Geomorphological investigation of the drainage networks and calculation of the peak storm runoff of Skarmaga and Agia Triada streams

Odysseus Manoliadis

Department of Geotechnology and Environmental Engineering
Technological Educational Institute, Koila 50100, Kozani, Greece
e-mail the author

Kostaninos Sachpazis

GEODOMISI S.A., 32 Marni Street, Athens 10442, GREECE
e-mail the author

Submit discussion

ABSTRACT

Drainage basins of Agia Triada and Skarmaga streams lie on Northern Attica (Greece) and their torrents cross the city of Avlon. They belong geotectonically to the Sub Pelagonic zone and consist of schists and sandstones. The paper deals with the geomorphologic and statistical study of the drainage systems, as well as the calculation of the peak storm in the river exits. The statistical analysis showed that the drainage systems were influenced by lithology, as well as all the systems were in advance maturity stage of development. The peak storm runoff that was estimated, based on the land use before and after the disastrous to the forest fire and concerns the extreme values of the maximum probable peak storm runoff, with a 50 years recurrence period. The flood levels of the torrents and streams should be taken seriously into consideration in order to foresee and anticipate the necessary sewage and drainage work systems. Maintenance of the channels are finally suggested.

KEYWORDS: peak storm runoff, drainage basins, SCS method

INTRODUCTION

The drainage basins of Agia Triada and Skarmaga streams lie in Northern Attica. They are surrounded by Koryfi, Agia Trias, Armenias and Drompala Myti and Vounalaki mountains. The city of Avlon lies 2700m downstream. of the basin areas. The purpose of this paper is the geomorphological and statistical study as well as the calculation of the peak storm runoff of the above drainage systems before and after the fire in the forest area. Since forest consisted a large percentage of the basin area the results of this investigation should be taken into account for urban planning and related drainage works.

In the following Table the drainage network is presented that was used to study the drainage network of Agia Triada (B1) and Skamaga (B2) as well as the drainage basins. They belong geotectonically to the Sub Pelagonic zone and consist of schists and anthracites. The drainage network map includes the channels of the topographical map in HAGS geographical system derived from airphoto-interpretation and field observations.

The drainage network of the two drainage basin has an area of 1.89Km^2 and 1.76Km^2 for the Agia Triada and Skarmaga respectively. The characteristics of the two drainage basins are presented in TABLE 1.

Table 1. Drainage basin characteristics

Basin	Area(m^2)	Slope (%)	Highest Altitude (m)	Lower Altitude (m)	Length (km)
B1	1 869 162	28	759	847	1.62
B2	1 764 897	30	195	160	1.41

METHOD OF ANALYSIS

The method of Soil Conservation Service *S.C.S. 1972,* is used for the calculation of the peak runoff discharge: For the metric system the peak storm runoff of the hydrographic basins are given by the following equation:

$$Q_p = 0.278\ \pi A\ I\ CN \qquad (1)$$

where
A is the area of the drainage basin in Km

I is the maximum height of rainfall in a period equal to the total basin concentration time Tc, in mm/hour
CN is the runoff curve number or Specific runoff coefficient in various humidity conditions, in decimal values
Q_p Peak storm runoff in m3/sec and
π is the rainfall uniformity coefficient ($\pi = E^{-1/12}$)

An empirical equation is used for rainfall - runoff relation:

$$Q/P = (P - Q) / S \qquad (2)$$

where:
P rainfall height
Q is the basin discharge
S maximum storage

hence

$$Q = P2 / (P + S) \qquad (3)$$

and if the initial losses (Iα) (*Hawkins, 1978*; *Hjelmfelt 1980a; Hjelmfelt 1980b*; *Hjelmfelt 1991*) are substituted:

$$Q = (P - I\alpha)2 / (P + S - I\alpha) \qquad (4)$$

with the assumption (*Cheng-Lung Chen 1982*) $I\alpha = 0.2$ S, yields:

$$Q = (P - 0.2\,S)2 / (P + 0.8\,S)\ (1) \text{ for } P > 0.2\,S \qquad (5)$$

S can be used to the Curve Nunber equation:

$$CN = 1000 / [10 + S/25.4)]\ (2) \qquad (6)$$

We separate soil in three categories according to soil wet or dry conditions (TABLE II).

