation zone, intensive sedimentation of turbidity and sediments leads to a narrowing of the live cross-section of the consumer channel receiving water from the main channel and leads to bank deformation.

Failure to take into account the natural processes of bed changes and the hydrodynamic parameters of the flow in measures to prevent siltation of the channel bed leads to the fact that these measures are ineffective and also very expensive in economic terms. There are objective reasons for the fact that the problems of the theory of bed processes are still not sufficiently studied at present. One of the reasons for this is the extreme complexity of the problem and its dependence on many factors. When studying the problem, it is first of all necessary to take into account the hydromorphological changes occurring in the bed. Therefore, it is necessary to approach this problem from a hydraulic and hydrodynamic point of view, as well as from the issues of soil mechanics. From this we can say that this process is in the direction of physical and mathematical processes. Therefore, an approach from a hydraulic point of view alone will not be enough. Because the deformation processes occurring in the division zone of the bedrock occur in a three-dimensional direction. In this case, an approach from a hydrodynamic point of view brings considerable clarity to the solution of the problem of studying the process of bedrock changes.

Results and Discussion

Many scientists have studied the issue of flow separation and have achieved certain results in their research. However, a number of questions related to this issue have not yet been answered. It is clear from this that the study of the kinematic characteristics of the flow in the flow separation area is one of the important tasks of natural hydraulics.

The fact that the deflection of the dividing flow does not depend on the geometry of the banks was shown in experimental studies by A.N. Lotsievsky. According to him, the velocity in the consumer channel in the division zone after the division is greater than the velocity in the main channel. [1;3]

G. Bulle, D.Y. Sokolov, A.Y. Milovich, V.A. Shaumyan, A.S. Ofitserov, Shi Wei Lo systematically conducted experiments at different values of the angle of confluence of the main channel and the consumer channel. According to the results of the research, a complex deformation of the free surface occurs in the division area. The greatest decrease in the water level in the division zone occurs in the section just above the division. The free surface rises upward in the area where the consumer channel joins, and decreases below the division. According to V.A. Shaumyan, the deviation of the flow from the main channel to the side channel occurs first at the bottom of the channel, and then in the layer close to the free surface of the channel. Therefore, the consumer channel “collects” more sediment. [2;4]

According to the experiments conducted by A.S. Ofitserov, the flow characteristics in the main channel do not depend on the angle of the consumer channel. Despite the results of many experiments, there are no theoretical studies to determine the volume of discharges collected in the consumer channel and the areas of accumulation. Theoretical studies on the division of channels provide analytical formulas for calculating the flow rates and velocities of the dividing flow. However, theoretical studies aimed at determining the deformation of the bed that occurs on the banks of the dividing channels and the shape of the consumer channel that does not form an accumulation area have not yet been carried out.

S. Ramamurthy studied the problem of water distribution in a branched channel with a non-deformable rigid base. He used the momentum and energy conservation and continuity equations for fluids to solve the problem of water flow from the main channel to the consumer channel [1;4;6].

I. Zihan and H. Saerabny experimentally studied the problem of a branching flow covered with sand [5;8]. The same problem was also investigated by H. Hydar and Y. Badronnisa in 2019. The aim of the above experiments was to determine how long the consumer channel becomes filled with sand, when it needs to be cleaned, and the thickness of the sand [6;7].

The results of the experiment showed that the intensity of sediment accumulation in the consumer channel increases around the separation angle of the consumer channel from the main channel. According to them, the smallest size of the accumulated area in the consumer channel is determined when the separation angle is [3;8;10]. Also, Pandey and Ravi observed that the main part of the sediments at the bottom of the channel in the separation zone goes to the consumer channel [6;4].

The channel deformation equation is derived by many authors in hydraulics by constructing the equilibrium of moving flows in rivers and channels, and it is similar to the hydraulic equation of continuity in unsteady flow motion [1].

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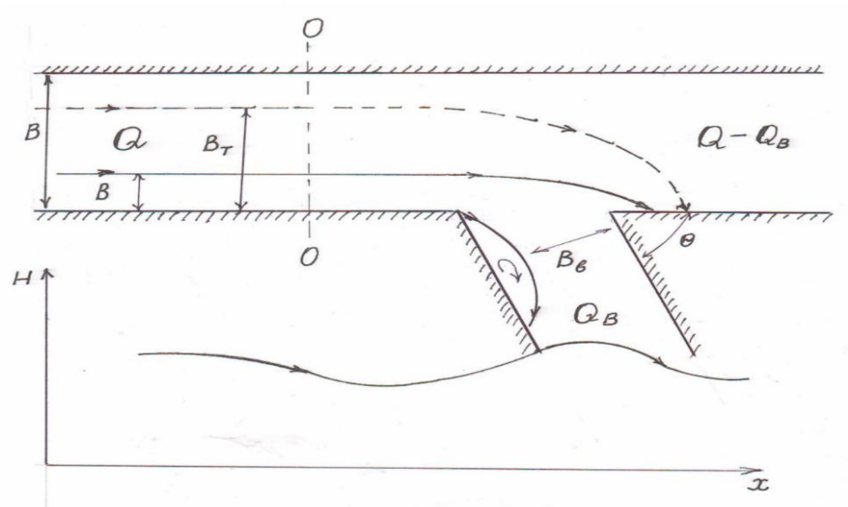

