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Elements of Method Improvement of Flood Zones Determination

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Abstract. The article suggests a possible application of mathematical modeling zones and flooding characteristics that will improve the methodological basis in hydrological calculations and forecasting will provide opportunities for a better understanding of the complex mechanisms of formation flow. The computational scheme is applicable for vertically homogeneous flow conditions extending from steep river flows to tidal influenced estuaries. The system has been used in numerous engineering studies.

Keywords: stochastic models, methods of extreme estimation, optimization problems, software, automated information systems.

INTRODUCTION

Establishment of a set of catchment modeling tools, which can provide the basis of analyяing the likely outcome of carefully selected management actions (scenarios, alternatives). Within this the objectives are the development of - Hydrological and hydraulic models to support the solution of flood control problems and to provide basis for other models, - Catchment models focussing on the control of nonpoint source pollution, - River water quality models for nutrients, oxygen household processes and specific other pollutants that might prove to be necessary when issues are fully identified, - Pollution spill models, to form the basis of the establishment of an operative quasi-on-line pollutant wave propagation forecasting system (only an illustrative description of the spill-modeling options will be given, as the evaluators of the project, wished to exclude this “specific incident” oriented tool), - Lake (wetland) and reservoir ecosystem models to help managing the unique aquatic ecosystems, - Promotion of the application of the novel ecohydrological means of water and environmental management in a catchment where a high number of unique riparian wetlands exists and are endangered. Upon the evaluation of the project proposal, this became one of the most important objectives of the project, with much focus on the “ecohydrological approach”. Last but far not the least promotion of the application of the requirements of the Water Framework Directive of the European Union and other respective directives of the EU and of international agreements such as the UN/ECE Transboundary Water Convention in a catchment which is shared by countries in various stages of their process of accession to the EU [1].

It comprises a comprehensive suite of routines for performing extreme value analysis. These include A pre-processing facility for extraction of the extreme value series from the record of observations. Support of two different extreme value models, the annual maximum series model, and the partial duration series model. Support of a large number of probability distributions, including exponential, generalized Pareto, Gumbel, generalized extreme value, Weibull, Frechét, gamma, Pearson Type3, Log-Pearson Type3, log- normal, and square-root exponential distributions. Three different estimation methods: method of moments, maximum likelihood method, and method of L-moments.

For evaluating the risk of extreme events a parametric frequency analysis approach is adopted. This implies that an extreme value model is formulated based on fitting a theoretical probability distribution to the observed extreme value series. Two different extreme value models, the annual maximum series (AMS) method and the partial duration series (PDS) method, also known as the peak over threshold (POT) method [1-5].

MAIN RESULTS AND THEIR DISCUSSIONS

A method of geospatial modeling of runoff processes and changes in land-use types at the global level is proposed, which, unlike the known ones, takes into account the mutual influence of these processes, which allows to jointly analyze and forecast these processes depending on the economic situation and water flow constraints. A method for modeling the spatial propagation process for a global geospatial model by taking into account the flow intensity is proposed for use, which makes it possible to more accurately reproduce the spatial structure of the formation.

A method of modeling the decision-making process to reduce water runoff for geospatial models of runoff and land-use change is proposed, which is based on the principle of maximizing the combination of information on factors of influence at different spatial levels and allows simulation of drainage and environmental strategies. Using this, a global geospatial model of stock formation processes is proposed for use [5].

The model includes decision-making processes for land-use change and parameters of factors influencing water flow. Also, a version of the model was proposed for use in which the available geospatial data was additionally used, which made it possible to improve the method of modeling the decision-making process. The parameters and data necessary for the adaptation of the geospatial model of runoff processes and land-use change of the ecosystems of the Tisza river basin are proposed.

A method for identifying the parameters of the model that are responsible for modeling the processes of land-use change, which made it possible to reproduce the historical levels in the sector and land-use change. Predict levels in different scenarios of socio-economic development at appropriate water levels. As a result of the analysis of inaccuracies of input data, it is offered to use a model where the data are characterized by rather high uncertainty. As a result of the analysis of the sensitivity of the model to changes in individual parameters, it was found that the results of modeling the flow rate of water and flooding without the influence of runoff delay factors are most sensitive to changes in gross domestic product. The general analysis and calculations will provide an opportunity to use research by design institutes [1, 5].

To generalize the study of the Tisza river basin as a whole, the floodplain of the Borzhava River from the narrow-gauge railway bridge near the village of Shalanki to the road bridge on the section of the Za-richchya-Vilkhivka highway. Figure 1. The calculation of the definition of possible flood zones has been improved to optimize the operation of the flood protection system based on mathematical modeling using the automation of calculations by software [5].

