PAPER • OPEN ACCESS

Effect of deformation processes on hydraulic efficiency in open drainages

To cite this article: D A Abduraimova *et al* 2023 *IOP Conf. Ser.: Earth Environ. Sci.* **1231** 012066

Effect of deformation processes on hydraulic efficiency in open drainages

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Abstract. In agriculture based on irrigated farming, the role of drenage networks is important. The variability of seepage water in the season of irrigation and salt washing has a great impact on the technical condition of the collectors. As a result of the leakage of a large amount of groundwater into the drainage, the sidewalls of the drainage fall by sliding, and as a result, the slided soil fills the bottom, which causes a number of negative problems. The main construction parameter of open drainage is the depth and slope coefficient, which ensures the strength of side wall. When the problem was investigated, it became known that the drainage capacity and water transfer capacity decreased as a result of the deformation of the side slopes of the "CK-2-2" inter-farm collector. So, as you can see in the graphs, when the bottom of the ditch rises to 1.2 meters as a result of deformation, the width of the bottom of the drainage increases to 6 meters. Using Darcy's formula for filtration flow, it was found that the - comparative seepage water in the drainage was reduced from 0.375 L/sec to 0.265 L/sec, i.e. a reduction of 41%. As a result, the depth of the water in the drainage should have decreased, but the depth of the water is reflected growth as reeds and similar plants grow on the bottom and sides of the drainage. According to the results of the calculation, it was found that water permeability of the drainage reduced by up to 30%.

1. Introduction

In agriculture based on irrigated farming, the role of drenage networks in improving land reclamation is important. Our republic has a total length of more than 142.9 thousand km of drainage systems, and 45.7% of the 4.3 million hectares of cultivated land that they serve are salted to varying degrees [1,2]. The reason for this is the high mineralization of irrigation water and the unplanned organization of reclamation work, on the other hand, the unsatisfactory technical condition of reclamation facilities. Today, several State Programs have been developed in order to improve the land reclamation conditions of different salinity levels, and work in this regard is being carried out rapidly [2].

The variability of seepage water in the season of irrigation and salt washing has a great impact on the technical condition of the collectors [4]. Due to this, in these processes, as a result of the leakage of a large amount of groundwater into the drainage, the side walls of the drainage are slided, and as a result, the slided soil fills the bottom of the drainage. Despite the scientific results of evaluating the dynamic stability of open collector drainages in irrigated areas, today there are a number of problems with the operation of these drainage networks due to the lack of these scientific innovations in the design norms [5].

The main parameter in the hydraulic calculation of open drainage is the construction depth and slope coefficient, which ensures the strength of side wall. It is necessary to design the depth of the open drainage that are planned to be built in the irrigated areas based on the value of the drainage rate [6]. The concept of drying rate means the depth of seepage water, which provides air exchange in the root layer of plants and creates optimal humidity for the normal development of agricultural crops, and which provides the possibility to carry out agricultural work in areas where the soil is being drained [7]. Several recommendations have been developed by researchers to determine the rate of drying, which includes factors such as the mechanical composition of the soil, the mineralization [8,9,10,11].

The construction depth of open drainage ensures the maintenance of the groundwater level in the specified area at a certain level, but the reduction of this value as a result of the deformation of the side wall of the drainage has a significant impact on the groundwater level [12]. The reduction of the construction depth first affects the drainage capacity of the network, and on the other hand, it significantly affects the water carrying capacity of the network as a result of the development of algae in the widened channel as a result of deformation [13].

