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A Method for Calculating Characteristics of Maximal River Runoff in the Absence of Observational Data: Case Study of Ukrainian Rivers

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Abstract—Scientific and methodological approaches to calculating characteristics of maximal runoff in Ukrainian rivers are considered.

Keywords: maximal runoff, rain floods, spring flood, channel isochrone model

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PROBLEM FORMULATION

Numerous regional approaches to calculating maximal water discharges have led to their classification (separately for rain floods and spring floods) presented in [7]. The formulas for maximal spring flood runoff, in their turn, are divided into two groups:

(1) reduction formulas, explicitly reflecting the reduction of unit-area spring flood discharges with increasing watershed size;

(2) volumetric formulas, expressing the maximal water discharge as a function of the flood volume, its duration, and geometric shape.

By their structure and content, maximal-runoff formulas for rain floods are divide into four groups:

(1) based on the maximal rainfall rate over the design travel time τ;

(2) reduction structures;

(3) calculation methods based on hydromechanical theories;

(4) volumetric formulas.

In the general form, the formula of limiting intensity can be written as:

$$q_m = \overline{\Psi}(\tau) H_d \eta, \tag{1}$$

where $\overline{\Psi}(\tau)$ are ordinates of reduction curve of mean precipitation intensity over the design time τ, H_d is the daily maximum of rain, η is an overall runoff coefficient.

The formulas relying on hydromechanical theories of storm runoff are based on equations of dynamic equilibrium and continuity of runoff for elementary areas or on models of channel isochrones (for watersheds of any size). In the general form, A.N. Befani [1] derived the following basic equation:

$$\frac{\partial \omega}{\partial x} + \frac{\partial}{\partial t}(\omega + \omega_f + \delta\omega_a) = \alpha q_t' B_t, \tag{2}$$

where ω is the cross section of an open flow, ω_f is the cross section of a floodplain flow, ω_a is cross section in alluvium, δ is the free porosity of alluvium.

With some simplifications, such as assuming a linear relationship between ω, on the one hand, and ω_f and ω_a, on the other hand, integration of (2) yielded a generalized structure of the calculation formula

$$q_m = \frac{Y_m}{t_c} \varphi k_h \varepsilon, \tag{3}$$

where Y_m is runoff depth, t_c is channel travel time, φ is a coefficient of completeness of slope inflow, contributing to the formation of q_m;
at $t_d < T_0$,

$$\varphi = \int_0^{t_d} q_t' dt; \tag{4}$$

at $t_d \geq T_0$,

$$\varphi = 1.0, \tag{5}$$

T_0 is the duration of water inflow from slopes into channel network, k_h is hydrographic coefficient;
at $t_c < T_0$,

$$k_h = \frac{\int_0^{t_h} q_t' B_t dt}{B_m \int_0^{t_c} q_t' dt}, \tag{6}$$

at $t_c \geq T_0$,

$$k_h = \frac{\int_0^{T_0} q_t^{'} B_t dt}{B_m \int_0^{T_0} q_t^{'} dt}, \tag{7}$$

B_t is the width of watersheds by isochrones of channel travel time, B_m is the mean width of watersheds, ε is the coefficient of channel–floodplain flood regulation.

As to volumetric formulas, their structure is based on nonlinear schematization of channel hydrographs. The general variant of volumetric formulas is as follows:

$$q_m = k_s \frac{Y_m}{T_f}, \tag{8}$$

where T_f is the duration of rain floods (spring floods), k_s is the shape coefficient of channel hydrographs.

The authors' analysis of the existing approaches to calculating maximal water discharges shows that the calculation formulas should be classified not by their application fields (rain floods or spring floods) or a structural base, but on some theoretical prerequisites. From this viewpoint, individual categories are required for formulas based on a geometrical model of hydrographs of rain or spring floods (reduction and volumetric formulas) and those based on a model of channel isochrones (hydromechanical and with extreme intensity).