Fig. 1. An image of Zavadka territory

In the presence of the river retaining structures, or the staff of the receiving water, allowed to use a simplified method for determining the distance prop [5, 6]:

$$L = \alpha\,(h_o + z) / I,$$

where L is a distance dis-proliferation thereof, km; h_o - average depth in the absence thereof, m; z - the value of the staff at the facilities or at the mouth of the city; I - water surface slope, m / km; α - coefficient depending on the ratio z/h_o.

Let W_{fl} is a forecast flood volume. To determine the surface area that is subject to flooding floodwater on systems according to topographic surveys built dependence $S^z = f(W^z)$. The volume of excess water, that comes from the banks of the channel, find the value of

$$W_i^z = W_{fl} - W_{fl,i} - W_{gr,i} - W_{gv,i} - W_{dv,i}\ .$$

The area flooding is calculated, based on the layer floodplain inundation. If we assume that the cross-section of the floodplain on the j-th alignment line on top is a straight-on angle, the width of flooding in accordance left and right floodplain, the i-th option of placing dams were fallouts of the table:

$$B_{Lji} = \frac{h_{ji}^z}{i_{Lj}}\ ,\ B_{nji} = \frac{h_{ji}^z}{i_{nj}}\ .$$

Determine the area of flooding drained areas that must be divided into smaller sections [1, 5]

$$S_i^z = \left(\frac{B_1 + B_2 + \ldots + B_n}{n}\right)L\ .$$

So, by calculating the optimization mode of drainage systems during floods, this option would ensure a reduction in operating costs while also leading to increased crop yields.

Due to the difficulties in distinguishing between the amount of theoretical knowledge about runoff formation and empirical data, the use of such methods has been suspended. However, the use of epistemological models based on the knowledge of only physical laws does not take into account the randomness of the factors of influence that are the source of natural phenomena of flooding. Therefore, I focused on modeling the process of runoff formation taking into account the stochastic components.

Suppose that the stochastic components of the catchment characteristics A_{ij}, where i and j are the numbers of the nodes of the spatial network, are distributed according to the normal law with standard μ_A and standard deviation ν_A and form homogeneous and isotropic fields with autocorrelation function [5, 9].

There is a problem of flooding of settlements and agricultural lands in the Tisza river basin, in particular large areas of arable land in the Borzhava river basin. It is necessary to prevent the harmful effects of floodwaters. Timely accumulation of runoff will help reduce flood damage and ensure the preservation of crops.

Suppose, as a result of the experiment we obtained a data set

$$x_1^{(n)}, x_2^{(n)}, ..., x_i^{(n)}, y_1^{(n)}, y_2^{(n)}, ..., y_j^{(n)}, n = 1,2,..., N.$$

By which it is necessary to calculate

$$q_1, q_2, ..., q_k$$

the value x_i and y_j associated with the desired $q_1, q_2, ..., q_k$ dependencies

$$y_m^n = \varphi_m(q_1, q_2, ..., q_k; x_1^{(n)}, x_2^{(n)}, ..., x_i^{(n)}) \ .$$

The result of each process is a random variable with some probability density

$$f(y_1, y_2, ..., y_m).$$

The problem is reduced to the solution of the optimization problem using the methods of extreme estimation, which involves finding

$$y_i = f_i(x) \to \max$$

$$y_i = f_i(x) \to \min$$

The solution of such a problem follows from the problem of some rule of choice on a set of effective objects of a single solution, which is solved formally and is based on the application of heuristics and rationality conditions [11, 12].

For the description we will use a symbolic representation in the form of a tuple *(A, S, R, E, C, P)*, where

A is the set of objects,

S is the set of constraints,

R is the set of principles of optimality,

E is the set of formal characteristics,

C is the set of goals facing the researcher,

P is a system of advantages.

For each parameter, the weights of their relative importance can be known $\beta_1, \beta_2, ..., \beta_m$, it is important to specify the directions of parameter optimization. For quantitative (absolute, relative, or normalized) upper, average (most probable, most acceptable or desirable), and lower estimates are used. To calculate the point values of the parameters, the calculation is performed by one of the methods [5]

$$a^{(1)} = (3a^н + 2a^в)/5;$$
$$a^{(2)} = (a^н + a^в)/2;$$
$$a^{(3)} = (a^н + 4a^* + a^в)/6;$$
$$a^{(4)} = (a^н + 2a^* + a^в)/4,$$

where $a^н, a^в, a^*$ are respectively, lower, upper, and desired (predicted or most likely) estimates of the values of a parameter.