Table II. AMC Values

Condition of soil	**Winter period (October – April)**	**Rest periods (May-September)**
AMC I	<12.7	<35.6
AMC II	12.7 - 27.9	35.6-53.3
AMC III	>27.9	>53.3

For different land uses and hydrolithical categories the CN values are presented in TABLE III.

Table III. CN values according to *S.C.S. 1972.*

	Land use	Hydrolithological classification		
		highly permeable	moderately permeable	marginally permeable
1	Municipal	84	92	94
	Land size			
2	500 m^2	77	85	90
3	1.000 m^2	61	75	83
4	2.000 m^2	54	70	80
5	4.000 m^2	51	68	79
6	Industrial	81	88	91
7	not covered	77	86	91
8	Bushes	35	56	70
9	Forest	30	55	70
10	Crops	51	67	76
11	Fields	49	69	79
12	Vineyards	62	71	78
13	Cultvated trees	57	73	82

The following relationships are used for *CN*'s corresponding to AMC I, II, III according to *Chow 1964* and *Hawkins 1985*.

$$CNI = CNII / (2.281-0.01281\ CNII) \qquad (7)$$

$$CNIII = CNII / (0.427 + 0.00573\ CNII) \qquad (8)$$

In order to calculate the rainfall height – rainfall duration and rainfall intensity – rainfall duration curves, the maximum 24 hour rainfall according to Gumbell was used, for various recurrence periods. The Montana height-duration curve equation was accepted for this application:

$$H=at^b \qquad (9)$$

where *H* in height of a rainfall duration in time t

b constant usually from 0.33 to 0.50 (here b=0.33)

Equivalent

$$I = H/t = H_{hour} \text{ X } t^{b-1} \qquad (10)$$

Curves (1) and (2) are straight lines in logarithmic scale.

According to the above mentioned methodology, the intensity (I) of the rainfall in duration equal to the total basin concentration time Tc of each basin is given by:

$$Tc = \frac{4\sqrt{A} + 1.5\,L}{0.80\sqrt{Ym - Yo}} \qquad (11)$$

where:
Tc = concentration time of drainage basin (hours)
A = drainage basin area (km2)
L = length of drainage basin(km)
Ym = mean altitude of drainage basin(m)
Yo = min altitude of drainage basin(m)

RESULTS

The peak storm runoffs (Qp) were calculated at the exits of the drainage sub-basins. Geometry, basin concentration time and the uniformity coefficient of these drainage basins were estimated (TABLE I).

The mean annual height of precipitation is 374.5mm based on observations of the meteorological station of Marathon for the observation time-period 1958-1998.

Based on the maximum 24 hour rainfalls we estimated, according to Gumbell analysis, the expected rainfall height for a recurrence period of 5, 25, and 50 years as described in TABLE IV:

Table IV. Gumbell analysis for 5, 25 and 50 years

61.1	$< X_5 <$	104.5
72.9	$< X_{10} <$	133.2
87.3	$< X_{25} <$	170.1
104.1	$< X_{50} <$	216.9

The rainfall uniformity coefficient were calculated (TABLE V)

Then, the rainfall uniformity coefficient was calculated. TABLE V summarizes the rainfall uniformity coefficients for the two drainage basins:

Table V. Characteristics of the hydrographical basins.

BASIN NAME	RAINFALL UNIFORMITY COEFFICIENT
B1	0.949
B2	0.954

In order to calculate the runoff curve number or the specific runoff coefficient (CN) for every elementary homogeneous part of soil area of the two basins the following analysis was carried out :

a. A land use/cover map was drawn using the data of HAGS. The map was completed by field observation. The following categories can be distinguished. 1. Forest. 2. Annual cultivation. 3. Bushy areas. 4. Vineyards. 5. Uncultivated areas and urban areas. The results of the land use/cover are shown classified in Table IV
b. A hydrolithologic classification map was drawn. The lithological formations were classified in 4 categories according to the permeability coefficients. These categories are: 1. permeable formations, 2. moderately permeable formations. 3. low permeable formations and 4. impermeable formations..
c. The runoff curve number (CN) was calculated. This determination is a derivative of the land use/cover diagram and the hydrolithologic classification diagram. Data from air photos and satellite photos(*Suyfawara et al 1976*) of the studied area were used.

