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Method designing of open drainages

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Abstract. During the construction of open drainages, to achieve economic efficiency, it is very important an accurate assessment of their parameters and projection size. The article is devoted to the creation of a mathematical model by taking into account the variability of flow movement and discharge rate in open drainages. The appearance of a mode of uneven movement as a result of the influx of infiltration water from the sown area to the drainage is described. Recommendations are given for determining the hydraulic parameters of drains. To study the movement of water flow in open drainage, the results of studies in the Boevut drainage system of the Syrdarya region are disclosed. The results of the analysis of the studies are presented. Based on the analysis results, a method for designing open drainages is proposed. The hydraulic parameters of the constructed new open drainage are determined in field conditions. The data determined in the field conditions are compared with the values of the proposed design method. Based on the comparison results, the reliability of the proposed design method was evaluated.

1. Introduction

In order to divert mineralized waters from most moist areas and create conditions for the development of agricultural crops in the active soil layer of these areas, it will be necessary to create a drainage system [1, 2]. The drainage system fulfills the task of creating by removing excess moisture from the soil composition and moving it away from the sowing area. As a result, it is achieved to maintain the groundwater level at the normative level in sown areas. Because, wet capacity, air saturation, and salinization of the soil depend on the level of groundwater [3, 4]. The accumulation and outflow of groundwater lead to salinization and waterlogging of the soil. In saline and swampy lands, the development of agricultural products is hindered. Previously, these lands were called abandoned. If land reclamation measures are implemented in these lands, the groundwater regime improves, the land is desalinated and the yield of agricultural crops increases. Desalination of saline lands, especially in irrigated areas, it is difficult to develop agriculture without leaching [5, 6]. At this time, the water formed during the leaching of salty lands must be removed from the areas, artificial drainages are created for this. It is known that in the process of leaching, the main task remains to remove salts from the sown areas by melting from the soil composition. To do this, it is necessary to ensure the good functioning of the drainage system [7]. To this end, the improvement of the reclamation state of irrigated lands is being carried out to prevent salinization and waterlogging, cleaning, repair, and the creation of new drainage systems.

1.1 Object of research and problem solving

In the world in irrigation and land reclamation, in agriculture and other areas, drainage systems are widely used [8, 9]. In different periods, research was conducted on the development of land reclamation, justification of the design parameters of collector drainage and increasing the efficiency

of its work by such scientists as A.N. Kostyakov, S.F. Averyanov, A.P. Vavilov, V.A. Kovda, A.S. Rabochev, F. Rakhimboev, K. Mirzazhanov, H.A. Akhmedov [10, 11]. When performing hydraulic calculation of the designed open drainage, considering the flow movement is conditionally uniform, determine it using well-known hydraulic formulas. It is especially worth noting that, looking at the physical nature of the flow movement in open drainage, it is very difficult to fulfill the condition for uniform movement [12, 13]. Because, as a result of the influx of groundwater into the drainage water, the process of changing the depth and flow rate of the water along the length of the drainage, i.e. uneven motion mode appears.

Design of open drainage along the length, taking into account the variability of water flow, i.e. the correct vibration of the hydraulic parameters, during its construction together with economic efficiency, makes it possible to increase the dynamic strength. The study of the above problems and as a result of scientific research, the improvement of hydraulic calculation is considered the main task of the present.

2. Methods

The essence of water movement in open drains corresponds to the laws of mass change. The amount of water discharged from the sown area during the infiltration process increases along the drainage length.

