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ROUTING MODEL OF SEDIMENT YIELD FOR A REPRESENTATIVE HIMALAYAN DRAINAGE BASIN, INDIA

by
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ABSTRACT

For a large watersheds sediment yield can be more accurately estimated if the large watersheds is divided into sub-watersheds to compensate for non-uniformly distributed sediment sources. The effect of drainage basin hydraulics can be included by routing the sediment yield from sub-watersheds to the large watersheds outlet. Sediment routing increase prediction accuracy and determines individual watersheds contribution to the total sediment yield.

INTRODUCTION

Traditionally sediment yield has been predicted by applying a delivery ratio to the gross erosion. The gross erosion can be predicted with the universal soil loss equation given by Wischmeir and Smith (1965). Sediment is a pollutant of river ecosystem and for water quality modelling usually a shorter time interval than a year is required. Williams (1975) modified the universal soil loss equation by replacing the rainfall energy factor of the equation with runoff factor and also eliminated the need for delivery ratio.

THE MODEL

A linear reservoir is fictitious reservoir where the storage may be assumed to be directly proportional to the rate of sediment yield 'y' at a particular channel section, viz.,

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$$S = K_sY \qquad \text{........ (1)}$$

Where, K_s is a reservoir constant, called storage coefficient.

To determine the total sediment yield at the watershed outlet the following equation is applied:

$$\text{Total sediment yield} = \sum_{i=1}^{n} Y_1 e^{-T_i/K_s} \qquad \text{........ (2)}$$

Where, Y_i is the sediment yield from sub-watersheds 'i', T_i is the time between sub-watershed 'i' to watershed outlet and n is the number of sub-watersheds.

Williams (1975) developed a soil loss equation for an agriculture dominated watershed, i.e.,

$$Y = a\,(Q.q_p)^b\,KLsCP \qquad \text{........ (3)}$$

Where, Y is the sediment yield from an individual storm in appropriate units, Q is the storm runoff volume, q_p is the peak runoff rate, K is the soil erodibility factor, Ls is the slope length and gradient factor, C is the crop management factor and P is the erosion control practice factor, a and b are constants; where a is the unit conversion constants and b is the exponent and is equal to 0.56 in Williams equation.

On application of this equation to the sub-watersheds of the master watersheds (Figure 1) it is observed that due to a completely non-agricultural terrain of the watershed, the proposed equation is not applicable and needed modifications. Another sediment yield equation is thus developed which is found more suitable to the existing conditions.

The master watershed is divided into three sub-watersheds, namely, Saran, Ghansyal and the ungaged sub-watershed (Figure 1). Separate sediment yield models are developed for Saran and Ghansyal sub-watersheds and the average value of 'b' of the two models is taken as the standard value for each of the three sub- watersheds.

APPLICATION OF THE MODEL

For Saran and Ghansyal sub-watersheds the runoff volume 'Q' and peak flow rate 'q_p' are obtained from measured runoff hydrographs of the storms. For

