Journal of Hydro-environment Research 21 (2018) 86–95

Contents lists available at ScienceDirect

Journal of Hydro-environment Research

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

Distributed parameter unsteady flow model for the Han River

Li Li, Kyung Soo Jun*

Graduate School of Water Resources, Sungkyunkwan University, Suwon 16419, Republic of Korea

ARTICLE INFO

Keywords:
Unsteady flow model
Variable parameters
Manning's *n*
Han River

ABSTRACT

An unsteady flow model that allows a variable roughness coefficient for each computational point according to its spatial position (x) and the value of discharge (Q) was developed. A step function and a power function were considered for functional relationships between discharge and Manning's roughness coefficient (n). The model was applied to the main reach of the Han River and model parameters were estimated by optimization. From the model calibration, spatial variation and discharge dependence of Manning's n were identified by testing different $n(x, Q)$ functions. First, the value of the roughness coefficient is higher for the upstream reach of the Wangsook Stream junction than it is for the downstream reach. Second, estimated parameters of both the step function model and the power function model show that Manning's n decreases as discharge increases. This tendency is more noticeable for the upstream reach of the Wangsook Stream junction compared to the downstream reach. Further, the stages calculated by the variable roughness coefficient model are more consistent with the observed ones than those from the conventional constant parameter model. Regarding the variation of Manning's n relative to discharge, adopting a power function as the Manning's n-discharge relationship seems to be more appropriate than adopting a step function because it is easy to apply and the performance is as good as that of the step function model.

1. Introduction

Despite increasing efforts for flood control and damage reduction, the Han River is subject to frequent flooding due to heavy rain during the monsoon season. To evaluate and reduce potential flood damages, a flood routing model is essential. The validity of an unsteady flow model depends not only on the accuracy of the numerical method of the model, but also on the model parameters. Flood routing models based on the one-dimensional Saint-Venant equations utilize the Manning's roughness coefficient (n) as a model parameter representing flow resistance. The Manning's n for natural rivers does not only represent the frictional effects, i.e., skin friction related to the grain size of bed materials and form roughness due to bed forms, but it also includes other effects such as losses due to bank forms, gradual change in cross sections, and river bend. In addition, the Manning's n varies with flow conditions such as water stage and discharge (Chow, 1959; Coon, 1998; Rouse, 1965; Yen, 2002). Therefore, it is an essential step in the application of an unsteady flow model to determine the Manning's n through model calibration.

A trial-and-error procedure has been widely used in which the governing equations are repeatedly solved for various assumed values of Manning's n, and the one that results in the closest agreement between the solutions of the model and the field observations is selected. In addition, there have been studies on the application of optimization techniques for the calibration of unsteady open-channel flow models. Becker and Yeh (1972, 1973) proposed the influence coefficient method by minimizing the sum of the squares of the differences between the simulations and observations. Wasantha Lal (1995) used the singular value decomposition method to calibrate Manning's roughness coefficient in one-dimensional Saint-Venant equations. Liggett and Chen (1994) used the adjoint-equation method in the looped water-supply network, while Atanov et al. (1999) applied it for roughness identification in trapezoidal channels. This method was also used by many studies such as those by Navon (1998), Piasecki and Katopodes (1997), and Zou et al. (1993). The sensitivity-equation method was used by Ding et al. (2004) to identify Manning's n in shallow water equations. There are also studies by Ding and Wang (2005), Khatibi et al. (1997), Nguyen and Fenton (2004) and Ramesh et al. (2000). However, most of the previous studies have only dealt with a lumped-parameter model in which Manning's n is regarded as a constant.

Ayvaz (2013) determined the variation of the Manning's n along a river reach by partitioning the given reach into several sub-reaches in which the Manning's n values are assumed to be constant. The process

---

* Corresponding author.
E-mail address: ksjun@skku.edu (K.S. Jun).

