Development of Regression Equations for the Water Discharge Estimation in Tidally Affected Rivers

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Abstract

In the gauging station which tidal current effects are dominant, the reliable measuring methods are needed. In this study, the stage height difference is considered to derive the rating curve and the index velocity is considered to derive the mean velocity equation which discharge results from these equations are compared with the measured discharge collected in the Samrangjin station where tidal current effects are dominant. A robust minimum covariance determinant method, one of the nonlinear multi-regression methods, is applied to derive regression equations for the rating curve and mean velocity equation using 39 measurements collected at Samrangjin gauging station. The new rating curves allow superior in predicting discharge more precisely in tidally affected river as compared to existing equation. The discharge estimated using the mean velocity from the index velocity is in best agreement with the measured discharge data.

Keywords: instream flow, tidal river, rating curve, multiple regression analysis, index velocity method

1. Introduction

The discharges, especially in the estuary, are one of the most important information necessary for the flood control, water resources planning and management for allocations. Usually, river discharges are calculated from the stage heights through rating curves (Lambie, 1978; Kim et al., 2007; Oh et al., 2005). The relation of tidal stage height to discharge is usually controlled by a section or reach of channel downstream from the gauge that is known as the station control. A section control may be natural or manmade; it may be a ledge of rock across the channel, a boulder-covered riffle, an overflow dam, or any other physical feature capable of maintaining a fairly stable relation between stage height and discharge. Channel control consists of all the physical features of the channel that determine the stage height of the river at a given point for a given discharges. These features include the size, slope, roughness, alignments, constrictions and expansions, and shape of the channel. Chow (1986) suggests that the control section is best method for the measuring discharge and rating curves should be developed in these control cross section area. But these traditional processes are too ineffective and expensive to allow continuous measurement and have some problems in tidally affected rivers and estuaries because the rating curves in these areas are not static and also divided by twice-daily variations in the tidal stage height and the velocity. Acoustic velocity meters are particularly advantageous in obtaining a continuous record of the discharge of large rivers in estuary where neither a simple stage height-discharge relation nor a stage height fall-discharge relation can be applied satisfactorily. Those situations usually involve tidal flow or low affected by hydroelectric-power generation, where the acceleration head in the equations of unsteady flow cannot be ignored. Godin (1985) developed the rating curve with multiple parameters such as tidal stage height and stage height to consider the interactions between the river discharge and tidal current. For the development of the rating curve in tidally affected rivers, Chu et al. (2000) used function of stage height differences between the upstream and downstream which are influenced by tidal. Lee and Hwang (1994) used water slope measurements yielded errors to develop rating curves in Seomjin River where is one of tidally affected rivers of Korea. Kim (2004) used artificial neural network optimization to develop the loop rating curve for the water station of the Han River and Zealand et al., 1999; Liong et al., 2000; Kim, 2004; Kim and Cho, 2003; Kim and Lee, 2000; Kim et al., 2003; Shin and Park, 1999; Coulibaly et al., 2000a, b were also used the artificial neural network for analysis of rainfall-runoff and inflows into reservoirs. Generally, regression methods and curve fitting methods were used to predict output values in the nonlinear in and out hydrologic system in which bed leverage points such as outliers have an overriding influence on the fit to measured data. Thus, the robust optimization techniques are needed to develop the nonlinear multi-regression equations for the discharge estimation in which these leverage points could be come from the discharge data measured in stream.

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Accurate estimates of discharge in tidally affected rivers and estuaries are possible because of recently developed ultrasonic discharge measurement techniques (Ruhl and Simpson, 2005). Ultrasonic measurement methods consist of: i) the use of ultrasonic instruments for the measurement of a representative index velocity used for in situ estimation of mean water velocity, and ii) the use of the acoustic Doppler current discharge measurement system to calibrate the index velocity measurement data. Methods used to calibrate the index velocity to the channel velocity measured using the acoustic Doppler current profiler are the most critical factors affecting the accuracy of net discharge estimation. The index velocity must first be related to mean channel velocity and then used to calculate instantaneous channel discharge. An ultrasonic velocity meter discharge-measurement site in a tidally affected region of the Nakdong River was used to study the accuracy of the index velocity calibration procedure. Calibration data consisting of ultrasonic velocity meter index velocity and concurrent acoustic Doppler discharge measurement data were collected during 2005. To develop the rating curves and to calibrate the index velocity to the channel velocity at the Samrangjin gauging station in the Nakdong River basin, the river discharge, stage height, tidal stage height, and velocity were measured. Both equations of stage height-discharge equation and stage height differences between the stage height and tidal stage height-discharge equation are derived to estimate the discharge in tidally affected rivers. The equation for the index velocity to estimate of mean water velocity which is used to estimate the discharge at the Samrangjin gauging station is also derived in this study. To evaluate the new equations, the discharge estimated from new equations is compared with measured discharge collected on the Samrangjin gauging station in the Nakdong River basin, Korea.

In this study, existing rating curves used to compute the discharge were analyzed in depth to evaluate their behavior in predicting discharge in tidally affected rivers. In addition to the analysis of the existing rating curves, new rating curves using both the stage height and the stage height difference which is more easily obtained for natural streams has been developed. Correlation analysis was done, in order to select physically meaningful parameters which relate to mechanisms of flow discharge in estuary. A robust minimum covariance determinant method, one of the nonlinear multi-regression methods, is applied to derive regression equations for the discharge estimation using 39 measurements collected at Samrangjin gauging station.

2. Study Area and Evaluation of Existing Rating Curve

Tides from the Pacific Ocean enter the Nakdong bay system through the Nakdong River barrage which eight gates are in the Nakdong barrage and operated to control the flood and salinity concentration in Nakdong River basin. Most gauging points in Nakdong River basin are located in the bridge area where gauging points can be influenced by the tidal currents. The Samrangjin gauging points shown in Fig. 1 is located in the complex channel shapes with double trapezoidal channel on

Fig. 1. Map of the Nakdong River Basin, Korea