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CONDITIONS FOR OPTIMAL WATER RESOURCES MANAGEMENT

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ABSTRACT

This paper considers mathematical modeling of a river section. A detailed mathematical analysis of the irrigation channel is carried out. A network for studying the water surface based on formal-algebraic analysis is investigated. The object of the study is the Chirchik river basin. An algorithm of modelling water management system is developed in this article..

Keywords: mathematical modeling, river basin, algorithm, irrigation system, formal-algebraic analysis, surface grid, set.

INTRODUCTION

A whole range of research works is carried out in the world aimed at improving and developing methods, selecting criteria for water distribution in channels, and developing new and derived mathematical models for managing water resources in reservoirs, irrigation channels, main channels, and rivers. In this direction, one of the most important tasks is to model the processes of water resources management in distributed irrigation systems.

LITERATURE REVIEW

Among the countries most deeply involved in research on water resources, it should be noted the United States, China, France, Germany, Spain, Ukraine, Russia, and also Kazakhstan and Uzbekistan. The use of modern information technologies for water distribution is provided by the development of mathematical models for rational water resources management. According to research by the World Resources Institute, Uzbekistan is among the 13 countries with low water resources.

The task of modelling water resource management in rivers, main canals and canals of irrigation systems is given in the works Dooge J. C. I., M. Levent Cavvas, Ali Ercan, James Polsinelli, Waqar A. Khan, Nawaf Hamadneh N., Surafel L. Tilahun, Park C. C., B. M. Kaganovich, K. Morinishi, S. K. Godunov, A. V. bol'shakova, T. P. Klavesnici, M. M. Kamilov, T. F. Bekmuratov, R. H. Khamdamov, S. H. Fozilova, N. Rusanova, I. K. Khugaeva, sh. Kh. Rakhimov, A. J. Satava and others.

In modern science, Saint-Venant equations are used to describe the movement of water. In the most common form, they can be written as follows:

- water flow balance equation

$$\frac{\partial Q}{\partial L} + \frac{\partial \omega}{\partial t} = 0 \qquad (1)$$

- the equation of dynamic equilibrium

$$i - \frac{\partial h}{\partial L} = \frac{Q^2}{K^2} + \frac{v}{g}\frac{\partial v}{\partial L} + \frac{1}{g}\frac{\partial v}{\partial t} \qquad (2)$$

where i - the slope of the bottom, Q, K, v – flow rate, flow modulus, and average cross-section speed, ω, h - live cross section and flow depth in it, L – distance, t – time, g – constant of gravitation.

The mathematical modeling of unsteady water movement in streams was led by the research of Saint-Venant, Navier — Stokes, L. A. Rastigin, J. Stoker, and others.

In the method of characteristics Of S. A. Khristianovich, the system of Saint-Venant equations is replaced by an equivalent system of four ordinary differential equations, which are two equations of characteristics (forward and reverse) and two equations that connect the flow elements along these characteristics. A system of four equations is solved in finite differences and allows calculating the coordinates t and s of the nodes of the characteristic grid in the wave plane. Then the calculated coordinates are used to determine the values of the flow parameters: *Q(s,t), z(s,t).* In addition, equations in characteristic form are used in grid methods for calculating regime elements in boundary gates.

The method of hydrological analogy [1] is based on the construction of a graphical relationship between the flow of two rivers. Let's say that for river Y there is a hydrological series of observations for n years. The coefficient of variation is determined and the standard error is calculated based on it (<10%):

$$C_v = \sqrt{\frac{\sum(k_i - 1)}{n-1}}^{2} \qquad (3)$$

$$\delta q = \frac{C_y}{\sqrt{n}} \cdot 100\% \qquad (4)$$

Average annual expenditure:

$$Q_{\text{ср}.i} = \frac{\Sigma Q_{\text{ср.мес}}}{12} \qquad (5)$$

The rate of flow:

$$Q_0 = \frac{\Sigma Q_{\text{ср}.i}}{\text{n}} \qquad (6)$$

If the error exceeds 10%, the hydrographic characteristics are used to determine an analog river with a large number of flow measurements:

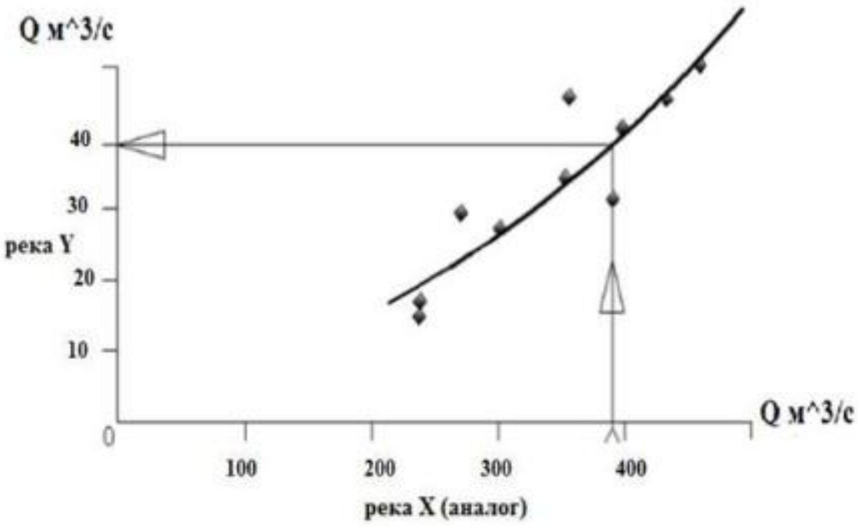

Fig. 1. Definition of an analog river.

DISCUSSION

Small catchment basins are usually studied using morphometric analysis, analysis of aerial photographs, where you can examine in detail the structure of slopes, lengths, areas, and vegetation cover features.

Scheme for studying a small catchment area:

1. Determining the spatial-temporal hierarchical level,
2. Analysis of morphological elements, and morphological structure,
3. Elucidation of characteristic features of dynamics and functioning,
4. Development of the forecast application and management recommendations.

The above diagram may vary depending on the depth of the study, but it describes the main steps in the study of small catchment areas.

In the middle reaches of the Chirchik river, we denote the water surface as the region D in 3-dimensional Euclidean space ε^3 with the boundaries ∂D, which we denote by s. Let the equation of this surface have the form $\gamma(x) = 0$. We introduce a generalized function $\delta(\gamma(x))$, or $\delta S(x)$, or δS – simple surface layer S, for which

$$(\delta_s, F) = \int_D \delta_s\,(x) F(x) dx = \int_S F(x)\, dS \qquad (7)$$

So, let $f(x)$ – continuous function on S. We introduce a generalized function

$\frac{\partial}{\partial n}\big(f(x)\delta_s(x)\big)$,

valid under the rule

$$\frac{\partial}{\partial n}\big(f(x)\delta_s(x), F(x)\big) = \int\limits_D F\,(x) \frac{\partial}{\partial n}\big(f(x), \delta_s(x)\big) dx =$$

$$= -\int_S \frac{\partial F(x)}{\partial n} f(x)\, dS. \qquad (8)$$

For equation 8 the standardizing function has the form

$$\omega(x) = f(x) - \frac{\partial}{\partial n}(g(x), \delta_s(x)). \quad (9)$$

This corresponds to the well-known solution of this problem, expressed in terms of the green function G(x, ξ):

$$Q(x) = \int_D G\,(x,\xi) f(\xi) d\xi - \int_S \frac{\partial G(x,\xi)}{\partial n_\xi} g(\xi) dS. \quad (10)$$

Changes in air temperature in space depending on the flow of water evenly distributed along a straight line perpendicular to the XY plane and passing through a point (ξ, η) planes *xy*. The free surface has a set temperature (concentration) independent of y.