The former category contains the slope and channel hydrographs in a reduction form:

slope

$$q_t^{'} = q_m^{'} \left[1 - \left(\frac{t}{T_0}\right)^n\right], \tag{9}$$

channel

$$q_t = q_m \left[1 - \left(\frac{t}{T_n}\right)^m\right]. \tag{10}$$

After integrating (9) and (10) with respect to T_0 and T_n and their combining, we obtain a generalized formula for q_m:

$$q_m = \frac{k_0 Y_m}{1 + t_c/T_0} k_m k_n, \tag{11}$$

where k_0 is the coefficient of slope transformation

$$k_0 = \frac{n+1}{n}\frac{1}{T_0}, \tag{12}$$

$\frac{n+1}{n}$ is the coefficient of time heterogeneity of the slope inflow,

$k_m = \frac{m+1}{m} \Big/ \frac{n+1}{n}$ is the coefficient of transformation of runoff hydrograph shape,

$\frac{m+1}{m}$ is the coefficient of time heterogeneity of the channel runoff,

$k_n = \frac{T_0 + t_c}{T_n}$ is the coefficient of channel–floodplain regulation of rain floods or spring floods.

Since coefficients k_m and k_n are determined by watershed areas F, then, if averaging over the area T_0 is possible, we obtain an equality

$$\frac{k_m k_n}{1 + t_c/T_0} = f(F) = \frac{1}{(F+1)^{n_1}}, \tag{13}$$

and formula (11) becomes

$$q_m = \frac{q_m^{'}}{(F+1)^{n_1}} = \frac{k_0 Y_m}{(F+1)^{n_1}}. \tag{14}$$

To obtain a volumetric formula, it suffices to substitute appropriate k_0, k_m, and k_n into (11) to obtain

$$q_m = \frac{m+1}{m}\frac{Y_m}{T_n}. \tag{15}$$

Comparing (8) and (15), we obtain

$$\frac{m+1}{m} = k_s. \tag{16}$$

PROPOSED PROCEDURE

Weak points of the hydromechanical model in [2] are the assumptions that the coefficient of hydrographic network density α is constant; a linear relationship exists between the areas ω, on the one hand, and ω_n and ω_a, on the other hand; and the existence of indeterminate ratios of the form of 0/0 when the watershed area $F \to 0$. Considering this, the authors, when substantiating the procedure for calculating maximal water discharges during rain and spring floods, use somewhat different approach to the implementation of channel isochrone model. Taken as the basis were reduction plots of functions of slope inflow $q_t^{'}$ and areas between isochrones f_t: the former as an equation (9), and the latter, in the form

$$f_t = f_m \left[1 - \left(\frac{t}{t_p}\right)^{m_1}\right], \tag{17}$$

where f_t are areas between isochrones ($f_t = B_t V_t \Delta t$), V_t is the rate of channel travel time of rain or spring floods.

Because of the lack of data on the dynamics of channel–floodplain regulation of rain and spring floods, we will express the respective transformation function in a symbolic form ε_t.

Basing on the classical theory of channel isochrones, we write the equations of maximal water discharges of rain or spring floods Q_m:

at $t_c < T_0$,

$$Q_m = V_t \int_0^{t_c} q_t' B_t \varepsilon_t dt, \tag{18}$$

at $t_c \geq T_0$,

$$Q_m = V_t \int_0^{T_c} q_t' B_t \varepsilon_t dt. \tag{19}$$

To simplify (18) and (19), we average function ε_t over t_c or T_0, then

at $t_c < T_0$

$$(Q_m)_{\text{appr}} = q_m' \bar{\varepsilon}_{t_c} \frac{m_1}{m_1+1} V_t t_c \times \left[1 - \frac{m_1+1}{(n+1)(m_1+n+1)} \left(\frac{t_c}{T_0}\right)^n\right], \tag{20}$$

at $t_c \geq T_0$

$$(Q_m)_{\text{appr}} = q_m' \bar{\varepsilon}_{T_0} \frac{m_1}{m_1+1} V_t T_0 \frac{n}{n+1} \times \left[\frac{m_1+1}{m_1} - \frac{n+1}{m_1(m_1+n+1)} \left(\frac{T_0}{t_c}\right)^{m_1}\right], \tag{21}$$

where $(Q_m)_{\text{appr}}$ is an approximate value of maximal water discharge associated with averaging ε_t with respect to t_c and T_0, respectively.