The diagram has five categories of the runoff curve numbers. For each category a single mean runoff number was used. The runoff curve number (CN) for every drainage basin resulted from the integration of every combination of land use and hydrolithologic classification was calculated by the method of Soil Conservation Method S.C.S. 1972, before and after the disastrous fire are presented in TABLE VI:

Table VI. CN for the drainage areas before and after the disastrous fire

BASIN NAME	CN before normal/wet	CN after normal/wet
B1	0.47/0.67	0.56/0.78
B2	0.36/0.56	0.42/0.66

The runoff curves of wet and dry periods were calculated by the known equations as the S.C.S. method suggests. The maximum 24 hour runoffs (Q) calculated for the two drainage basins are presented in TABLE VII

The results were based on the maximum 24 hour rainfall which resulted in the rainfall analysis according to Gumbell, with occurrence period 50 years both in wet and dry soil conditions before the rainfall.

Table VII. Maximum probable 24 hour runoff

Drainage basin name	Maximum probable 24 hour runoff (*Q*) in mm		Maximum probable 24 hour runoff ((in m^3 / 24 hour	
	normal conditions	wet conditions	normal conditions	wet condition
B1	57.12	116.15	106763	217103
B2	27.72	83.19	48919	146813

In order to estimate the maximum peak storm runoff of the two drainage basins of Agia Triada and Skarmaga streams it is necessary to know the mean rainfall intensity (I) of duration equal to the total basin concentration time Tc of each basin which is defined as the maximum rainfall height that happened at time Tc in the basin, with recurrence period of 5. 25 or even 50 years.

The rainfall height-rainfall duration and rainfall intensity – rainfall duration curves according to 24 hour rainfall resulted by the Gumbell method for rainfalls that took place in the area with recurrence period T of 50 years and the rainfall height – rainfall duration curve $H= HhourXt^{0.333}$ are given in TABLE VIII. The basin concentration time and rainfall intensity are given in TABLE IX.

Table VIII. Correlation of height and intensity of rainfall and the duration of rainfall

Rainfall duration (hours)	Rainfall duration (mm)	Rainfall height (mm)	Rainfall intensity (mm/hour)
0.1	6	22.440	224.403
0.15	9	25.684	171.228
0.2	12	28.266	141.332
0.25	15	30.447	121.788
0.3	18	32.353	107.842
0.4	24	35.605	89.013
0.5	30	38.352	76.704
0.6	36	40.752	67.921
0.7	42	42.889	61.284

0.8	48	44.850	56.062
0.9	54	46.644	51.826
1	60	48.309	48.309
1.5	90	55.293	36.862
2	120	60.852	30.426
2.5	150	65.546	26.218
3	180	69.648	23.216
4	240	76.650	19.163
5	300	82.563	16.513
6	360	87.731	14.622
7	420	92.352	13.193
8	480	96.651	12.069
9	540	100.413	11.157
10	600	103.999	10.400
12	720	110.509	9.209
15	900	119.033	7.936
20	1200	131.000	6.550
24	1440	139.200	5.800
30	1800	149.938	4.998
40	2400	165.012	4.125

Table IX. Concentration time *Tc* and rainfall intensity

DRANAGE BASIN NAME	Basin concentration time (*Tc*) in min	Rainfall intensity (i) with a duration equal to the basin concentration time in mm/hour
B1	37	103.9
B2	34	109.9

Finally the peak storm runoff according to the present cover and land use conditions was estimated. These results are given in Table X

Table X. Peak runoff coefficient

Drainage basin name	Area of the basin (m^2)	Maximum probable storm runoff (*Qp*) (m^3/s) under normal conditions before and after the fireand recurrence period (50 years)	Maximum probable storm run (*Qp*) (m^3/s) under wet conditic before and after the fire and recurrence period (50 years)
B1	1869162	25.36/30.43	36.15/43.48

B2	1764897	19.40/23.13	30.18/36.52

CONCLUSIONS

The research conducted was based on empirical models upon experience of the consultants involved in similar basins. The above mentioned values of storm runoff refer to extreme values of the maximum probable peak storm runoff that might ever happen in the study area with 50 year recurrence period. There is no significant change of the CN values after the disastrous fire merely the soil condition is highly permeable. The corresponding peak storm runoff resulted in a change of less than 20%.

The flood levels of the streams should be taken seriously into consideration in order to foresee and anticipate the necessary sewage and drainage work systems

It must be mentioned that the channels of the streams of the area must be maintained and cleaned regularly.

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