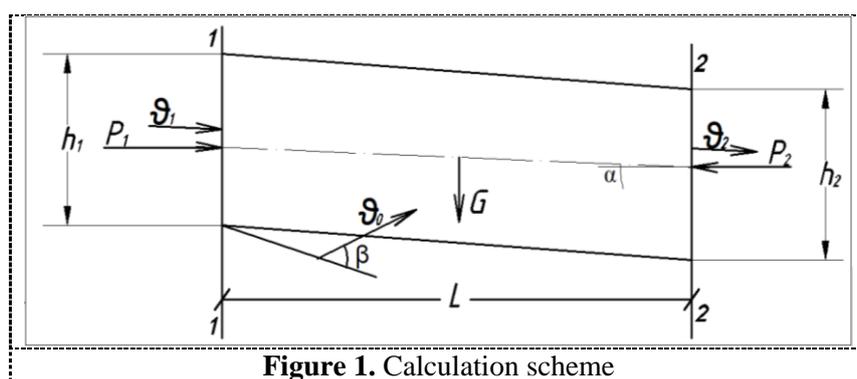For clarity of this process, the following calculation scheme was adopted (Fig. 1).

Figure 1. Calculation scheme

According to the adopted scheme, the amount of water for the adopted drainage volume ΔV consists of the main amount of water $V1$ and the volume of water which additionally supplied [14, 15].

Then, for 1-1 and 2-2, the change in the momentum can be written as

$$d(m\vartheta) = \rho(Q\vartheta_2 - Q\vartheta_1)dt, \tag{1}$$

there: ϑ_1, ϑ_2 are the flow velocity for sections 1-1 and 2-2;

Q is the water discharge.

For the case under consideration, flow discharge Q_1 flows through section 1-1, through section 2-2 Q_2.

$$Q_2 = Q_0 + Q_1 \tag{2}$$

This shows that Q_0 is the additional discharge of flow.

Then, for the sections under consideration, the change in the momentum can be written as

$$d(m\vartheta) = \rho(Q_1\vartheta_1 + Q_0\vartheta_0 \cos\beta - Q_2\vartheta_2)dt \tag{3}$$

It is known that $dQ_0 = dQ$ is the amount of flow change, then

$$Q_0\vartheta_0 \cos\beta = \int_0^L dQ_0\vartheta_0 \cos\beta dQ \tag{4}$$

Based on the foregoing (3), it can be written as

$$d(m\vartheta) = \rho(Q_2\vartheta_2 + \int_0^L \vartheta_0 \cos\beta \, dQ - Q_1\vartheta_1)dt$$

(5)

The above expression (5) shows the change in momentum along the drainage length.

3. Results

From the theorem on the change in the momentum for sections 1-1 and 2-2, the total momentum of the force is determined [16, 17].

$$\sum_{i-1}^{n} F_i dt = (G\sin\alpha + P_1 - P_2 + P_0 \cos\beta)dt,$$

there: $\sin\alpha$ is a sine of the angle of repose relative to the horizon; G is the weighted force.

The projection of the weight force relative to the axis of motion.

$$G\sin\alpha = \rho g \int_0^L \omega dL \sin\alpha = \rho g \sin\alpha \int_0^L \omega dL,$$

there: P_1; P_2 are the respectively, the pressure force in sections 1-1 and 2-2

$$P_1 = p_1\omega_1, \ P_2 = p_2\omega_2$$

The amount of force acting on the walls of the drainage is determined

$$P_0 \cos\beta = \int_0^L p\chi dL \cos\alpha = \int_0^L p \, d\omega$$

The friction force in the walls of the drainage, i.e. tangential force is determined

$$F_u = -\int_0^L \tau\chi dL,$$

there: τ is the tangential stresses;

χ is the wetted perimeter.