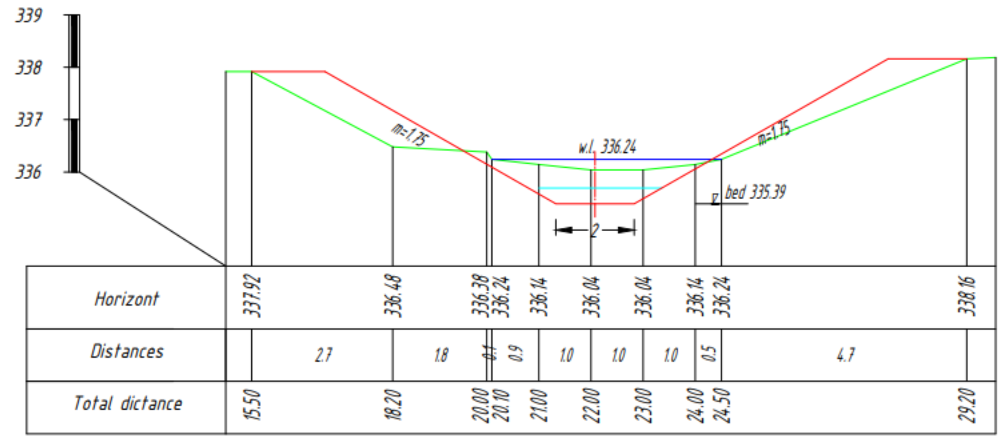
Scientific research is being conducted in order to find a solution to the above-mentioned negative consequences and current problems. In this article, on the example of inter-farm collector "CK-2-2" in Khavos district of Syrdarya region, it is studied how much the deformation in the core affects the work efficiency of the network.

Inter-farm collector "CK-2-2" passing through the territory of farms "Farhod" and "Zhambil" in Khavos district of Syrdarya region was built in 1958, the total length is 5.2 km, water carrying capacity is 0.84 m^3/sec (Tab 1). The collector serves to improve the land reclamation of 1200 hectares of agricultural land in the territory of "Farhod" and "Jambil" farms.

Table 1. Project parameters of inter-farm collector “CK-2-2”

Name of the collector	Plots from… to…		Length, *m*	Slope	The width of the bottom, *m*	Flow		
						discharge, $m^3 \cdot s^{-1}$	depth, *m*	velocity, $m \cdot s^{-1}$
CK-2-2	0+00.0	0+45.0	45	0.00179	2.0	1.0	0.48	0.76
	0+45.0	3+70.0	325	0.00154	2.0	1.0	0.50	0.72
	3+70.0	13+61.0	991	0.0003	2.0	1.0	0.78	0.41
	13+61.0	37+85.0	2424	0.00056	2.0	0.8	0.56	0.50
	37-85.0	41+10.0	325	0,00028	2.0	0.5	0.55	0.32
	41+10.0	57+35.0	1625	0.00038	2.0	0.5	0.50	0.36

According to the conducted research, at present, the depth of the water flow in PK-10 of the inter-farm collector CK-2-2 is h=0.48 m, the width at the water level is B=4.40 m, the slope is i=0.0003, the cross-sectional surface is ω =0.35 m2, wetted perimeter χ=4.67 m, water discharge Q=1000 l/s, average velocity ϑ=0.20 m/s. According to the analysis of the design and determined results, the bottom of the open drainage bed was raised by an average of 0.95 m as a result of deformation of sliding (Fig. 1).



- designed, -current.

Figure 1. Cross-section of inter-farm collector CK-2-2, PK-10.

When the problem was investigated, it became known that the drainage capacity and water transfer capacity decreased as a result of the erosion of the side slopes of the "CK-2-2" inter-farm collector (Fig. 1). 950 hectares of agricultural land in the territory of Farhod farm and 750 hectares in the territory of Jambil farm serving the collector are moderately saline and the groundwater level is 1.5-1.8 meters [19,20,21].

2. Methods

In open collector drainage, the reduction of the drainage construction depth as a result of the collapse of the side wall of the channel has a significant impact on the drainage efficiency of the drainage. In the irrigated areas, the task of the inter-farm collector is to remove the seepage water formed in the farm drainages, as well as to improve the amelioration condition of the area on its route, i.e. to serve to remove the seepage water. According to the analysis of the conducted theoretical research, the water balance equation for a certain plot of the drainage network is as follows [14,15].

$$Q_{in} + \sum_{i=1}^{n} Q_i + \sum_{i=1}^{L} Q_{0_i} - Q_{out} = 0$$

where: Q_{in} - water discharge entering the balance zone; Q - water discharge entering the balance zone from the farm drainage; Q_0 - comparative seepage water output; Q_{out} - water discharge leaving the balance zone.