To pass from $(Q_m)_{\text{appr}}$ to Q_m, we introduce a conversion factor $k_\varepsilon = \dfrac{Q_m}{(Q_m)_{\text{appr}}}$. Considering k_ε,

$$q_m = q_m' \Psi(t_c/T_0) \varepsilon_F, \tag{22}$$

Here q_m' is the maximal unit-area runoff from slope inflow:

$$q_m' = \frac{n+1}{n} \frac{1}{T_0} Y_m, \tag{23}$$

$\dfrac{n+1}{n}$ is a coefficient of time heterogeneity of water inflow from slopes into channel network, T_0 is the duration of water inflow from slopes into the channel network, $\psi(t_c/T_0)$ is a transformation function reflecting the flattening of rain or spring flood waves under the effect of channel travel time:

at $t_c/T_0 = 0$,

$$\psi(t_c/T_0) = 1.0, \tag{24}$$

at $0 < t_c/T_0 < 1.0$,

$$\psi(t_c/T_0) = 1 - \frac{m_1+1}{(n+1)(m_1+n+1)} \left(\frac{t_c}{T_0}\right)^n, \tag{25}$$

at $t_c/T_0 \geq 1.0$,

$$\psi(t_c/T_0) = \frac{n}{n+1} \frac{T_0}{t_c} \times \left[\frac{m_1+1}{m_1} - \frac{n+1}{m_1(m_1+n+1)} \left(\frac{T_0}{t_c}\right)^{m_1}\right], \tag{26}$$

at $t_c \gg T_0$,

$$\psi(t_c/T_0) = 0. \tag{27}$$

As an example, we give a calculation of maximal runoff of spring flood in the Yuzhnyi Bug basin.

MATERIALS OF STUDY

To substantiate the design characteristics of spring flood, we used the materials of long-term observations on 39 river watersheds with areas varying from 36.5 (Yuzhnyi Bug R., Chernyava V.) to 46 200 km^2 (Yuzhnyi Bug R., Aleksandrovka Settl.) for observation periods from 13 to 97 years (up to year of 2010, inclusive).

Study Results and Their Analysis

The calculation of the maximal unit-area discharge of a spring flood with a given recurrence for rivers of the Yuzhnyi Bug basin is based on formula (22). Below, we consider parameters of this model separately.

Standardization of design unit-area discharges of slope inflow. As can be seen from equation (23), the evaluation of maximal unit-area discharges of slope inflow amounts to establishing three characteristics of the slope hydrograph: a coefficient of time heterogeneity of slope inflow $(n + 1)/n$, the duration of water inflow from slopes into channel network T_0, and the total inflow depth Y_m.

The calculation and spatial generalization of the runoff depth of spring flood with a given recurrence causes no problems, as the source series are available from reference books, while nearly no direct measurements of other characteristics of slope water yield in periods of formation of maximal runoff at the current stage of studies are being carried out. However, an inverse problem can be solved by retransformation of the channel hydrograph or by numerical evaluation of unknown parameters.

Spatial distribution of design characteristics of runoff depths of spring floods. The examined area shows a distinct relationship of $Y_{1\%}$ on the latitudinal position of watersheds with a significant correlation coefficient ($r = 0.69$). The existence of such relationship formed the basis for compiling a map given in Fig. 1. The contour lines are drawn with an interval of 20 mm. Overall, the runoff depths in the examined area vary from