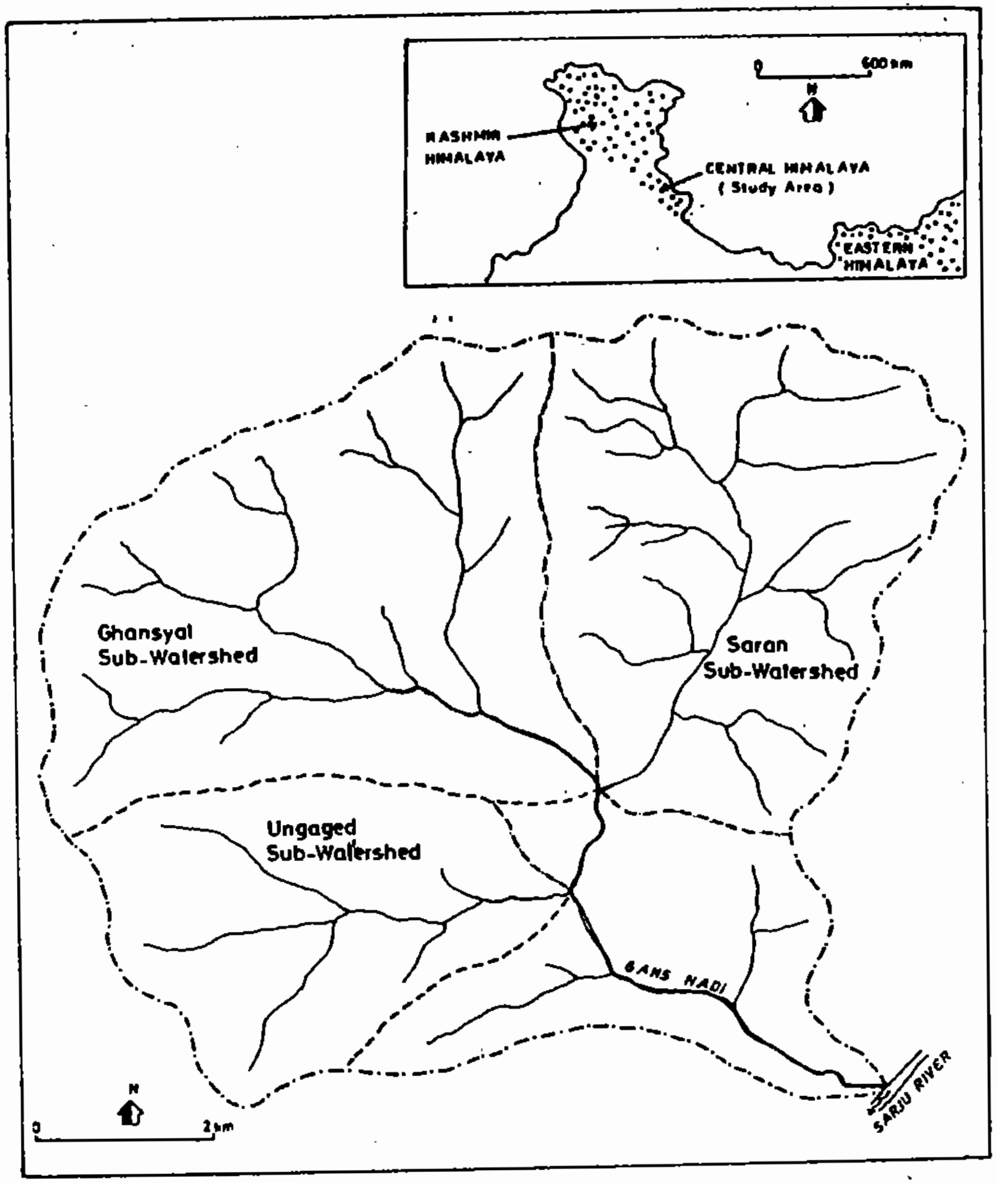

Figure 1. Location of Representative and Sub-watershed

the ungaged watershed, Q is determined by obtaining the equivalent uniform depth by Thiessen method and then substracting the infiltration index. The values of Q and q_p thus obtained for the three sub-watersheds are presented in figure 2.

The soil erodiability factor of a soil is determined by its characteristics and related qualities. Using the technique of USDA (1978) (Ashoken, 1981) the 'K' values for different types of landuse are estimated and the values of weighted soil erodiability factor are presented in Table 1.

TABLE 1. WEIGHTED PARAMETERS AND TRAVEL TIME OF SUB-WATERSHEDS

Parameters/ Travel time	Sub-watersheds Saran	Ghansyal	Ungaged
K	0.57	0.53	0.54
Ls	64.16	37.494	51.15
C	0.09	0.19	0.24
P	0.95	0.87	0.86
T_i (hr)	1.70	5.44	1.81

Williams *et al.* (1976) suggested a contour-length method to determine the 'Ls' values. The following equation is used for the determination of slope length and gradient factor:

$$Ls = (L/22.1)^M (0.065 + 0.0454 S + 0.00655^2) \quad ..... (4)$$

Where, Ls is the slope length factor, exponent M is 0.5 for slopes > 5 percent, 0.4 for slopes between 1 to 3 percent and 0.2 on uniform gradient of less than 1 percent. Due to the hilly terrain of the representative watershed the value of M is taken as 0.5 for the present case.

The cover and management factor 'C' is the ration of soil loss from clean tilled-continous fallow. Based on the techniques of USDA (1978) and personal observations a value of 0.4 is taken as the average 'C' value for the agriculture land in the watershed. A weighted C factor for each sub-watershed is estimated and listed in Table 1.

The support practice factor 'P' is the ratio of soil loss with a specific support practice to the corresponding loss with up and down slope culture. Only the cultivated area of the watershed is considered for the computation of the P factor. The P factor for terraced agricultural area is estimated to be 0.6 and for the rest of the area as 1.0 (USDA, 1978). Finally, the weighted P factor is estimated for each of the three sub-watersheds (Table 1).