The work efficiency of the drainage in the considered section is evaluated by the amount of seepage water seeping into it. That is, the technical condition of the drainage (H_c) should be sufficient to maintain the level of underground water in the area it serves. According to Darcy's expression for filtration flow [16], there is a relationship between filtration flow and drainage depth as follows:

$$Q_0 = k_f \cdot \frac{H_c^{\,2} - h_0^{\,2}}{2 \cdot L}$$

Where: k_f – filtration coefficient of soil; H_q – construction depth of the drainage; h_o – depth of flow in the drainage; L – the width of the area served by the drainage;

On the basis of this equbtion, it is possible to analyze the effect of the rise of the bed of the drainage, i.e., the decrease of the depth of the drainage as a result of deformation, on the comparative seepage water (Q_0) entering the drainage.

Decreasing the depth as a result of deformation has a significant impact not only on the drainage efficiency, but also on the efficiency of water transfer as a result of the increase in the wetted perimeter of the flow, the decrease in the average velocity of the flow and a result of the development of algae in the channel. The water carrying capacity of the collector is directly related to the technical condition of the drainage, and the increase in hydraulic resistance on the drainage surface is inversely proportional to the water carrying capacity [17]:

$$\alpha' Q_d \leq Q \leq Q_d$$

where: Q_d - designed water discharge; Q – current water discharge; α' - effect coefficient of technical condition.

$$\alpha' = \frac{n_d}{n}$$

n_d, n - designed and current roughness coefficient.

As a result of the increase in hydraulic resistance, the decrease in water permeability can also be evaluated by the change in the normal depth of flow [18]. That is, the increase in the effect of hydraulic resistance on the flow causes its damping.

3. Results and discussion

Based on the results of field research, the influence of the deformation processes occurring in the CK-2-2 collector on its drainage capacity was studied (Fig. 2).

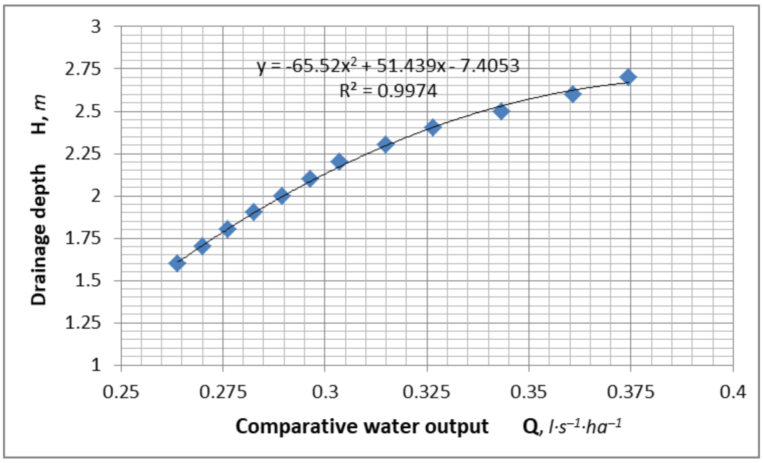


Figure 2. Correlation of the comparative water entering the drain with the depth of the drain, PK -10.

Since PK-10 is set near the last water outlet of the drainage, the deformation is more noticeable there, and as a result, we can see that the comparative seepage water in the drainage has decreased from 0.375 l/sec to 0.265 l/sec, which is a reduction of 41%.

According to the research carried out in the inter-farm collector CK-2-2, it was found that the water carrying capacity of the collector bed could not transfer the comparative seepage water at the maximum velocity. The velocity of the flow depends on the width of the bottom of the bed [19], and as the width increases, the velocity decreases (Fig. 3).