The same is true for a half-plane isolated on both sides, with the boundary maintained at a given temperature.

$$-\left[\frac{\partial^2 Q(r,\theta)}{\partial r^2} + \frac{1}{r}\frac{\partial Q(r,\theta)}{\partial r} + \frac{\partial^2 Q(r,\theta)}{\partial \theta^2}\right] = f(r,\theta),$$

(1.22)

$$|Q(0,\theta)| < \infty, \qquad \frac{\partial Q}{\partial r}(R_1,\theta) = g_1\theta, \qquad \frac{\partial Q}{\partial r}(R_2,\theta) = g_2\theta,$$

$$Q(r, \theta + 2\pi) = Q(r,\theta),$$

$$R_1 \le r \le R_2, \qquad 0 \le \theta \le 2\pi.$$

Indeed, equation 10 shows the flow of water in a plane isolated on both sides. However, this dissertation examines an irrigation system that is not restricted on both sides. And the inclination of the bottom cannot be strictly taken at right angles. Therefore, equation 10 cannot be used as a basis for this study.

RESULTS

To compile long-term statistics in the middle reaches of the Chirchik river, the following channels were selected: Karasu, Parkent and Khandam. The length of the Karasu canal is 89.9 km, the Parkent canal is 87.94 km, and the Khandam canal extends for 73.3 km. Karasu was built in 1900. The Parkent canal was built in 1983 and reconstructed twice in 1998 and 2012. The Handam canal was built in 1971. The capacity of Karasu is 260 m^3 / sec, the bound area is 40359 ha, 10530 ha of them are grown cotton, 11726 ha – grain crops, 18102 ha-other crops. Karasu has 4 large waterworks. In total, it has 42 hydraulic structures, 17 of which are intended for water distribution, 2 water intakes, 17 hydraulic posts, and 5 duckers.

The capacity of the Parkent canal is 57 m^3 / s, the linked area is 26871 ha, 124 ha of which are grown cotton, 4211 ha – grain crops, 22536 ha-other crops. Parkent has 1 large waterworks. In total, it has 281 hydraulic structures, 99 of which are intended for water distribution, 10 water intakes, 90 hydraulic posts, 13 duckings, 13 bridges.

The throughput capacity of Khandam is 30 m^3 / sec, the linked area is 7376 ha, 443 ha of them are grown cotton, 1723 ha – grain crops, 5209 ha-other crops. In total, there are 197 hydraulic structures on Khandam, 81 of which are intended for water distribution, 1 water intake, 81 hydraulic posts, and 16 duckers.

Thus, to study the balance of water resources in the middle reaches of the Chirchik river, we will consider an irrigation canal with two sections connected by a hydraulic structure as a research unit.

