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Price Characteristics Of The Project To Construct The Precipitation Runoff System Regulation.

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ABSTRACT

Currently, for the further effective development of the Black Sea coast of the North Caucasus and the Republic of Crimea, the problem of providing them with fresh water is very relevant. There is a tendency to increase freshwater consumption by 1% annually. There is an acute shortage of this resource, especially for agricultural production. In the Kuban State Agrarian University, a technology has been developed, implemented by a complex of hydraulic structures, designed to solve this problem. However, the effective operation of this system requires the optimization of the ratio of structural and technological parameters in its components. In this paper, they are theoretically consecrated through the distribution of the probability densities for the fulfillment of planned activities by the elements of the system and their capabilities, which ultimately will reduce uncertainties in management decisions.
Keywords: fresh water, the Black Sea coast of the Republic of Crimea, water supply technologies, management decisions, the feasibility of options.

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INTRODUCTION

In the river basins of the Black Sea coast, the main problem of water supply is the lack of reserves of drinking groundwater during the low-flow low-water period. On all rivers of the coast, the smallest runoff is observed in the summer-autumn period, when little precipitation falls and the rivers switch to underground feeding. In existing water intakes, artificial replenishment of reserves is used to increase operational reserves, and measures are being developed for the construction of regulating tanks (reservoirs).

To solve the problem in the Kuban State Agrarian University, a system for regulating the flow of atmospheric precipitation (CPC JSC) has been developed. This is a complex of interconnected hydraulic structures. The main components of the system are above-ground and underground reservoirs (one or more, of one kind or another); mechanical water lifting stations; transport conduits or pipelines; protective structures and other elements.

Naturally, a large variety of structures, structurally and functionally different from each other, should and impose certain requirements on the "boundary" conditions of a constructive-technological nature. First of all, this is the relative position both in plan and in height of the main components of the system. Further, it is imperative that technological communication capabilities be taken into account. For example, the rate of flow of costs from the above-ground reservoir to the underground or vice versa; carrying capacity of catastrophic structures; capacity of water transport facilities and pipelines and other aspects.

When designing such a complex system, starting from the construction stage, as well as at the operation stage, the engineering decisions should be considered taking into account the estimated total price of the planned measures. The cost of the effectiveness and financial sustainability of the planned event (construction and operation of the CPC JSC) will include the cost of the construction and operation of the system itself, taking into account the climatic factors that significantly affect the operational capabilities. It is natural and climatic factors, and more precisely, the presence of precipitation is decisive, though not the only factor that can cause an unfavorable state of the system.

MATERIALS AND METHODS

The article discusses the mathematical apparatus for assessing the basic characteristics of the price of an event for the construction and operation of an AIS, presented in Figure 1, depending on the initial state of the system elements and the degree of influence of the probabilities of an unfavorable state.

Figure 1: Practical implementation of the system for regulating the flow of precipitation

The development of quantitative methods to substantiate the choice of the most appropriate options and making management decisions are relevant at present.

RESULTS AND DISCUSSION

Consider one of the possible mathematical models of the process of reducing the price of the planned event. Our article describes a model of continuous change in the price of an event.

In order to create a model when evaluating proposed measures to reduce the uncertainty of management decisions, probabilistic models of processes for reducing the price of planned measures are proposed for consideration.

Let S be the price of the planned event. Let us now find the probability density of the duration of the planned event, using the Laplace transform. We introduce a function

$$G_t(q,S) = M\{e^{-q\tau} \mid S(t) = S\}. \quad (1)$$

Looking at the moment in time $t + \Delta t$ come to the ratio

$$G_t(q,S) = \lambda R(S)\Delta t \cdot e^{-q\Delta t} + (1-\lambda R(S)\Delta t)e^{-q\Delta t}G_t(q,S+\Delta S) + o(\Delta t). \quad (2)$$

Next we have

$$e^{-q\Delta t} = 1 - q\Delta t + o(\Delta t),$$

$$G_t(q,S+\Delta S) = G_t(q,S) + \frac{\partial G_t(q,S)}{\partial S}\Delta S + o(\Delta t).$$

Substituting all this into expression (2) and collecting the terms of the order, we get

$$G_t(q,S) = G_t(q,S) + \frac{\partial G_t(q,S)}{\partial S}\Delta S - (\lambda R(S)+q)G_t(q,S)\Delta t + \lambda R(S)\Delta t + o(\Delta t).$$

Cutting $G_t(q,S)$, dividing by Δt and going to the limit $\Delta t \to 0$, will find

$$\frac{\partial G_t(q,S)}{\partial S}a(S) + (\lambda R(S)+q)G_t(q,S) = \lambda R(S),$$

or

$$\frac{\partial G_t(q,S)}{\partial S} + \left(g(S) + \frac{q}{a(S)}\right)G_t(q,S) = g(S). \quad (3)$$