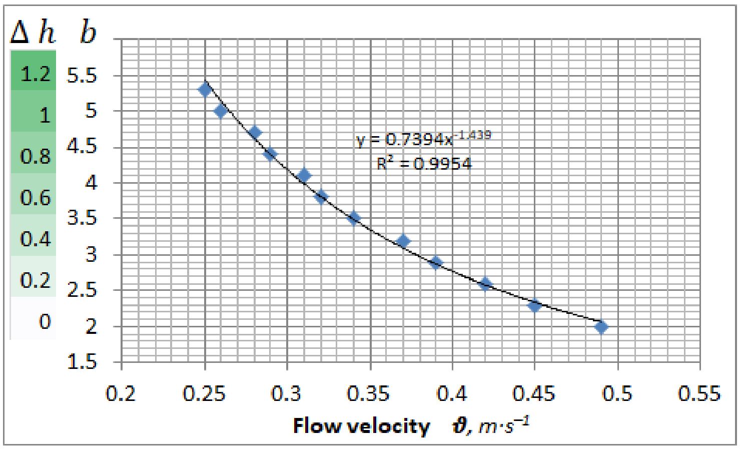


Figure 3. The graph of the dependence of the flow rate on the width of the drainage bottom.

We can see that the water velocity in the drainage decreased from 0.49 m/sec to 0.25 m/sec, i.e. by 50%, as a result of the sliding of the side walls and the widening of the bottom of the drainage. As a result, reeds and similar plants begin to develop at the bottom and side of the bed. Increased resistance due to vegetation growth affects the depth and velocity of the stream and consequently its capacity to carry water.

As a result of the deterioration of the technical condition of the channel, the decrease in water carrying capacity can be estimated by how much the flow depth (h_0) in the channel has increased compared to the design condition. That is, the increase in hydraulic resistance in the core has a direct effect on the flow depth (h_0) (Fig. 4).

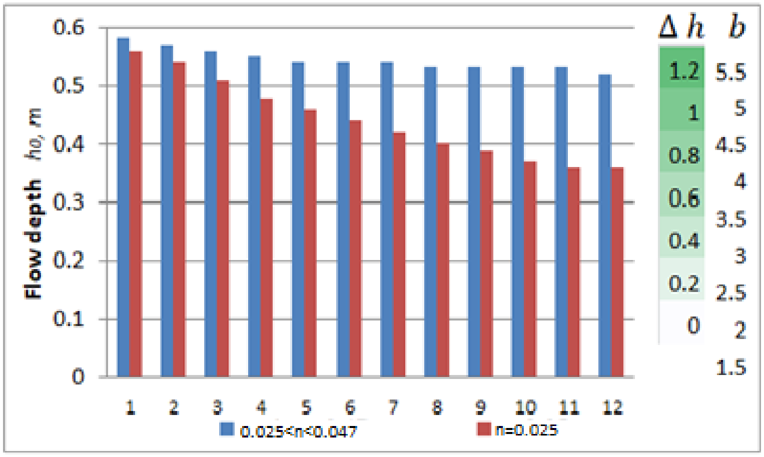


Figure 4. Graph of dependence of the flow depth on the technical condition of the drainage.

So, as you can see in the graph, when the bottom of the ditch rises to 1.2 meters as a result of deformation, the width of the bottom of the drainage increases to 6 meters. As a result, the depth of the water in the drainage should have decreased, but the depth of the water is reflected growth as reeds and similar plants grow on the bottom and sides of the drainage. According to the results of the calculation, it was found that the change of the hydraulic roughness in the drainage from 0.025 to 0.047 reduces the water permeability of the drainage by up to 30%.

4. Conclusion

We can often meet the cases of ground slide on the banks of open drainages built in irrigated fields. It is observed that open drainages expand their core, raise their bottoms, change their design dimensions and undergo a deformation process. As a result of this, there is a rise in the level of groundwater and soil salinity. A similar situation can be found in almost all regions of our Republic. In the conducted studies, the performance of open drainages was investigated. Factors influencing the drainage capacity were evaluated. Deformation processes not only change the cross-section of the riverbed, but also affect the speed of water flow. Under the influence of deformation processes, as a result of the growth and development of various types of plants in the bottom of open drainage, the flow becomes damp; as a result, the drainage capacity deteriorates.

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