COMPUTATION OF FLOOD FLOWS IN OPEN PITS

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ABSTRACT : The paper presents the method of computation of flood flows of different recurrence intervals, under open pit working conditions. The method applied is based on the wellknown relationship for maximum overland flow rate per unit drainage area versus the rainfall depth for the relevant time of duration of the storm event and the runoff coefficient. The paper will be illustrated with an application of the suggested method for the given open pit working conditions.

RESUME : Ce travail présente la méthode de calcul du débit de crue pour différents intervalles de récurrence dans des chantiers à ciel ouvert. La méthode qui est appliquée ici est basée sur la relation connue entre le ruissellement maximal et la hauteur de précipitation pour le temps de durée de l'averse et le coefficient d'ecoulement. Le travail sera illustré par une application de la méthode pour les exploitations à ciel ouvert.

RESUMEN : Este trabajo presenta el método de cálculo del caudal de crecida, para diferentes intervalos de recurrencia en explotaciones a cielo abierto. El método que se aplica aquí se basa en la conocida relación entre el arroyamiento máximo, la altura de precipitación para el tiempo de duración de la tormenta, y el coeficiente de escorrentía. El trabajo estará ilustrado por una aplicación del método para las explotaciones a cielo abierto ya citadas.

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The computation of floods of different return periods in open channels no longer represents a practical difficulty. However, the problem is more complicated in the case of overland flow from natural slopes. The present paper proposes the application of the method of Soviet hydrologist Alekseev, based on the well-known expression for maximum overland runoff

$$q_{max_p} = 16,67 \cdot \varphi \cdot \frac{H_\tau}{\tau} \qquad (1)$$

where

q_{max_p} - maximum overland flow rate per unit drainage area ($m^3/s/km^2$)

φ - dimensionless summarized runoff coefficient

H - rainfall depth for relevant time of storm duration τ

τ - relevant time of storm duration

The dimensionless summarized runoff coefficient is given by the product

$$\varphi = \varphi_1 \cdot \varphi_2 \cdot \varphi_\tau$$

where

$\varphi_1 \leq 1$ coefficient of nonuniformity of rainfall spatial distribution

$\varphi_2 \leq 1$ coefficient which describes the natural regulation ability of the drainage area

φ_τ - coefficient of runoff from maximum rainfall depth $H = a_\tau \tau$ for relevant time of storm duration τ.

$a_{\tau,p}$ - maximum average rainfall rate during the relevant time of storm duration τ with the given return period (mm/min).

To render expression (1) practically applicable it is necessary to determine the relevant time of storm duration. This can be done by means of an expression which takes into account the physical and morphological characteristics of the drainage area, in the form

$$\phi = \frac{(100L)^{1/2}}{m_1 I^{1/4} \cdot (\varphi H)_p^{1/2}} \qquad (2)$$

where

L - mean length of the slope; (km)

I - mean gradient of slope;

m_1 - coefficient of resistance of the slope

$(\varphi H)_p$ - daily rainfall total multiplied by the summarized runoff coefficient

One of the key quantities to be determined is the product of the daily rainfall total and the summarized runoff coefficient $(\varphi H)_p = \varphi . H_p$. It is found from the expression

$$(\varphi H)_p = \frac{100 \cdot q_i}{S(\tau_i)} \qquad (3)$$

using actual extreme discharge records and the corresponding values from the regional curve for reducing the average rainfall rate for the time

$$\tau_i = \frac{16,67 \ L}{a \cdot I^{1/3} \ Q_i^{1/4}} \qquad (4)$$

where a is a coefficient.

This method implies the availability of the following storm reduction curves for various time intervals:

1 regional rainfall intensity reduction curve

$$\Psi_p(\tau) = \frac{H_{\tau,p}}{H_p} = f(\tau); \tag{5}$$

2 regional average rainfall intensity reduction curve

$$S(\tau) = 1667 \frac{\Psi_p(\tau)}{\tau} = 1667\,\overline{\Psi}_p(\tau)\ ;\ \text{and} \tag{6}$$