Then, the total momentum of the force has the form:

$$\sum F dt = (\rho g \sin\alpha \int_0^L \omega dL + p_1\omega_1 - p_2\omega_2 + \int_0^L p \, d\omega - \int_0^L \tau\chi dL)dt :$$

After the well-known mathematical transformations, the differential equation of the flow in the drain is written as follows

$$\frac{Qd\vartheta}{\omega g} + \frac{\vartheta dQ}{\omega g} + \frac{dp}{\rho g} + dz - \frac{\vartheta_0 \cos\beta}{g\omega}d\omega + idL = 0.$$

Knowing that $\dfrac{Qd\vartheta}{\omega g} = \dfrac{\vartheta dQ}{g} = \dfrac{d\vartheta^2}{2g}$ and taking $z + \dfrac{p}{\gamma} = h$ for open drainages, the equation is written as follows

$$\frac{\vartheta_1^2}{2g} + h_1 = \frac{\vartheta_2^2}{2g} + h_2 + \int_0^L \frac{\vartheta - \vartheta_0 \cos\beta}{g\omega}dQ + iL$$

6)

The peculiarity of the equation is that here the water flow rate and the additional amount of water are determined as a function of length. When using the equation, it will be necessary to determine dQ.

The amount of water per 1 meter of drainage length is determined based on the Darcy formula [18, 19].

$$Q_0 = S \cdot \vartheta_f = k_f \cdot y \cdot \frac{dx}{dy}$$

(7)

there: Q_0 is the water discharge per 1 meter of drainage length; S is the area of groundwater at a distance x to the drainage; ϑ_f is the speed of the groundwater.

$$\vartheta_f = k_f \cdot \frac{dx}{dy}$$

(8)

By distinguishing between variables

$$dx = \frac{k_f \cdot y \cdot dy}{dQ_0}$$

and integrating for extreme conditions this formula from *x=0* to *x=L* and from *y=h* to *y=H* the amount of water per 1 meter of drainage length is determined [20].

$$Q_0 = k_f \cdot \frac{H^2 - h^2}{2 \cdot L}.$$

(9)

In order to evaluate the accuracy of the given equation, the studies were carried out in field conditions. The studies were conducted in the irrigated areas of the system located in the inter-farm open drainage B-2-1 of the Syrdarya Region. This open drainage located in the Boyavut collector-drainage system serves the outflow of 112 ha of irrigated groundwater. The total length of the studied open drainage B-2-1 is $L = 2752$ m, the average slope is $i = 0.00127$, and the average depth relative to the ground level is $H = 2.3$ m. The maximum water flow rate is $Q = 300$ l/s. The results of the studies, as well as their analyzes, are shown in the following figures and tables.

The depth of the water flow in the channel $h = 0.40$ m, the width along the top $B = 3.7$ m, the living area $\omega = 1.01$ m^2, the wetted perimeter $\chi = 3.82$ m, the water flow $Q = 230$ l/s, average speed $\vartheta = 0.23$ m / s. (Fig. 2).
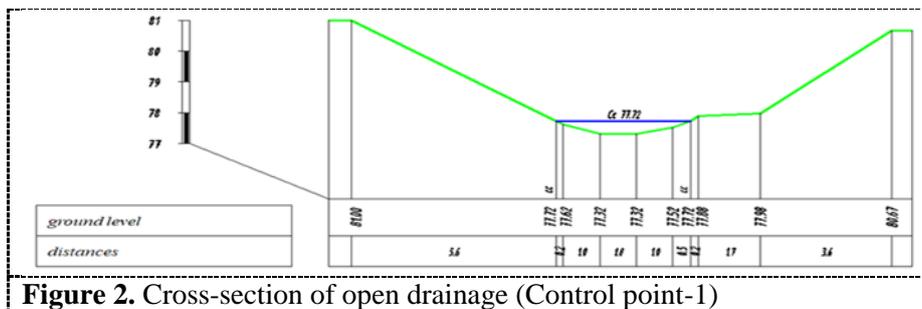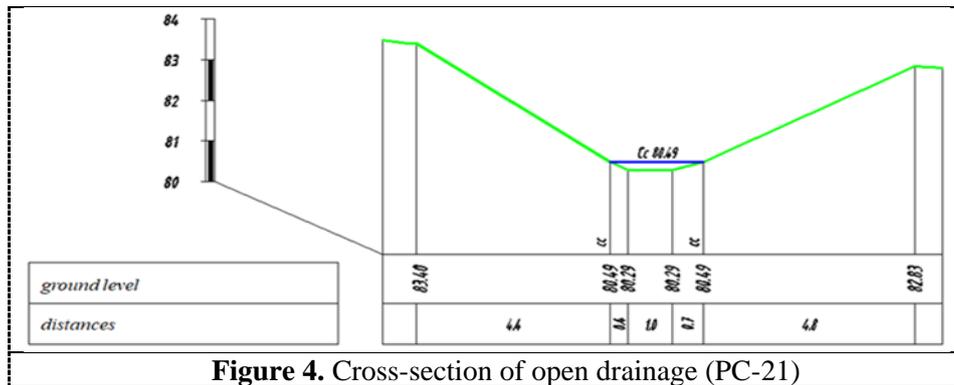