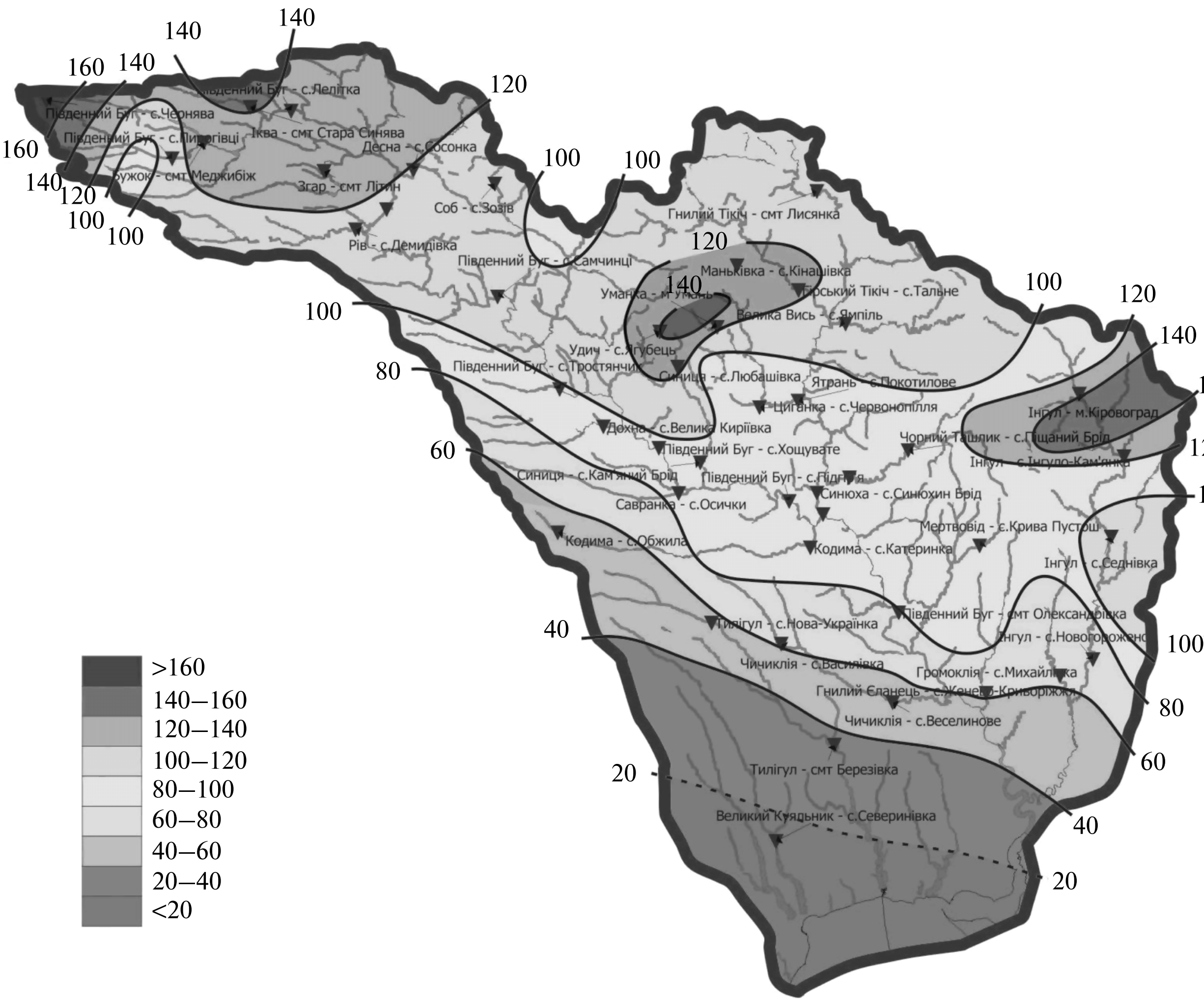

Fig. 1. Distribution of runoff depth for a spring flood of 1% recurrence over Yuzhnyi Bug basin.

160-140 mm in its northwestern part to 40–20 mm in the south.

Coefficients of time heterogeneity of slope inflow. The characteristics of channel inflow are measured only at water balance stations; however, there are no such stations in the territory in question. An efficient method for determining heterogeneity coefficients in the absence of observation data on water balance stations is the analysis of channel runoff hydrographs [7], which in the context of the problem under consideration can be described by reduction equation (10).

By integrating (10) with respect to T_n, we obtain

$$\frac{m+1}{m} = \frac{Q_m T_n}{Y_m F} = \frac{Q_m}{\bar{Q}_{T_n}}, \tag{28}$$

here Q_m is maximal water discharge, Y_m is runoff depth over a spring or rain flood, F is watershed area.

Analysis of the distribution of the values of coefficients $(m + 1)/m$ over the area showed that they can be integrally represented with the size of watershed taken into account. The upper limit $(m + 1)/m$ at $(F \Rightarrow 0)$ is the required parameter of heterogeneity of slope hydrographs $(n + 1)/n$.

In [4, 5, 10], it is recommended to evaluate $(m + 1)/m$ based on the mean many-year characteristics of spring (rain) floods: $\bar{Q}_m, \bar{Y}_m, \bar{T}_n$.