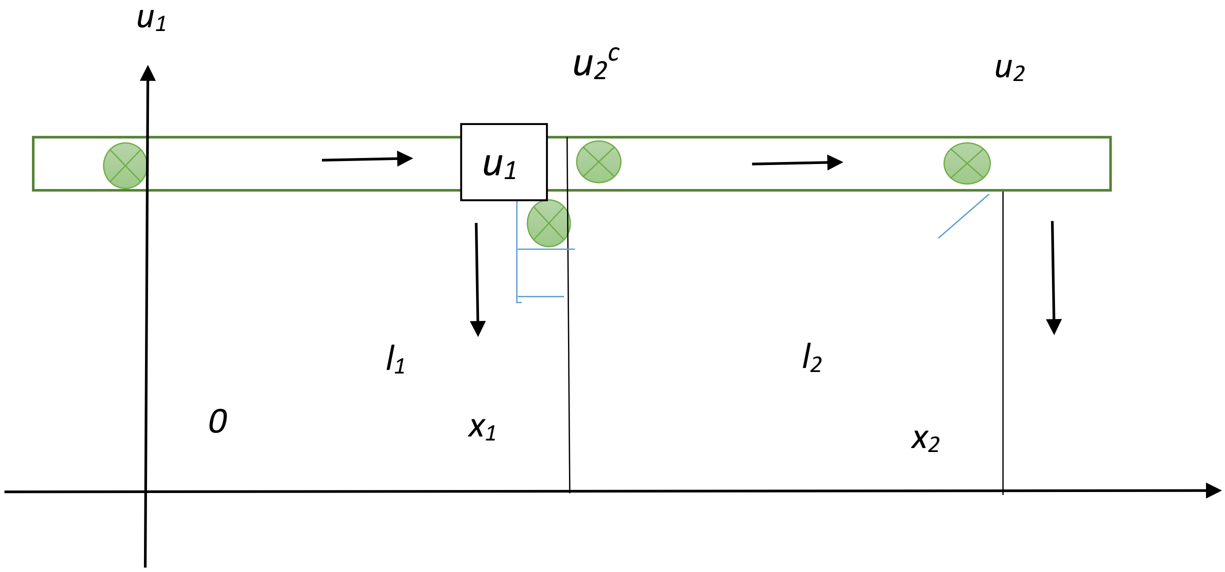

Fig. 2. Scheme of the irrigation channel.

As a mathematical model of the selected sections of the channel, we take a simplified system of Saint-Venant differential equations. It can be written as follows:

$$\partial h/\partial t+\mathrm{div}(h\bar{u})=\mathrm{div}(h\varpi) \qquad (11)$$

$$\partial(h\bar{u})/\partial t+div(h\bar{u}\otimes\bar{u})+g\nabla(h^2/2)=2\mathrm{div}(\nu h\delta(\bar{u}))+$$
$$+\mathrm{div}(h\varpi\otimes\bar{u}+h\varpi\otimes\varpi^*)+g\nabla(\tau h\ \mathrm{div}(h\ \bar{u})) \qquad (12)$$

Vectors $\varpi, \varpi*$ *and tenzor* $\delta(\bar{u})$ calculate by formula:

$$\varpi=(\tau/h)div(h\ \bar{u}\otimes\bar{u})+g\nabla h),$$

$$\varpi *=\tau((\bar{u}\cdot\nabla)\bar{u}+g\nabla h),$$

$$\delta(\bar{u})=\delta=1/2[(\nabla\otimes\bar{u})+(\nabla\otimes\bar{u})^{T}]. \qquad (13)$$

Here $\bar{u}$ – the average height of the current velocity, h – the vertical distance from the flat bottom of the water to its free surface. The system (11) – (12) contains the gravitational constant g=9,8 m/s^2, which we have taken to consider for two spatial variables (n = 2). The coefficient of kinematic viscosity of the liquid V and the characteristic relaxation time τ will be considered as already set positive constants.

Next, we establish that:

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$\tau = \nu / c_s^2$

here c_s – the speed of sound in a liquid.

Formally passing to (11) – (12) to the limit at $\tau \to +0$, we get the equations of the shallow water theory taking into account the influence of viscosity:

$$\partial h/\partial t + \mathrm{div}(h\bar{u}) = 0 \qquad (14)$$

$$\partial(h\bar{u})/\partial t + div(h\bar{u} \otimes \bar{u}) + g\nabla(h^2/2) = 2\mathrm{div}(\nu h \delta(\bar{u})) \qquad (15)$$

Later the passage to the limit in (14) – (15) when $\nu \to +0$ gives the classical Saint-Venant hyperbolic system:

$$\partial h/\partial t + \mathrm{div}(h\bar{u}) = 0 \qquad (16)$$

$$\partial(h\bar{u})/\partial t + div(h\bar{u} \otimes \bar{u}) + g\nabla(h^2/2) = 0 \qquad (17)$$

CONCLUSION

This paper presents the necessary conditions for optimal management of water resources in distributed irrigation systems. For optimal control, the values on the left side of equality (15) must be non-positive if the control reaches the lower bounds and non-negative if the control reaches the upper bounds. This is a necessary condition for optimal control. The following shows a model for managing information processing in a network of distributed irrigation systems. A verbal algorithm for solving problems of modeling water management processes in distributed irrigation systems is developed in this article.

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