Figure 2. Cross-section of open drainage (Control point-1)

The depth of the water flow in the channel $h = 0.20$ m, the width along the top $B = 3.4$ m, the living area $\omega = 0.36$ m^2, the wetted perimeter $\chi = 3.42$ m, the water flow $Q = 90$ l/s, average speed $\vartheta = 0.25$ m / s. (Fig. 3).
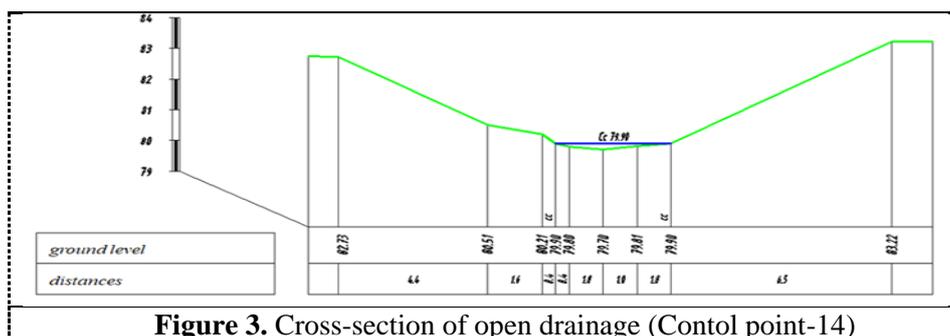
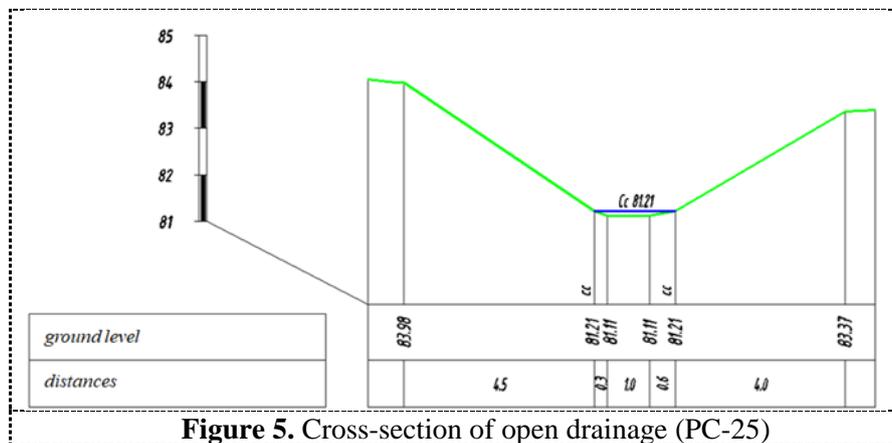

Figure 3. Cross-section of open drainage (Contol point-14)

The depth of the water flow in the channel $h = 0.20$ m, the width along the top $B = 2.1$ m, the living area $\omega = 0.31$ m^2, the wetted perimeter $\chi = 2.17$ m, the water flow $Q = 83$ l/s, average speed $\vartheta = 0.27$ m / s. (Fig. 4).