Figure 1. Flow division diagram

The channel deformation equation was developed based on the recommendations of I.A. Velikanov, N.M. Vernadsky, and others, and is considered appropriate for one-dimensional fluid motion [2;3].

Channel deformation processes occur with spatial variations against the background of changes in bed morphology. It is especially desirable to study the bed deformation process in the flow division zone for at least two-dimensional motion (Figure 1).

Hydraulic problems related to the division of flows are common in rivers, various canals, and hydraulic structures. The calculation of the hydraulic problems of the division process mainly consists of two problems.

First issue – Calculation of water capacity in the distribution networks. In this process, the condition of continuity of flow is used to calculate this

$$Q = \sum Q_i = \sum \omega_i \vartheta_i = \omega_1 C_1 \sqrt{h_1 I_1} + \omega_2 C_2 \sqrt{h_2 I_2} + \dots \qquad (1)$$

the equation can be written as follows. Here and Q are Q_i -the water flows in the main stream (the part of the stream before the division) and in the branches, respectively. If the morphometric characteristics (ω_i, h_i) and the water surface slope I_i in the branches are known, the solution to the first problem is easy to solve.

Second issue - the calculation of discharges in the networks is a rather complicated problem. There is also no analytical solution to this problem.

It is shown from experience that during the bifurcation of the flow, the main part of the sediment falls into the consumer channel, and this process does not depend on the angle of division (Table 1.1) [3;4.].

This picture is almost repeated in the author's experimental measurements in natural conditions.

Let's look at the reasons for this phenomenon. At the entrance to the consumer channel at the flow division, the jet bends and compresses, and due to the bend, a stream with a cross-section is observed.

When a current bends a water surface stream as it passes through a consumer channel, a stream channel formed at the bottom of the channel directs the flow along the consumer channel. This effect can cause vertical velocity variations at the channel split.

Thus, against the background of the compression of the flow at the entrance to the consumer channel, the velocity at the bottom of the channel increases more than the velocity at the water surface. In this case, as a result of the simultaneous effect of turning and compression, the draft width of the flow at the bottom of the channel becomes B_T, and the draft width of the flow above V_s becomes greater.

It is known that the main sediment flow flows along the stream bed, therefore, the main part of the sediment is "sucked" into the consumer channel.

Experiments show that the curvature of the flow usually does not depend on the shape of the river cross section [3; 4].

Table 1.1

Bulle experimental data

Flow deflection angle θ, grad	Water consumption($10^{-3}\ м^3/c$)		$\frac{Q_B}{Q}$, %	The flow rate of effluents in the consumer channel compared to the main channel, %
	Until it is divided	Q_B in the consumer channel		
30	5,0	2,5	50	97,3
60	5,0	2,41	48	96,2
90	5,0	2,26	45	90,6
120	5,0	2,35	47	87,5
150	5,0	2,37	48	92,0

We review and summarize the main results of laboratory research on flow splitting.

1. At the point of flow division, a complex deformation of the free surface occurs. The minimum value of the water level in the division zone is formed slightly above the division point. In the expansion zone at the division point, a rise in the water level is observed (due to the division), and the rise process ends slightly below the branch channel.

2. Starting from the point of turning into the consumer channel, a sedimentation zone is formed. It should be noted that in the sedimentation zone, intensive erosion occurs. On the consumer channel wall opposite the sedimentation zone, erosion is observed.

3.A steep slope is formed at the water level in the main channel $\vartheta^2/2g$ towards the consumer channel.

4. Standing waves may form in the lower part of the consumer channel.

5. The deviation of the flow from the flow dynamic axis occurs above the consumer channel. In this case, first the flow at the bottom of the channel begins to flow, and then the surface flow. [4;5]

6. At the entrance to the consumer channel, an intense daytime crowd forms.

7. The flow characteristics in the main channel do not depend on the angle that the consumer channel forms with the main channel.

8. The line separating the flows directed to the consumer channel and the main channel will be close to a parabola (Figure 2).

