ABSTRACT

The infiltration losses along the stream channels of a basin are included into the Instantaneous Unit Hydrograph (IUH). The IUH is derived as a function of the basin geomorphological and physiographic characteristics, and the response of the individual channels to upstream and lateral inflows. This response is obtained by solving the linearized continuity and momentum equations, including approximate infiltration losses terms, for the boundary conditions established by the definition of a linear system response to an instantaneous unit input. A methodology is proposed for the estimation of the parameters involved in the channel response. Based on this result, a procedure is suggested to include infiltration losses in the common linear reservoir representation of channel segments. Comparisons indicate that this approximation is adequate under certain conditions.

For the first time channel infiltration is explicitly included in an analytical physically based linear model of channel response potentially useful in traditional hydraulic routing problems.

1. INTRODUCTION

Recently, methodologies have been proposed to relate river response to basin geomorphology (Rodríguez-Iturbe and Valdés, 1979), which are useful in the estimation of the hydrologic behavior in regions with sparse or no data. The Instantaneous Unit Hydrograph, IUH, is interpreted as the probability density function (PDF) of the travel time spent by a drop to reach the outlet of the basin, which is a function of the geomorphology quantified by the Horton numbers, and the response of individual channels, assumed to behave like linear reservoirs. This IUH is called the Geomorphologic IUH (GIUH).

In its derivation, the Strahler’s channel ordering scheme is used, which allows us to express
the cumulative density function (CDF) of the time that a drop takes to travel to the outlet of

\[ P(T_B \leq t) = \sum_{s \in S} P(T_s \leq t)P(s) \]

where \( P(\cdot) \) represents the probability of the event given in parenthesis, \( T_B \) is the travel time to the outlet of the basin, \( T_s \) is the travel time through a path \( s \), belonging to \( S \), the set of all possible paths that a drop, falling randomly on the basin, may follow to reach the outlet. The travel time, \( T_s \), in a particular path, must be equal to the sum of travel times in the elements of the path:

\[ T_s = T_{r(i)} + \cdots + T_{r(\Omega)} \]

where \( T_{r(i)} \) is the travel time in a stream of order \( i \), \( \Omega \) is the order of the basin.

Given that there exists several streams of a given order, \( T_{r(i)} \) may be considered an independent random variable with a given probability density function, \( f^{(i)}(t) \), so that the cumulative density function of \( T_s \) is the convolution of the individual cumulative density functions, \( F^{(i)}(t) \):

\[ F^{(i)}(t) = F^{(i)}_1(t) * \cdots * F^{(i)}_n(t) \]

where * indicates the convolution operation. The probability of a given path \( s \) is:

\[ P(s) = \Theta_i \cdot P_{ij} \cdots P_{k\Omega} \]

where \( \Theta_i \) is the probability that a drop falls in an area draining to a stream of order \( i \) and \( P_{ij} \) is the transition probability from streams of order \( i \) to streams of order \( j \). Rodríguez-Iturbe and Valdés (1979) show that the initial and transition probabilities are functions only of the geomorphology of the basin, namely the bifurcation and area ratios. Table 1 summarizes these probabilities for a basin of order 3. The GIUH is, then:

\[ h(t) = \frac{dP(T_B \leq t)}{dt} \]

\[ = \sum_{s \in S} f^{(i)}(t) * \cdots * f^{(\Omega)}(t)P(s) \]

Rodríguez-Iturbe and Valdés (1979) argue for an exponential behavior of the individual channels:

\[ f^{(i)}(t) = \lambda_i e^{-\lambda_i t} \]  

(2)

where

\[ \lambda_i = \frac{v}{L_i} \]

and the assumption that for a given rainfall-runoff event the velocity, \( v \), at any moment is approximately the same throughout the whole drainage network, is made (Pilgrim, 1977).

Kirshen and Bras (1981) suggested that a physically based form of \( f^{(i)}(t) \) can be obtained by