We set the set S has constraints:

$$s_{*l} \le s_l(a^1, a^2, ..., a^m) \le s_l^* \ , \ l \in \{l, ..., l_0\},$$

where s_l is the arbitrary real-value functions of a discrete argument, , $a^i, i \in J$ is a parameter of objects, s_{*l}, s_l^* is a real numbers, l_0 is a number of constraints.

To solve the problem, we have stochastic components of the catchment characteristics aij, where i and *j* is a are the numbers of spatial network nodes distributed according to the normal law with standard μ_A and standard deviation ν_A and form homogeneous and isotropic fields with autocorrelation function [5, 7].

$$f_A(l) = \exp(-\alpha_A |l|),$$

where *l* is the distance between two points of the field;

α_A is a correlation radius.

The value will be set

$$a_{ij} = \mu_A + e_{ij}\nu_A,$$

where e_{ij} is a random process with a mean equal to zero, a standard deviation equal to one, and a correlation radius α_A .

The value e_{ij} is modeled by the Monte Carlo method [2] by formulas:

$$e_{ij} = (2/n)^{1/2} \sum_{m=1}^{N} \cos(w_m(x_i \sin\gamma_m + y_j \cos\gamma_m + \varphi_m),$$

$$w_m = \alpha_A((\frac{1}{1 - G(w_m)})^2 - 1)^{\frac{1}{2}},$$

where *N* = 50; γ_m, φ_m are the random variables evenly distributed on the segment [0, 2 π];

G(w_m) is a special random function with a change range of 0-1.

Marks of the catchment surface z_{ij} will be set using a two-dimensional spatial network in the form of [5]

$$z_{ij} = I * y_n (1 - (\frac{y_j - y_n}{y_n})^2)^{1/2} + e_{ij} v_z ,$$

where i and j are the network node numbers along the x and y axes; I is the average slope between $y = 0$ and $y = y_n$; y_n is the width of the catchment along the y-axis (the value y_n is assumed to be constant for all x); v_z is a change of the stochastic component of the quantity z_{ij}.

The movement of water on the surface of the catchment was determined by shifting the flow at the time of completion. The value of the catch-up time will be found by the formula

$$t_{ij} = g_T y_j + h_T x_i + e_{ij} v_T ,$$

where g_T, h_T are the parameters that are determined by the specified speeds of the slope and channel runoff;

v_T is a change of the stochastic part.

The calculation of water infiltration into the soil can be done according to the formula:

$$c_{ij} = 0{,}3(2k_{ij} b_{ij} (n_{ij} - \theta_{ij}^0))^{1/2} ,$$

obtained from the equation of moisture diffusion under some additional assumptions. Here k_{ij} is the filtration coefficient; n_{ij} is the porosity:

$$b_{ij} = \frac{1}{k_{ij}} \int_{\theta^0}^{n_{ij}} d_{ij}(\theta) d\theta,$$

where θ^0 is the initial moisture;

$d_{ij}(\theta)$ is a diffusion coefficient. Each of these parameters is modeled by formula. Precipitation intensity fields are modeled [Brass and Rodriguez-Iturbe] taking into account the spatial correlation of precipitation and rainfall velocity. For the amount of precipitation for rain H_r. Suppose that the values T_r, H_r and duration of non τ_p is a rainy periods are distributed exponentially [1]. The velocity of the shower is modeled by the normal distribution $T(\mu_u, \nu_u)$, where μ_u is the mean value of the velocity, u_r and σ_u is its standard deviation.

In terms τ_p, c_{ij} of values, we calculate the changes in the average level of groundwater.

$$z_{ij}^{''} = z_{ij} - z_{ij}^{'} .$$

The initial distribution of moisture is determined by the dependence:

$$\theta_{ij}^0 = n_{ij} (\exp(-d_1 Z_{ij}^{''}) \exp(-d_2 (\tau_p - \mu_\tau)) + e_{ij} \sigma_\theta ,$$

where d_1, d_2 are the coefficients; σ_θ is a standard deviation of the stochastic component of soil moisture. The initial moisture deficit was defined as:

$$s_{ij}^0 = \Delta x \Delta y z_{ij}^{''} (n_{ij} - \theta_{ij}^0).$$

The creation of a normal random process was carried out by generating the vector of independent random numbers in the usual way and constructed an interpolation dependence in the intervals between them.