For rivers in the basin of the Yuzhnyi Bug, the relationship $(m + 1)/m = f(F)$ is relatively close $(r = 0.56)$; it can be described by the equation $(m+1)/m = [(n+1)/n] - b\log(F+1)$. For rivers in the area under study, $(n + 1)/n = 12.0$ (whence $n = 0.09$), and $b = 1.99$.

Estimated duration of slope inflow. Programs of stationary hydrometeorological observations in different countries, including Ukraine, do not involve systematic organized studies of the duration of slope inflow during rain and spring floods, though, as it was mentioned above, this is a basic characteristic in the calculation and prediction schemes for maximal runoff of rain floods and spring floods.

Table 1. Parameters in formula (32) for rivers in different geographic zones of Ukraine

Parameter	Forest–steppe	Poles'e	Steppe	Crimea	Carpathians
a_2	1.51	1.37	1.19	1.14	1.44
α_2	0.17	0.12	0.14	0.13	0.16

In 1975, E.D. Gopchenko proposed a method for numerical evaluation of T_0 [3] in the context of the well-known formula of A.N. Befani [2]:

at $t_c < T_0$

$$T_0 = \left(\frac{Y_m \varepsilon_F}{nq_m}\right)^{\frac{1}{n+1}} \left[(n+1)T_0^n - \frac{m_1+1}{n+m_1+1}t_c^n\right]^{\frac{1}{n+1}}, \quad (29)$$

at $t_c \geq T_0$

$$T_0 = \left[\left(\frac{m_1+n+1}{n+1} - \frac{q_m}{Y_m \varepsilon_F}\right) \times \frac{m_1+n+1}{(n+1)(m_1+1)}(m_1+1)t_c^{m_1}\right]^{\frac{1}{m_1}}. \quad (30)$$

The solution of (30) with respect to T_0 is a simple algebraic procedure. Equation (29) is of transcendent type ($n < 1.0$); therefore, for the calculation of T_0 in its structure, mathematical calculations are required. As shown in [3], simple one-step iteration can be effective in this case.

Equations (29) and (30) contain two unknowns—T_0 and ε_F, and do not form a system. At the first step, we assume $\varepsilon_F = 1$ (this is its upper limiting value at $F = 0$). The determination of the roots of equations (29) and (30) should begin from structure (29) with the initial value of T_0 taken certainly larger than the channel travel time t_c. If at some iteration we find that $T_0 < t_c$, the search for T_0 is automatically switched to the structure (30). Once the root T_0 is found in the structure of equations (29) or (30), (23) can be used to evaluate ε_F for each watershed. After generalization of ε_F, depending on watershed sizes, the values of T_0 are sought for in structures (29) and (30). The authors used Caguar computer model [5], which enables automatic calculations and construction of required relationship within any territory, to evaluate T_0.

The next task is the spatial analysis and generalization of the estimated duration of inflow over the territory. In flat areas, the characteristics of spring flood are correlated with the geographic positions of watersheds. Indeed, the dependence of the form $T_0 = f(\varphi° \text{ N})$ for the basin of the Yuzhnyi Bug shows a significant correlation coefficient ($r = 0.42$); therefore, this characteristic, as well as the runoff depth $Y_{1\%}$, is represented in the form of an isoline map (Fig. 2).

The isolines are drawn with an interval of 50 h, varying from northwest to south from 400 to 50 h.

Transformation of spring flood under the effect of channel travel time. As mentioned above, the maximal unit-area water discharge from slopes into channel network q'_m under the effect of transformation effects, associated with spring flood wave motion, their regulation by the channel–floodplain storage and flow-through water bodies (lakes, reservoirs, and ponds), allows reduction, the extent of which is the greater, the larger the size of rivers.

The transformation function $\psi(t_c/T_0)$ is determined by the ratio t_c/T_0 in accordance with formulas (24)–(27).

The channel travel time t_c is the ratio

$$t_c = \frac{L}{V_c}, \quad (31)$$

Where L is the hydrographic length of the river, km; V_c is the channel travel velocity, km/h.

According to [6], the travel velocity V_c, km/h, for Ukrainian rivers has the form

$$V_c = a_2 F^{\alpha_2} I_{wm}^{0.33}, \quad (32)$$

where a_2 is a velocity parameter; α_2 is an exponent to be determined by Table 1, depending on the natural zone; I_{wm} is weighted mean river slope, ‰.