Figure 4. Cross-section of open drainage (PC-21)

The depth of the water flow in the channel $h = 0.10$ m, the width along the top $B = 1.9$ m, the living area $\omega = 0.15$ m^2, the wetted perimeter $\chi = 1.92$ m, the water flow $Q = 40$ l/s, average speed $\vartheta = 0.27$ m/s. (Fig. 5).


Figure 5. Cross-section of open drainage (PC-25)

In field studies, as a result of scientific research in the open drainage of B-2-1, it became known from the analysis of the obtained data that the flow movement is uneven. As a result of the influx into the channel of groundwater drainage and merging with the flow of water in the channel, a mode of uneven movement is observed along its length.

Table 1. Hydraulic parameters of open drainage (B-2-1)

PC	h, m	Q, l/s	ω, m²	χ, m	R, m
1	0.40	230	1.01	3.82	0.26
14	0.21	90	0.36	3.42	0.11
21	0.20	83	0.31	2.17	0.14
25	0.10	40	0.15	1.92	0.08

The variability of water flow along with hydraulic parameters in each section continues along the length of the channel (Fig. 6).
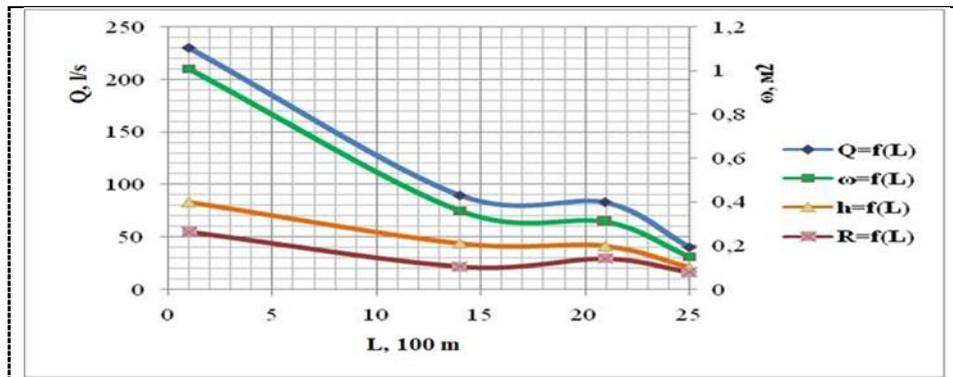
Figure 6. Change in water flow and hydraulic parameters by the length of open drainage (B-2-1)

Based on the above analyzes, some changes have been made in the design and construction of open drainage. Given the mode of uneven movement in the channel of open drainage, following the variability of water flow, the shapes of the live section are reduced. The length of the designed open drainage is 2 km, divided into 20 sections. The average slope is i = 0.0005 and performs the task of head drainage. The design carried out in the following way. Given the levels of groundwater and the passage of water through the soil, the flow rate in the sections of open drainage is determined theoretically based on the Darcy formula (9). Based on certain water flow rates, cross-sectional areas, and hydraulic parameters were calculated (Table 2).

Table 2. Determination of hydraulic parameters of open drainage

Pc	$k_f,$ m^2/day	H, m	h, m	$Q_0, l/s$	$Q, l/s$	$\vartheta, m/s$	ω, m^2
1	0.030	1.80	0.30	0.12	203.35	0.25	0.813
4	0.030	1.75	0.30	0.11	167.91	0.25	0.672
8	0.030	1.70	0.30	0.11	123.32	0.25	0.493
12	0.030	1.68	0.30	0.10	81.32	0.25	0.325
16	0.030	1.65	0.20	0.10	40.33	0.25	0.161
20	0.030	1.62	0.20	0.10	0.10	0.10	0.001