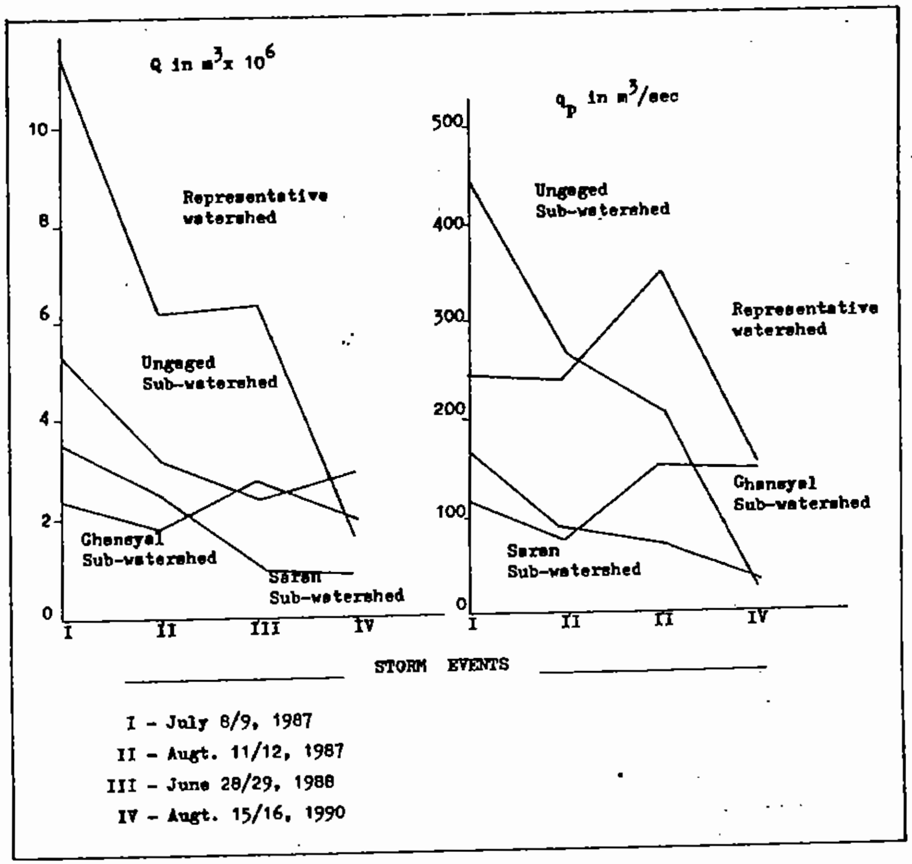

Figure 2. Diagramatic representation of storm runoff volume (Q) and peak runoff (q_p)

In equation 3 values of parameters are put in for each sub- watershed. The average value of exponent 'b' is determined as 0.257 and is considered as standard value. Now, the general equation for the representative watershed is developed as:

$$Y = 11.8\ (Q.q_p)\ 0.257\ KLsCP \qquad \text{........ (5)}$$

CONCLUSIONS

In equation 2 Y_i is required to be estimated from equation 5 for each sub-watersheds. The time $-T_i$ is assumed to be equal to the time of concentration between the outlet of the sub-watershed 'i' and the representative watershed. If an uniform distribution of KLsCP is assumed in the representative watershed the storage coefficient 'K_s' (equation 2) is estimated from the following equation:

$$(Q.q_p)^{0.257} = \sum_{i=1}^{n} (Q_i.q_{pi})^{0.257} e^{-T_i/K_s} \qquad \text{........ (6)}$$

This indicates that K_s is a function of the watershed fluvial system hydraulics only. The value of K_s for each storm can thus be estimated by solving the equation 6.

Storm events of July 8 and 9, 1987; August 11 and 12, 1987; June 28 and 29, 1988 and August 15 and 16, 1990 are taken to analyse sediment yield from the representative watershed. Equation 5 is used to compute sediment yield from the sub-watersheds. For the ungaged sub-watershed EUD of rainfall for each storm and the volume of runoff are estimated. The peak flow is determined by the synthetic unit hydrograph method. The travel time T_i is computed and is given in Table 1.

Putting the above mentioned values in equation 5 sediment yield is obtained. A comparison of routed and measured values of sediment yield are presented in Table 2.

TABLE 2. MEASURED AND ROUTED SEDIMENT YIELD

Storm events	Measured sediment yield (mt)	Routed sediment yield (mt)
July 8- 9, 1987	15290.00	15940.00
August 11-12, 1987	15260.00	15846.00
June 28-29, 1988	14500.00	15009.00
August 15-16, 1990	19800.00	19994.00

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