According to recommendations in [1, 2, 10], the exponent m_1 in the equation of isochrones curves should be taken equal to 1.0. Further, considering the values of $n = 0.09$ and $m_1 = 1.0$, obtained for the basin under study, the equations for $\psi(t_c/T_0)$ can be written as

at $t_c < T_0$

$$\psi(t_c/T_0) = 1 - 0.88\left(\frac{t_c}{T_0}\right)^{0.09}, \quad (33)$$

at $t_c \geq T_0$

$$\psi(t_c/T_0) = 0.083\frac{T_0}{t_c}\left[2 - 0.52\left(\frac{T_0}{t_c}\right)\right]. \quad (34)$$

Channel–floodplain regulation in the Yuzhnyi Bug basin. In the scheme proposed here, the channel–floodplain regulation is accounted for by coefficient ε_F. It is worth noting that the channel–floodplain transformation is the worst known in the calculation schemes of maximal runoff, a fact that is primarily due to the lack of field observation data.

The value of ε_F (especially at $t_c/T_0 < 1.0$) is strongly dependent on the shape of overland runoff hydrograph.

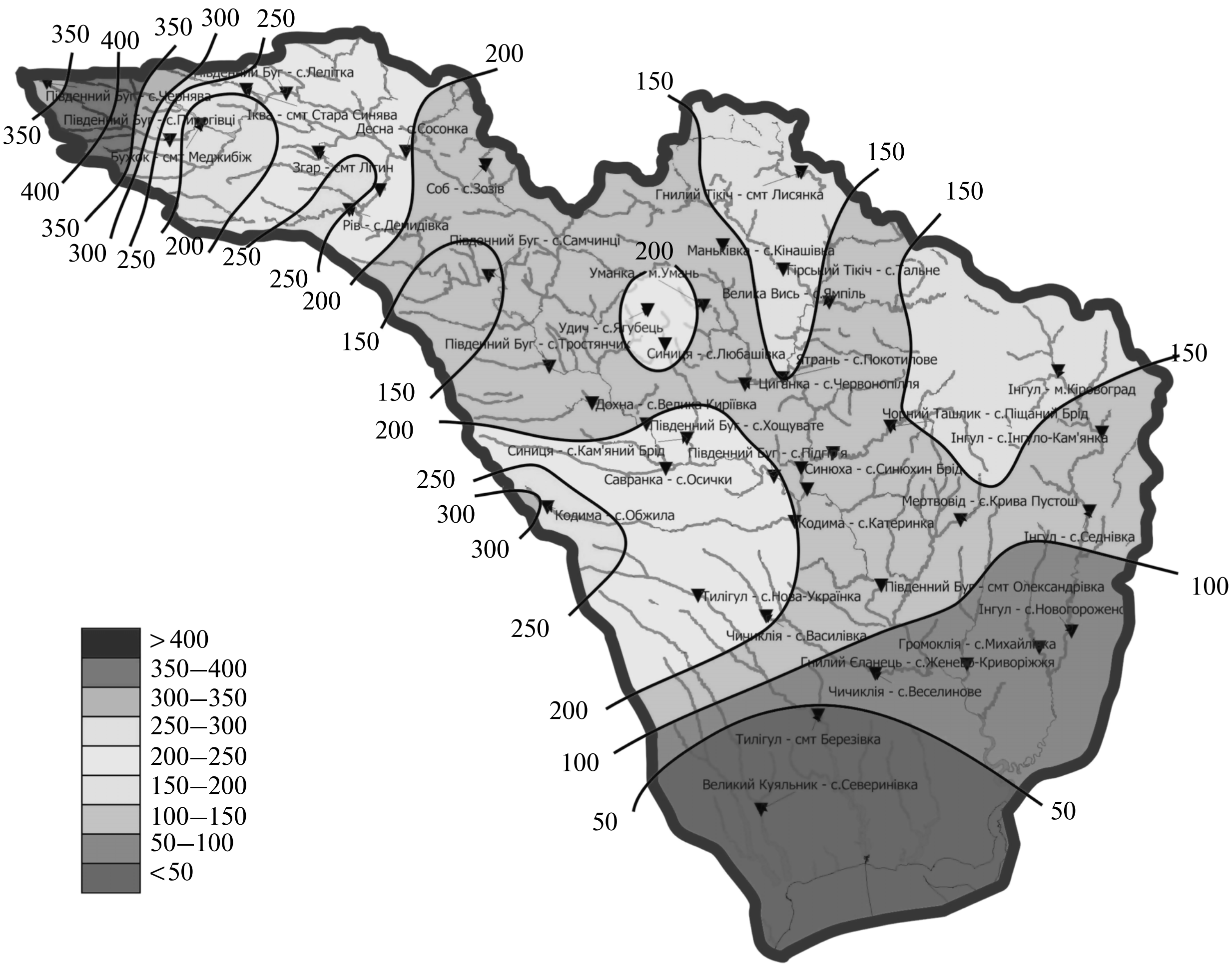

Fig. 2. Changes in the estimated duration of water inflow from slopes into the channel network in the Yuzhnyi Bug basin.

For rivers in the Yuzhnyi Bug basin ε_F can be written as

$$\varepsilon_F = e^{-0.28\log(F+1)}. \tag{35}$$

Spring flood transformation under the effect of flow-through water bodies. Flow-through water bodies are lakes, reservoirs, and ponds. Simplified methods for calculating r are often used, the best known among them being [6]

$$r = \frac{1}{1 + cf_1'}, \tag{36}$$

where c is a parameter, whose value is determined by the mean many-year runoff depth over rain or spring flood period; f_1' is weighted mean lake area percentage.

Table 2. Values of coefficient c in formula (49)

$Y_{1\%}$, mm	≥450	449–230	229–90	<90
c	0.2	0.2–0.3	0.3–0.4	0.4

In the proposed scheme, the calculations are carried out as applied to a runoff depth with 1% recurrence; the values of coefficient c are proposed to be determined by Table 2 with appropriate values of $Y_{1\%}$.

Determination of the recurrence coefficient. To avoid evaluating the parameters of formulas for different values of $P\%$, a method of coefficients λ_c for transition to a reference recurrence (for example, $P = 1\%$) is commonly used. Table 3 gives their values for recurrences $P = 1.0$, 3.0, 5.0, 10, and 25%.

