Journal of Hydrology (2006) **331**, 205–218

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journal homepage: www.elsevier.com/locate/jhydrol

Effect of loss model on evaluation of Manning roughness coefficient of experimental concrete catchment

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Received 19 July 2005; received in revised form 10 May 2006; accepted 10 May 2006

KEYWORDS
Catchment;
Concrete;
Hydrograph;
Kinematic wave;
Open channel flow;
Rainfall loss;
Roughness coefficient;
Runoff

Summary To simulate a runoff hydrograph from a concrete catchment that is subject to natural rainfall, the use of computer model is essential. To develop such a model, the modeller is required to specify the rainfall data, the physical characteristics of the catchment, the Manning roughness coefficient (Manning *n*) of the concrete surface, and the loss model. To evaluate the Manning *n* for simulating runoff hydrographs, it is common to use the hydrograph fitting technique. With this technique, the simulated hydrographs are actually dependent on the loss model. Hence, the Manning *n* that is being evaluated is also dependent on the loss model. In view of this, the effect of loss model on the Manning *n* has been examined. Based on the rainfall and runoff data on a 25 m^2 experimental concrete catchment comprising two overland planes and one rectangular channel, the examination shows that: (1) During the initial portion of the events, as the concrete was dry, the actual loss was higher than those assigned in the four loss models (the proportional, the initial and proportional, the upperbound, and the initial and upperbound). Hence, the evaluation of Manning *n* should omit this portion and only consider the subsequent wet portion of the events. (2) Based on the wet portions of the events, the effect of loss model on the optimum Manning *n* is small. (3) For the four loss models, the overall optimum Manning *n* for concrete are 0.013–0.015. These values are within the recommended Manning *n* for steady, uniform flow in concrete channel. Hence, the Manning *n* for steady, uniform flow is applicable to runoff simulation in which the flow is unsteady and non-uniform. (4) A comparison of the simulated hydrographs by the upperbound loss models and the proportional loss models shows that the upperbound loss models produce simulated hydrographs that are closer to the observed. (5) By adding one parameter to account for the initial loss in the loss

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0022-1694/$ - see front matter
doi:10.1016/j.jhydrol.2006.05.009

model, it produces simulated hydrographs that are marginally closer to the observed. (6) The loss model that produces simulated hydrographs that are closest to the observed is the initial and upperbound loss model.

Nomenclature

C	runoff coefficient
D_{rain}	rainfall depth
D_{run}	runoff depth
I	rainfall intensity
L_I	initial loss
L_U	upperbound loss rate
Q_m	mean of all observed discharges
Q_o	observed discharge at a given time
Q_s	simulated discharge at the same time as the observed
R^2	objective function
t_L	time lag
t_{rain}	time when rainfall commences
t_{run}	time when runoff commences
Δt	rainfall interval

Introduction

To simulate a runoff hydrograph from a concrete catchment that is subject to natural rainfall, the use of computer model is essential. To develop such a model, the modeller is required to specify the rainfall data, the physical characteristics of the catchment, the Manning roughness coefficient (Manning *n*) of the concrete surface, and the loss model. To evaluate the Manning *n* for simulating runoff hydrographs, it is common to use the hydrograph fitting technique, i.e., matching the simulated hydrographs to the observed hydrographs. With this technique, the simulated hydrographs are actually dependent on the loss model. Hence, the Manning *n* that is being evaluated is also dependent on the loss model. In view of this, the effect of loss model on the Manning *n* is examined. The rainfall and runoff data over an experimental concrete catchment (25 m long by 1 m wide) are used in the examination. The concrete catchment comprises two identical overland planes and one rectangular channel. The flow from both planes drains towards the channel, and the outflow from the channel is the outflow of the catchment. Four loss models are investigated. They are (1) the proportional loss model; (2) the initial and proportional loss model; (3) the upperbound loss model and (4) the initial and upperbound loss model.

Experimental setup and data

In this study, a rainfall—runoff facility has been set up at the Nanyang Technological University (NTU) comprising an outdoor experimental plot, and instrumentation for monitoring rainfall and runoff. There is one fundamental difference between the facility in the present study as compared to those in the earlier studies (Izzard, 1944; Izzard and Augustine, 1943; United States Army Corps of Engineers, 1954; Woo and Brater, 1962; Yen and Chow, 1969; Woolhiser et al., 1971; Langford and Turner, 1973; Muzik, 1974; Reed and Kibler, 1983; Bell et al., 1989; Wong, 2002, 2005). All those in the earlier studies were catered for artificial rain, while the present facility is catered for natural rain.

Experimental plot

As shown in Fig. 1, the plot consists of four testing bays and one collection chamber. Two bays are prepared with asphalt surface, and two bays are prepared with concrete surface. The dimensions of each bay are 25 m long by 1 m wide. The testing bays are separated by concrete walls, about 1 m high. The concrete catchment is situated within one of the concrete bays. As shown in Fig. 2, it comprises two overland planes and one rectangular channel. Each plane is 25 m wide and 0.45 m long with a slope of 11% towards the channel. The rectangular channel is 0.1 m wide and 0.175 m deep with a bed slope of 2%. The overall area of the catchment is 25 m^2.

Instrumentation

The instrumentation consists of two tipping-bucket raingauges, a flowmeter, weigh tanks, and a data logger. Both raingauges are positioned at 300 mm from the edge of the 5% asphalt bay. One raingauge is positioned at 6.25 m from the upstream end of the testing bays, while the other is positioned at 6.25 m from the downstream end of the testing bays (Fig. 1).

An electromagnetic flowmeter is used to calibrate the weigh tanks under the steady state condition. The weigh tank comprises a rectangular flow measurement tank (1.5 m long by 0.5 m wide by 0.5 m high) with a 20 mm wide rectangular notch at the outlet, and a weigh balance. The balance monitors the combined weight of the tank, and the water inside the tank, and sends a voltage signal to the data logger. By calibration, the voltage