Solve this equation. Homogeneous equation

$$\frac{\partial G_t(q,S)}{\partial S} + \left(g(S) + \frac{q}{a(S)}\right)G_t(q,S) = 0$$

has a solution

$$G_t(q,S) = C(q)\cdot \exp\left(-\int_{S_m}^{S}\left(g(x) + \frac{q}{a(x)}\right)dx\right).$$

Therefore, the general solution of equation (3) will be sought in the form

$$G_t(q,S) = C(q,S)\cdot \exp\left(-\int_{S_m}^{S} \left(g(x) + \frac{q}{a(x)} \right) dx \right).$$

Substituting this expression into (3) we get that

$$\frac{\partial C(q,S)}{\partial S} = g(S)\cdot \exp\left(\int_{S_m}^{S} \left(g(x) + \frac{q}{a(x)} \right) dx \right),$$

from where

$$C(q,S) = C_0(q) + \int_{S_m}^{S} g(y)\cdot \exp\left(\int_{S_m}^{y} \left(g(x) + \frac{q}{a(x)} \right) dx \right) dy.$$

Thus, the general solution of equation (3) is

$$G_t(q,S) = C_0(q)\exp\left(-\int_{S_m}^{S} \left(g(x) + \frac{q}{a(x)} \right) dx \right) + \int_{S_m}^{S} g(y)\cdot \exp\left(-\int_{y}^{S} \left(g(x) + \frac{q}{a(x)} \right) dx \right) dy \quad (4)$$

Expression for $C_0(q)$ found from the following considerations. Take $S(t) = S_m$. Then $p(S_m) = 1$ and the planned event immediately reaches the goal. Since the flow of potential interventions is a Poisson flow of intensity λ, then the probability density of the magnitude of the time interval to fulfill the intended goal will be $p(\tau) = \lambda e^{-\lambda\tau}$ and the Laplace transform of this function is $\frac{\lambda}{\lambda + q}$. Putting in (4) $S = S_m$, we finally get

$$G_t(q,S) = \frac{\lambda}{\lambda + q}\exp\left(-\int_{S_m}^{S} \left(g(x) + \frac{q}{a(x)} \right) dx \right) + \int_{S_m}^{S} g(y)\cdot \exp\left(-\int_{y}^{S} \left(g(x) + \frac{q}{a(x)} \right) dx \right) dy \quad (5)$$

In particular, if the intended event at a time $t = 0$ estimated S_0, i.e $S(0) = S_0$, that

$$G_t(q,S_0) = \frac{\lambda}{\lambda + q}\exp\left(-\int_{S_m}^{S_0} \left(g(x) + \frac{q}{a(x)} \right) dx \right) + \int_{S_m}^{S_0} g(y)\cdot \exp\left(-\int_{y}^{S_0} \left(g(x) + \frac{q}{a(x)} \right) dx \right) dy \quad (6)$$

We now find the inverse Laplace transform of this expression. Let's start with the second term

$$J_2 = \int_{S_m}^{S_0} g(y)\cdot \exp\left(-\int_{y}^{S_0} \left(g(x) + \frac{q}{a(x)} \right) dx \right) dy = \int_{S_m}^{S_0} g(y)\cdot \exp\left(-\int_{y}^{S_0} g(x)dx - q\int_{y}^{S_0} \frac{dx}{a(x)} \right) dy.$$

Calculate $\int_{y}^{S_0} \frac{dx}{a(x)}$. Remembering that expression $S = S(t)$ may be uniquely resolved *t,* i.e $t = t(S)$, and also that $a(S) = -\left.\frac{dS}{dt}\right|_{t=t(S)}$, we get

$$\int_{y}^{S_0} \frac{dS}{a(S)} = -\int_{y}^{S_0} dt(S) = t(y) - t(S_0) = t(y),$$

So as $t(S_0) = 0$. therefore

$$J_2 = \int_{S_m}^{S_0} g(y) \cdot \exp\left(-\int_{y}^{S_0} g(x)dx - qt(y) \right) dy.$$

Function $a(S)$ was introduced.

Inverse Laplace transform from $\exp(-qt(y))$ there is $\delta(\tau - t(y))$. Therefore, the inverse Laplace transform of the expression *J* there is

$$\int_{S_m}^{S_0} g(y) \cdot \exp\left(-\int_{y}^{S_0} g(x)dx \right) \delta(\tau - t(y))dy. \tag{7}$$

To calculate this integral, we make the change of variables $\tau - t(y) = z$. Then $y = S(\tau - z)$, $dy = -S'(\tau - z)dz$ and integral (7) takes the form

$$-\int_{\tau - t(S_m)}^{\tau} g(S(\tau - z)) \cdot \exp\left(-\int_{S(\tau - z)}^{S_0} g(x)dx \right) S'(\tau - z)\delta(z)dz =$$

$$= -g(S(\tau))\exp\left(-\int_{S(\tau)}^{S_0} g(x)dx \right) S'(\tau), \tag{8}$$

which gives the inverse Laplace transform from J_2. Note that in this case $0 \le \tau \le t(S_m)$.