The accuracy of the proposed procedure for calculating the maximal runoff of spring flood in the Yuzhnyi Bug basin. The accuracy of the method for calculating the maximal runoff of spring flood can be evaluated based on the results of the following calculations.

The required minimum of input data: watershed area F, km^2; weighted mean stream slope I, ‰; the hydrographic length of the river L, km; f_1'.

Table 3. Transition coefficients from maximal spring flood discharges with reference recurrence $P = 1\%$ to other recurrences

P, %	1.0	3.0	5.0	10.0	25.0
λ_{cQ}	1.0	0.72	0.59	0.44	0.25

The reference value $q_c = q_{1\%}$ is evaluated by the following procedure:

1. the maximal unit-area slope inflow $q'_{1\%}$ is evaluated by (23);

1.1. the coefficient of heterogeneity of the slope inflow over time for the entire area is taken equal to 12.0;

1.2. the runoff depth with 1% recurrence $Y_{1\%}$ is determined by the schematic map in Fig. 1 for geometric centers of watersheds;

1.3. the duration of water inflow from slopes into the channel network T_0 are determined, as well as the runoff depths $Y_{1\%}$ from the schematic map in Fig. 2;

2. the values of transformation functions $\psi(t_c/T_0)$ are evaluated as functions of t_c/T_0 by formulas (33) or (34);

2.1. in the equation of isochrones, the values of exponents are chosen as $m_1 = 1.0$, $n = 0.09$;

2.2. the channel travel time t_c, h, is evaluated from the equation

$$t_c = \frac{L}{1.19 I_{\mathrm{wm}}^{0.33} F^{0.14}}; \quad (37)$$

3. the coefficient of channel–floodplain regulation ε_F is determined by formula (35);

4. the coefficient of regulation of maximal runoff by lakes, reservoirs, and ponds r is determined by formula (36);

5. the recurrence coefficients λ_c are given in Table 3.

The mean deviation of the calculated values $q_{1\%\mathrm{calc}}$ from the actual values $q_{1\%\mathrm{act}}$ is ±18.4%, which lies within the accuracy of measurements of maximal water discharges during the passage of spring floods and corresponds to the accuracy of calculation of 1%-recurrence discharges for the input series ($\sigma_{Q_{1\%}} = 18,7\%$).