3 auxiliary regional curve

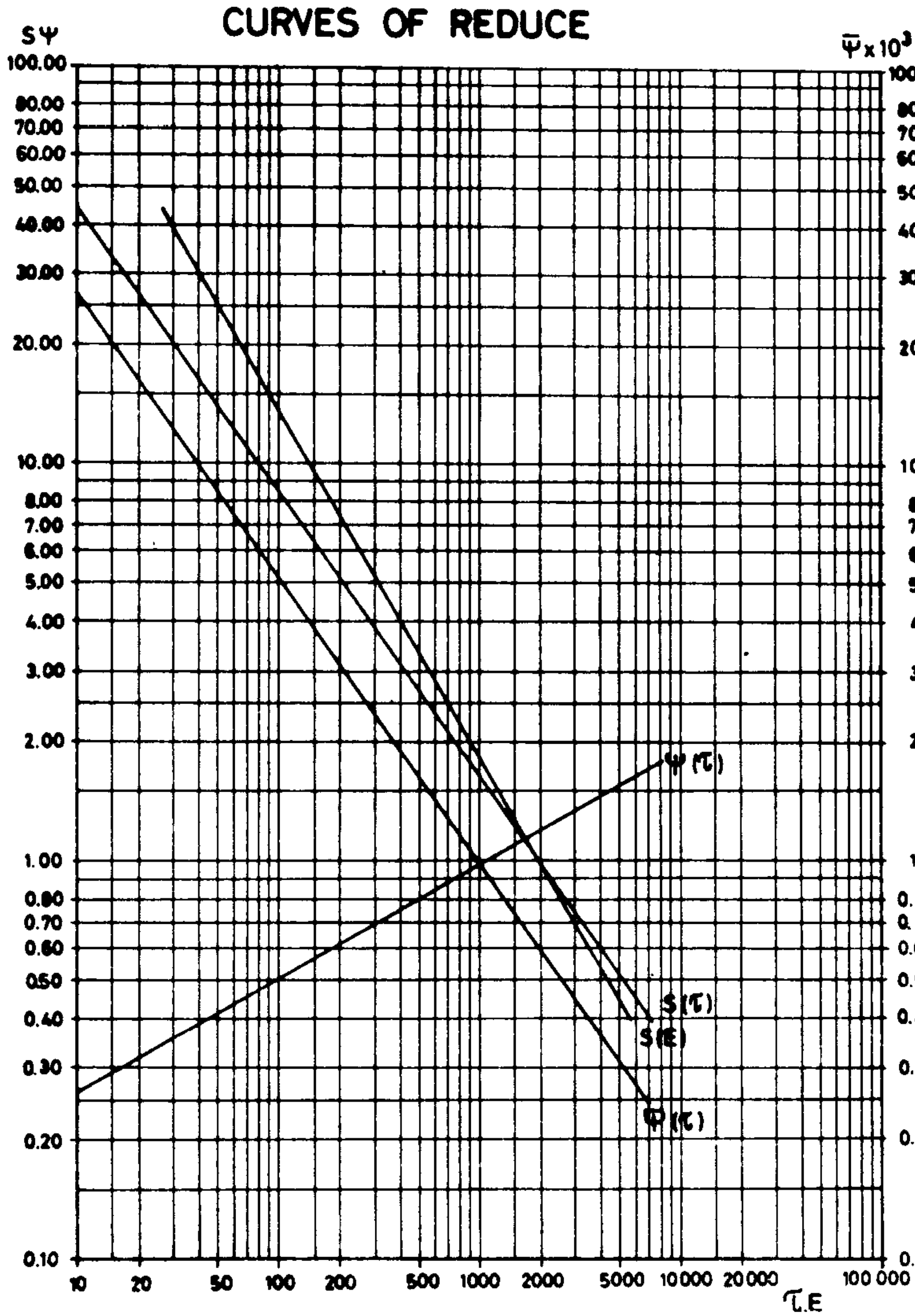
$$E(\tau) = \sqrt[4]{S(\tau)} \tag{7}$$

The procedure for obtaining these curves will be demonstrated on a practical example.

For various values of ϕ determined from expression (2), reference [1] gives corresponding values of τ. For each τ values of $\Psi(\tau)$ are found from curve 1, and then H is found by expression $H=\Psi_\tau H_{1\%}$; $H_{1\%}$ is the rainfall depth with a 100-year return period. Thus all the quantities appearing in (1), and hence the overland flow rate per unit drainage area for different return periods can be determined. Multiplying these values by the drainage area F yields the corresponding total overland flows Q.