Consider now the first addend.

$$J_1 = \frac{\lambda}{\lambda + q} \exp\left(-\int_{S_m}^{S_0} \left(g(x) + \frac{q}{a(x)} \right) dx \right) = \frac{\lambda}{\lambda + q} \exp\left(-\int_{S_m}^{S_0} g(x)dx - q\int_{S_m}^{S_0} \frac{dx}{a(x)} \right).$$

Given written above, $\int_{S_m}^{S_0} \frac{dx}{a(x)} = t(S_m)$, and therefore

$$J_1 = \frac{\lambda}{\lambda + q} e^{-qt(S_m)} \cdot \exp\left(-\int_{S_m}^{S_0} g(x)dx \right).$$

Inverse Laplace transform from $\dfrac{\lambda}{\lambda+q}$ there is $\lambda e^{-\lambda\tau},\ \tau\ge 0$. Therefore, according to the shift theorem, the inverse Laplace transform of J_1 there is

$$J_1=\lambda e^{-\lambda(\tau-t(S_m))}\cdot\exp\left(-\int_{S_m}^{S_0}g(x)dx\right),\quad \tau\ge t(S_m)\,. \tag{9}$$

So finally

$$p(\tau)=\begin{cases}-g(S(\tau))\exp\left(-\int_{S(\tau)}^{S_0}g(x)dx\right)S'(\tau), & 0\le\tau<t(S_m),\\ \lambda e^{-\lambda(\tau-t(S_m))}\cdot\exp\left(-\int_{S_m}^{S_0}g(x)dx\right), & \tau\ge t(S_m).\end{cases} \tag{10}$$

In conclusion, we verify that for $p(\tau)$ the normalization condition is satisfied. We have

$$\int_{t(S_m)}^{\infty}\lambda e^{-\lambda(\tau-t(S_m))}d\tau\cdot\exp\left(-\int_{S_m}^{S_0}g(x)dx\right)=\exp\left(-\int_{S_m}^{S_0}g(x)dx\right).$$

Further,

$$-\int_0^{t(S_m)}g(S(\tau))\exp\left(-\int_{S(\tau)}^{S_0}g(x)dx\right)S'(\tau)d\tau=\int_{S_m}^{S_0}g(y)\exp\left(-\int_y^{S_0}g(x)dx\right)dy=$$

$$=\int_{S_m}^{S_0}d_y\exp\left(-\int_y^{S_0}g(x)dx\right)=\exp\left(-\int_y^{S_0}g(x)dx\right)\Bigg|_{S_m}^{S_0}=1-\exp\left(-\int_{S_m}^{S_0}g(x)dx\right).$$

It follows that $\int_0^{\infty}p(\tau)d\tau=1$, that is, the normalization condition is satisfied.

In the case when $\int_{S_m}^{S_0}g(x)dx=+\infty$ и $t(S_m)=+\infty$, expression for $p(\tau)$ has the appearance

$$p(\tau)=-g(S(\tau))\exp\left(-\int_{S(\tau)}^{S_0}g(x)dx\right)S'(\tau),\ \tau\ge 0 \tag{11}$$

and it can be written in a simpler form. Indeed, in this case

$$g(S)=-\frac{\lambda R(S)}{S'(t(S))},$$

and therefore

$$-g(S(\tau))\cdot S'(\tau)=\lambda R(S(\tau))\frac{S'(\tau)}{S'(t(S(\tau)))}=\lambda R(S(\tau))\frac{S'(\tau)}{S'(\tau)}=\lambda R(S(\tau)).$$

Further

$$\frac{1}{S'(t(S))}=\frac{1}{dS/dt\big|_{t=t(S)}}=\frac{dt(S)}{dS},$$

and therefore

$$\int_{S(\tau)}^{S_0} g(x)dx=-\int_{S(\tau)}^{S_0}\frac{\lambda R(S)}{S'(t(S))}dS=\int_{S(\tau)}^{S_0}\lambda R(S)dt(S)=\int_{\tau}^{0}\lambda R(S(t))dt.$$

Finally get

$$p(\tau)=\lambda R(S(\tau))\exp\left(-\int_0^{\tau}\lambda R(S(t))dt\right), \quad (12)$$

which is much simpler than the original expression (11).

Many regions and entire states face a shortage of certain resources. In this regard, fresh water is almost a defining resource on a global scale. Development of technology for the extraction and accumulation of fresh water is certainly an urgent task of great importance. The proposed technologies for obtaining fresh water, implemented by a complex of hydraulic structures, will naturally be more effective in assessing and reducing the price of the planned measures. The probabilistic models of management processes by planned measures considered in the article make it possible to solve the assigned tasks and reduce the risks of uncertainties when making management decisions.

CONCLUSION

In the considered probabilistic model of the process of reducing the price of planned activities, the estimated parameters are interpreted as random variables. The model can be used in the development of measures to reduce the uncertainty of management decisions, in the development of alternative management decisions and the informed choice of measures aimed at reducing the irrevocable withdrawal of flow in the low summer period, which will save water resources.

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