CONCLUSIONS

The scientific–methodological advantages of the formula (22) over other structures are as follows:

the proposed model describes the natural process of formation of rain and spring floods in rivers as a transformation of slope inflow into the channel runoff;

formula (22) has a universal structure; it is equally applicable to rain and spring floods;

formula (22) is applicable to drainage areas from individual slopes to branched river systems.

The proposed procedure served as the basis for the development of a software complex at the Chair of Land Hydrology, Odessa State Ecological Univercity, for numerical evaluation of the nonmeasurable runoff characteristics, such as the duration of slope inflow T_0 and the coefficient of channel–floodplain regulation of rain or spring floods ε_F.

The proposed scientific–methodological base was implemented in the standardization of design characteristics of maximal runoff of rain and spring floods in the basins of the Dnieper, Dniester, Don, Crimea, Carpathians, Algeria, etc. [4, 5, 8, 10–12].

REFERENCES

1. Befani, A.N., Fundamentals of storm runoff theory, *Tr. OGMI* (Trans. OGMI), 1955, Pt. II, Iss. XIV.
2. Befani, A.N., Befani, N.F., and Gopchenko, E.D., *Regional'nye modeli formirovaniya pavodochnogo stoka na territorii SSSR* (Regional Models of Flood Runoff Formation in USSR Territory), Obninsk, 1981, part 2.
3. Gopchenko, E.D., On the reduction of maximal unit-area rainwater discharges over area, *Meteorol. Gidrol.*, 1975, no. 2, pp. 66–71.
4. Gopchenko, E.D. and Ovcharuk, V.A., *Formirovanie maksimal'nogo stoka vesennego polovod'ya v usloviyakh yuga Ukrainy* (Formation of Maximal Spring Flood Runoff in Southern Ukraine), Odessa: TES, 2002.
5. Gopchenko, E.D. and Romanchuk, M.E., *Normirovanie kharakteristik maksimal'nogo stoka vesennego polovod'ya na rekakh Prichernomorskoi nizmennosti* (Standardization of Maximal-Runoff Characteristics of Spring Flood in Rivers of Prichernomorskaya Depression), Kiev, 2005.
6. *Posobie po opredeleniyu raschetnykh gidrologicheskikh kharakteristik* (Textbook for Determining Design Hydrological Characteristics), Leningrad: Gidrometeoizdat, 1984.
7. Sokolovskii, D.L., *Rechnoi stok* (River Runoff), Leningrad: Gidrometeoizdat, 1968.
8. Gopchenko, E.D., Ladzhel' Makhmud, Ocharuk, V.A. Maximal Flood Runoff in Wadies of the Northern Algeria, *Vísnik Odes'kogo derzhavnogo ekologíchnogo uníversitetu*, Odesa: TES, 2007, no. 4, pp. 287-296.
9. Gopchenko, E.D. and Ovcharuk, V.A. A procedure for calculating the channel travel velocity in Ukrainian rivers, in *Prichornomors'kii ekolog³chnii byul.*, 2007, no. 2(24) (June), pp. 53–55.
10. Gopchenko, E.D., Ovcharuk, V.A., and Shakírzanova, Zh.R. *Rozrakhunki ta dovgostrokoví prognozi kharakteristik maksimal'nogo stoku vesnyanogo vodopíllya v baseiní r. Prip'yat'* (Estimates and Long-Term Forecasts of Maximal Runoff Characteristics for Spring Floods in the Pripyat R. Basin), Odesa: Ekologiya, 2011.
11. Ovcharuk, V.A., Specifics of application of an operator-type formula for evaluating maximal river runoff under different physiographic conditions, *Meteorologíya, Klímatologíya ta Gídrologíya* (Meteorology, Climatology, and Hydrology), Odessa: Ekologiya, 2008, no. 50, P. 2, pp. 93–101.
12. Gophenko, E. and Ovcharuk, V., Theoretical ground of normative base for calculation of the characteristics of the maximum runoff and its practical realization, *Transboundary Floods: Reducing Risks Through Managment. NATO Sciences Series. IV Earth and Environ. Sci*, 2006, vol. 72, pp. 91–99.

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