https://doi.org/10.1016/j.jher.2018.08.004

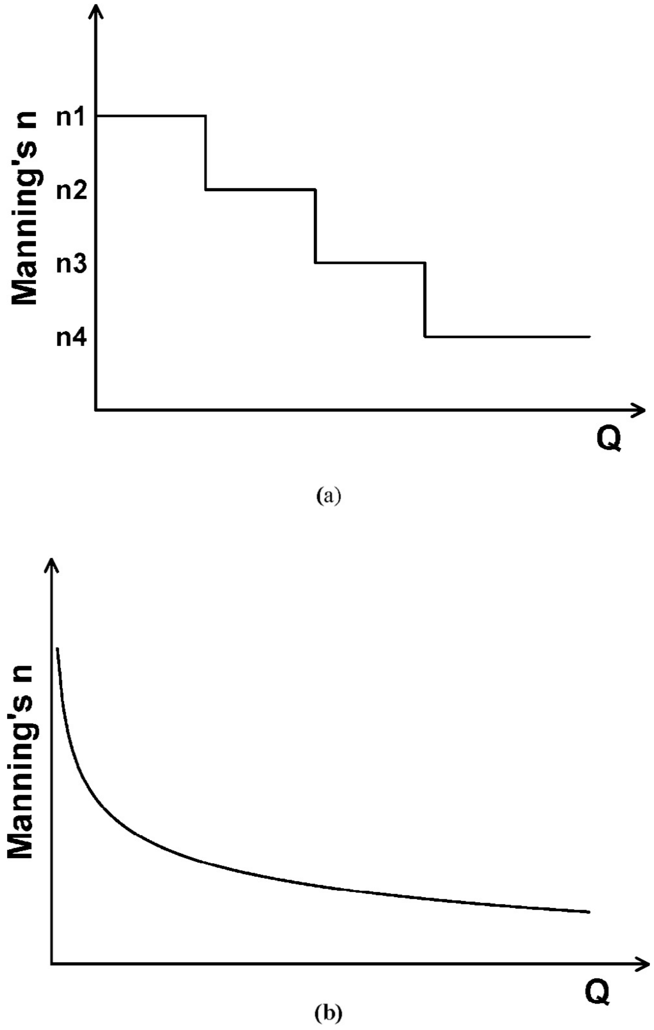

Fig. 1. Functional relationship between Manning's n and discharge. (a) step function; (b) power function.

of creating sub-regions was performed through a one-dimensional Voronoi Diagram, which is a partitioning tool (Tsai et al., 2003). Huang and Lee (2009) investigated the effects of spatially heterogeneous roughness on flow hydrographs. They considered three types of surface roughness scenarios and found that runoff generation would be obviously influenced by the spatially heterogeneous roughness. Maske

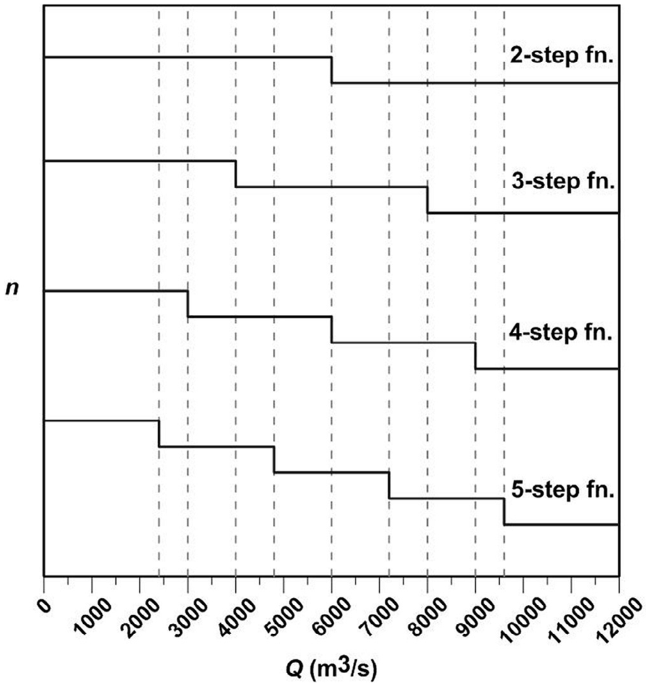

Fig. 3. Adopted step functions.

(2014) also investigated the influence of variability in roughness on overland flow. However, the assumption in these studies that Manning's n is constant in time is not realistic owing to the physical characteristics of the roughness parameters. Fread and Smith (1978) presented a variable-parameter unsteady flow model and the calibration methodology, adopting a piecewise linear function for the functional relationship between Manning's n and discharge. They also considered the reach-by-reach variation of Manning's n along with the variation of Manning's n with discharge. They divided the entire river reach into several sub-reaches, and starting from the uppermost one, successively calibrated each sub-reach. While their calibration technique is very unique, it requires that sub-reaches are bounded by gauging stations and that stages as well as discharges are given at the upstream boundary of the reach. However, gauging stations are not necessarily located at the positions where the channel characteristics change, and there are instances where both the stage and the discharge data are not available at the upstream boundary of a reach.

This paper presents a distributed parameter unsteady flow model in which Manning's n varies with space (x) and discharge (Q) for the main

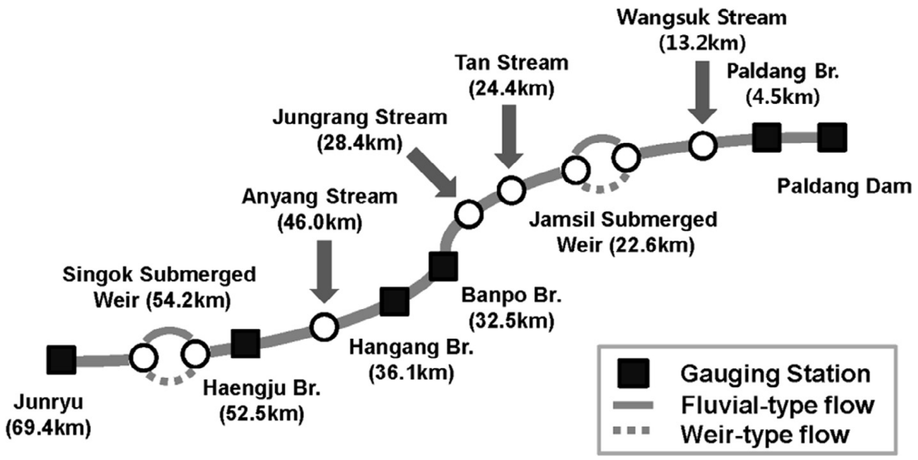

Fig. 2. Schematic representation of the modeled river reach.