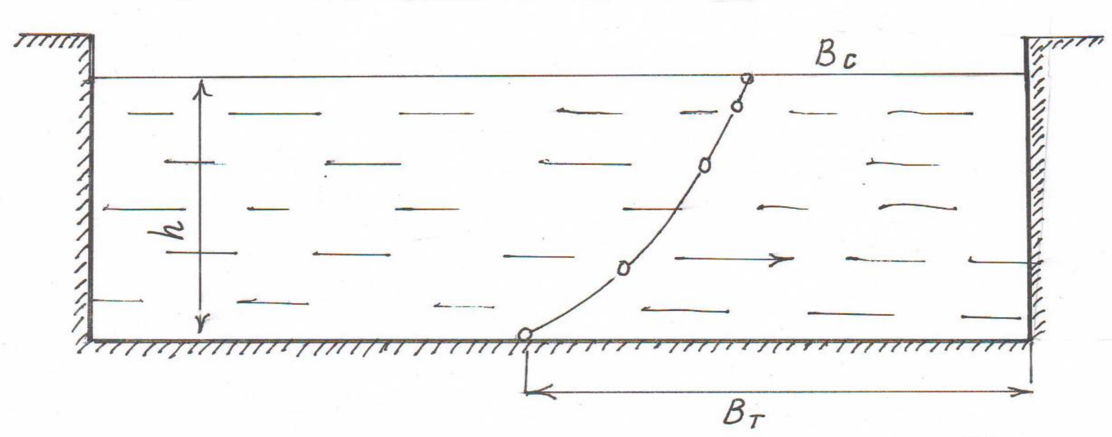

Figure 2. The line of separation of flows leading to the consumer channel and the main channel

Due to the fact that a theoretical solution to the problem of calculating sediments entering the consumer channel is sometimes not available, and sometimes it is necessary to over-simulate the process, a number of empirical formulas for calculating the flow quantities in the channel bed have been developed. These relationships were obtained for rigid bodies and deformable bodies, and we will consider some of them. [6;7]

For flows in a solid basin:

$$B_T = 1,55(\frac{q_B}{q} + 0,2)\,B; \quad \text{(Shaumyan)} \quad (2)$$

$$B_T = 1,40(\frac{Q_B}{Q})^{5/6}\,B; \quad \text{(Ofiserov)} \quad (3)$$

$$B_T = (1,65\frac{Q_B}{Q} + 0,04)\,B; \quad \text{(Obrazovskiy)} \quad (4)$$

For flows in deformable bodies:

$$B_T = (2,5\frac{Q_B}{Q} + 0,02)\,B \quad \text{(Ofiserov)} \quad (5)$$

$$B_T = (2,14\frac{Q_B}{Q} + 0,07)\,B \quad \text{(Obrazovskiy)} \quad (6)$$

here vis the width of the basin before the division. Q and Q_B- the water flow in the main and consumer canals before the division in the corresponding direction.

q and q_B- water consumption per unit width of the main and consumer canals, divided in a suitable manner.

Grishanin, assuming the depths of the main and consumer channels to be the same, generalizes the above formulas and recommends, in a form closer to the experiment:

$$\frac{B_T - \alpha B}{B_T} = \beta \frac{V_B}{V}$$

where V and V_B are the average velocities of water in the main channel flow before the split and in the consumer channel. [8;9] α and β are constant coefficients for rigid and deformable channels, respectively. $(0 \le \alpha \le 0,1; 1,4 \le \beta \le 2,7)$

The appearance of branching in natural systems is completely different, but they all obey the laws expressed above. At the same time, the natural system is fundamentally different from the modeled system. The main difference is that alluvial soil (soil consisting of rocks) basins can change their elevation and horizontal (in plan view) shape under the influence of flow, that is, as a result, the cross-sectional area and shape of the basin also change under the influence of flow hydraulics and sediments. Often, deformation changes occur in branching basins in practice. In such conditions, knowledge and experience of designers are required. Sometimes it is not clear which networks are primary and which are secondary.

Conclusion

One of the problems of open basin hydraulics is the problem of water intake from the main land basin channel to a secondary land basin channel (consumer channel) without a dam, or in other words, the problem of flow division. Under these conditions, the processes of flow division into channels in the division zone are much more complicated. A number of researchers have conducted studies on this issue and proposed calculation methods that are suitable for their theoretical and experimental research conditions, but they have not reached a clear general solution.

The analysis of the existing literature to date shows the need to improve effective hydraulic calculation methods to predict the flow parameters and associated deformations in channels in the division zone, which is a complex problem of open basin hydraulics.

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