In connection with the protection of one of the largest iron ore mines in Yugoslavia from surface water, it was the task of the present authors to determine the total volume of water falling directly into the open pit. The method described here was used. To render its application possible the following initial data were required: drainage area F, slope and average length of the slopes, storm daily rainfall totals in the region, maximum annual discharge records of a nearby gauging station on the same or on a

FIG. 1


CURVES OF REDUCE
S Ψ
$\bar{\Psi}$ x 10³
100.00
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.80
0.70
0.60
0.50
0.40
0.30
0.20
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1
0.8
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0.5
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0.3
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10
20
50
100
200
500
1000
2000
5000
10000
20000
100 000
τ.E
Ψ (τ)
S (τ)
S (E)
$\bar{\Psi}$ (τ)

neighboring watercourse of similar physical characteristics. In this particular case the drainage area was divided up into several characteristic parts; the numerical example is given for one of them.

The calculation procedure is as follows:

Using records of storm daily rainfall totals from a rain gauging station in the immediate vicinity, equations (5), (6) and (7) are used to calculate values of the three reduction curves for the relevant durations $\mathcal{T}$. This calculation is shown in Table 1. Values of $(\varphi H)_p$ are then determined for al the return periods of interest from discharge records of a gauging station on the same or a similar watercourse in the same basin and certain physical and morphological characteristics of the drainage area, using reduction curve 2 and equations (3) and (4), as shown in Table 2. The probability distribution function for (φH) is shown in Fig. 2. Values of ϕ are determined by means of equation (2), and using the tables in reference and the physical and morphological characteristics of the drainage area, values of $\mathcal{T}$ for each ϕ. Using reduction curve 1 and equation (8) H is determined, and thus al the elements needed for the application of equation (1) are found. Then the overland flow rates per unit drainage area are calculated for all the return periods of interest, and multiplied by the drainage area to obtain the floods with the given return periods, as shown in Table 3.

The parameter m_1 appearing in equation (1), and $\underline{a}$ in equation (4) were found by trial-and-error fitting with annual maximum discharge records of the guaging station, yielding in this case

$m_1 = 0,20$

$a = 0,15$

T = 100 years

H_p = 128 mm

Tabel 1.

Para-meter	TIME PERIOD τ [MIN]											
	10	30	60	120	240	360	720	1440	2880	4320	5760	7200
H	23.5	32.5	39.5	48.5	59.5	66.0	82.0	100.0	123.0	138.0	150.0	160.0
Ψ	0.252	0.349	0.425	0.525	0.640	0.710	0.882	1.075	1.323	1.484	1.613	1.720
$\bar{\Psi}$	0.025	0.012	0.007	0.004	0.003	0.002	0.001	0.001	0.0005	0.0003	0.0003	0.0002
S	42.12	19.42	11.80	7.24	4.44	3.29	2.04	1.25	0.77	0.57	0.47	0.40
E	25.48	62.98	111.20	196.84	348.38	484.84	860.48	1520	2694	3757	4761	6720