Algorithm for optimization of flood control measures:

- using the sensor of random numbers of the environment Mathcad generated time-varying catchment parameters ($z_{ij}, t_{ij}, k_{ij}, n_{ij}, b_{ij}$);
- spatial data correlation (τ_r, T_r, u_r, H_r) was modeled by Mathcad by calculating the correlation function of a random process;
- set the initial conditions ($z_{ij}^{'}, z_{ij}^{''}, \theta_{ij}^0, s_{ij}^0$);
- reproduce the spatial distribution of rain intensity;
- count infiltration of water in soil and efficiency of precipitations r_{ij} ;
- calculate the total hydrograph of the runoff:

$$Q^m = \sum_{i=1}^{N_x} \sum_{j=1}^{N_y} r_{ij}^{m-m'} ,$$

where $m' = t_{ij} / \Delta t$ (Δt is a step of time) [10].

As a result, the estimated water consumption was obtained, according to the measurements of the study of the Irshava River №19 and Borzhava River. Long approaching empirical data.

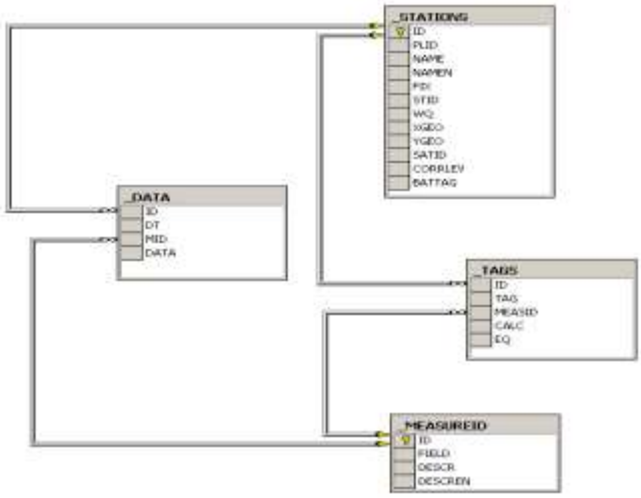

Fig. 2. Structure of the database of flood characteristics

CONCLUSIONS

The flooded area, or storage area, is defined at each h

point as the summation of the width times the distance between the *Q* points either side of the crosssection plus the additional flooded area. The width is automatically calculated when the cross-section raw data is processed or can be specified manually in the cross-section editors processed data menu. Additional flooded area data are specified manually by the user in the same editor.

The flooded area may have to be either increased or decreased manually by the user under certain conditions. An increase is necessary where there is an off-stream storage area (e.g. a harbor) connected to the river. A decrease is necessary where there is a duplication of flooded areas, (discussed below) [5].

To increase the flooded area specify additional flooded areas and/or increase the width values in the processed cross-section data editor. To decrease the flooded areas reduce the width values in the cross-section editors processed data menu.

The facility has been designed for modeling culverts of any shape, length or slope. All flow conditions are represented including full submergence, partial submergence, critical inflow, and outflow, orifice flow, and full culvert flow with a free outflow.

The formation of runoff - is a complex process due the influence and interaction of many natural factors. Calculation and prediction mode rivers and its characteristics (height, volume, flow time) always required proper attention. To address these practical problems successfully applied mathematical modeling of the flow processes, which today is a priority in the development of theoretical and practical hydrology. Such attention to mathematical modeling of the flow of water because this line of research can improve existing and create new practices hydrological forecasting and calculating the flow [5-12].

The generalization of the obtained results will allow to improve the existing mathematical models, to develop elements of the complex software of automation of the information-measuring system for improvement of the functioning of hydro-ecological geosystems of the territory of research. The technique can be used both for the study area and for identical basins of the Tisza River. Research works of forecasting the amount of melt and rainwater on the surface of the basins, determining possible flood zones at the location of embankment dams relative to the riverbed obtained results related to improving the hydro-ecological condition of geosystems within the Tisza River basin.

Based on the generalization of the study of the Tisza river basin as a whole, the floodplain of the Borzhava River from the narrow-gauge railway bridge near the village of Shalanki to the road bridge on the section of the Zarichchya-Vilkhivka highway. On the basis of stochastic modeling with the use of automation of calculations using software, the calculation of definition of possible zones of floods is improved. Calculated values and analysis of factors of influence on the establishment of zones of possible flooding at the location of embankment dams can be used to justify projects for the construction of hydraulic structures. Zones of possible flooding during floods of different security on the calculated section of the Tisza River are given in the references [5-12].

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