Based on the calculated hydraulic parameters, the design dimensions of open drainage are determined and applied during construction. According to the results of the construction of open drainage, a change in the cross-sectional areas according to the variability of water flow was achieved (Fig. 7).
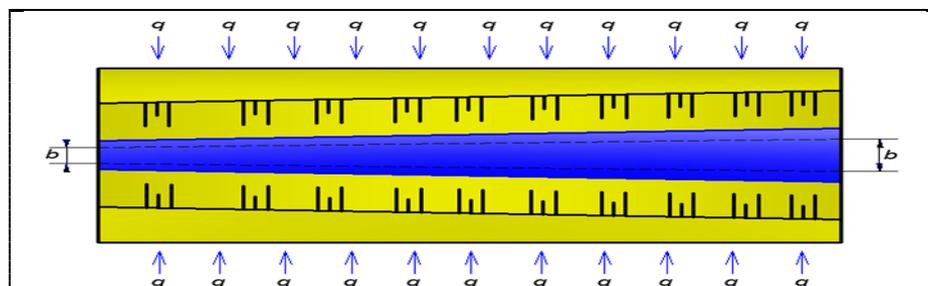

Figure 7. Plan of the constructed open drainage

On the basis of advanced design, to determine the hydraulic parameters of the constructed open drainage, measurements were carried out on the planned sections. The measured and calculated hydraulic parameters are analyzed (Tab. 3).

Table 3. Water discharge in sections of constructed open drainage

PC	Qm, l/s	Qc, l/s
1	203.35	212.56
4	167.91	159.26
8	123.32	119.27
12	81.32	86.75
16	40.33	37.56
20	0.10	0.15

According to the results of the analysis, the water flow rate of the constructed open drainage (Q_m) is very close to the water flow rate (Q_c) calculated in the design work (Fig. 8).
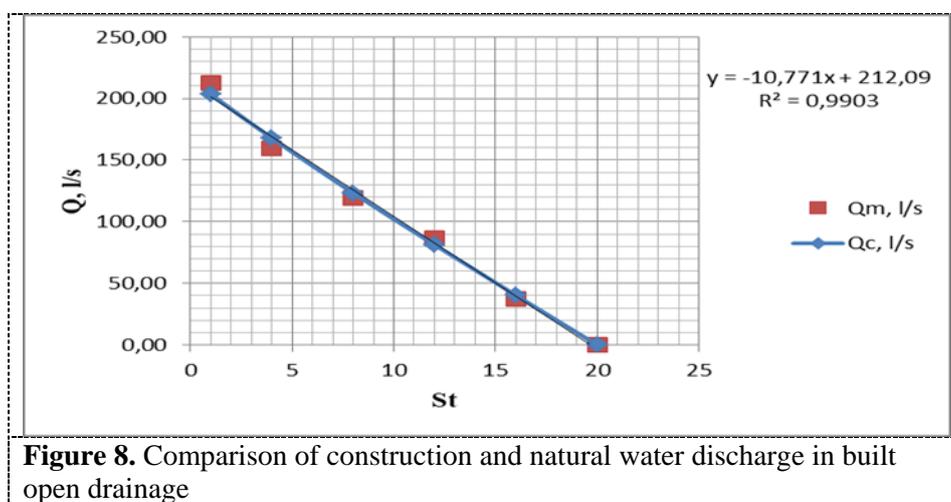
Figure 8. Comparison of construction and natural water discharge in built open drainage

4. Conclusions

The above equation, taking into account the uneven flow movement in open drains, expresses a mathematical model of the process. Based on the obtained model, an improved method for calculating open drainage parameters has been improved.

As a result, the opportunity was created to justify the hydraulic parameters, taking into account the influx of infiltration water from the sown area into the open drainage. When designing open drainages over sections, designing is recommended taking into account the variability of water flow. Because, in open drainages as a result of the flow of groundwater, a mode of uneven movement appears. The above recommended design method along the length of open drainage makes it possible to justify hydraulic parameters taking into account the variability of water flow.

Acknowledgments

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