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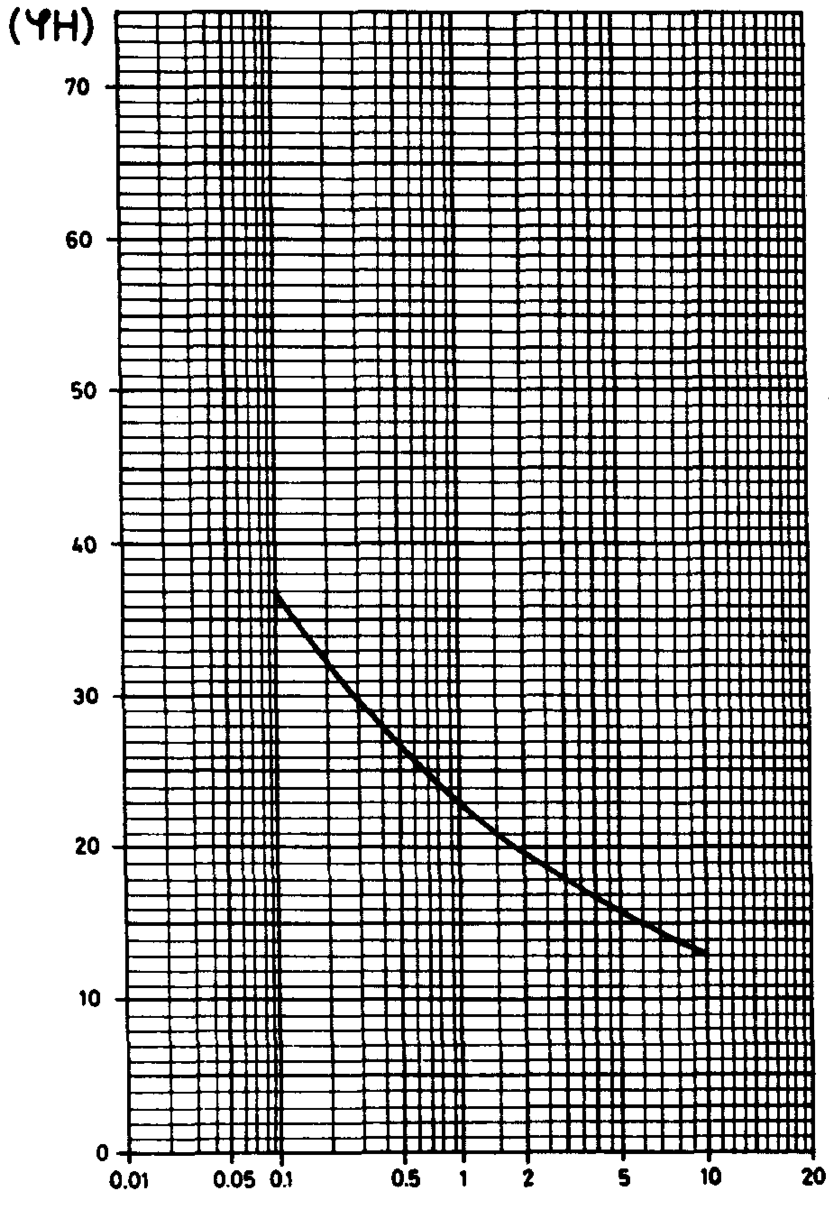
FIG. 2

PROBABILITY FUNCTION FOR (ΨH)



DRAINAGE AREA'S PARAMETERS

$F = 29,23\ km^2$

$I = 23.9‰$

$L = 8.14\ km$

Table 2

N°	Year	Q_{max}	q	τ	$S(\tau)$	φH	φH	$p=\frac{m-0,3}{n+0,4}$
1	1967	12.28	0.420	503.2	3.35	12.53	15.93	6.73
2	1968	9.24	0.316	540.6	3.30	12.15	15.27	16.35
3	1969	5.80	0.198	607.6	3.10	8.25	13.17	25.96
4	1970	9.24	0.316	540.6	3.30	12.15	12.15	35.96
5	1971	4.72	0.161	639.0	3.05	7.00	12.15	45.19
6	1972	5.44	0.186	616.8	3.08	7.75	9.22	54.80
7	1973	10.20	0.349	527.2	3.28	13.17	8.25	64.42
8	1974	5.80	0.198	608.1	3.10	8.25	8.25	74.04
9	1975	12.80	0.438	498.0	3.35	15.93	7.75	83.65
10	1976	6.60	0.226	588.3	3.13	9.22	6.09	93.27

OPEN PIT No. 1

$F = 0,244\ km^2$

$I = 171‰$

$L = 0,75\ km$

$1 = 0,29$

Table 3

Return Periods T	(φH)	Φ	τ	ψ_τ	H	q	Q
1000	36.52	8.15	185	0.61	78.08	4.93	1.20
100	23.21	9.11	210	0.63	58.59	3.26	0.80
50	19.90	9,46	220	0.63	52.92	2.81	0.69
20	15.96	10.02	230	0.64	46.72	2.37	0.58
10	13.33	10.51	250	0.66	42.24	1.97	0.48

In the author's opinion this method of calculating flood flows under open pit conditions offers certain advantages over standard synthetic procedures, since its parameters are calibrated with respect to actually recorded data for the basin. Its basic shortcoming is that it identifies the summarized parameter (φH) under streamflow and overland flow conditions, which was necessary in this case because no observation data for surface runoff from the slopes were available.

REFERENCES:

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