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# STUDY OF MODIFICATIONS OF THE RIVER PHYSICAL SPECIFICATIONS ON MUSKINGUM COEFFICIENTS, THROUGH EMPLOYMENT OF GENETIC ALGORITHM

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**ABSTRACT**

Sofar much research has been done of flood routing through Muskingum linear and non-linear model and genetic algorithm. Study of changed specifications of river such as waterway slope, width and length of the river, and the river bed which lead to determination of its roughness coefficient, and their impacts of flood hydrograph and finally on nonlinear model coefficients, are importance. In this research, effect of modifications of width and length of the ricer on coefficients of the Muskingum nonlinear model employing the genetic algorithm has been investigated. Obtained results, indicates the presence of a logical relation between fluctuations of the river specifications and coefficients of this model that through increase of data, there will be a possibility of finding a mathematical relations for expressing such modifications as well.



## INTRODUCTION

Flow routing in the river, is a mathematical process for predicting magnitude, velocity, and shape of the flood wave as a function of time in one or several points in the course of the waterway, channel or reservoir. The flood process can be studied through two hydrologic and hydraulic methods. If the water flow is only routing as a function of time in a specified location, it is called hydraulic routing. In this method, the equation of flow continuity, natural and unique hydrographs and discharge and maximum level surface of flood are employed. Amongst the hydrologic flood routing Muskingum models can be mentioned. Routing comparison of hydrologic and hydraulic method for flood indicates that flood routing using hydrologic methods is much easier than hydraulic ones however, precision of hydraulic methods is superior. Samani *et al*. (2000) compared the two flood routing through dynamic wave and the cinematic wave. Patricia *et al*. (2005) studied the methods of numerical solution of Saint Venant (1971) for investigating flood in the rivers and finally concluded that hydraulic parameters play a crucial role in studying the flood wave diffusion mechanism. Muskingum method was used for the first time by McCarthy in 1935 for controlling the flood flow in the Muskingum River in Ohio. Karimiyan *et al*. (2012) studied the flood routing in rivers using the cinematic wave and Muskingum-Cunge. Muskingum method is based on composition of two equations one of which satisfies the continuity equation and the other one expresses the volume-storage equation in the (flow section) interval (2001).

$$\frac{ds}{dt} = I - O \tag{1}$$

$$S = k[xI + (1-x)O] \tag{2}$$

From of the Muskingum equation is as follows:

$$S_t = k[xI_t + (1-x)O_t]^m \tag{3}$$

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$$S_t = k\left[xI_t^m + (1-x)O_t^m\right] \tag{4}$$

In which S indicates the storage volume in the studied interval at the time t, I is the inflow discharge to the interval and O is the outflow discharge from the interval. Also, x and k are parameters of the Muskingum method which are considered as a Function of flow course properties and the flood wave. Through writing the form of finite difference of equations 3 and 4, and their combination and finally simplification, the following equation is obtained based on which routing can be performed.

$$Q_2 = C_0 I_2 + C_1 I_1 + C_2 O_1 \tag{5}$$

In these relations, I stands for location of point in relation to x, k is temporal situation of point and c coefficients are define as follows:

$$C_0 = \frac{(-2kx + \Delta t)}{(2k - 2kx + \Delta t)} \tag{6}$$

$$C_1 = \frac{(2kx + \Delta t)}{(2k - 2kx + \Delta t)} \tag{7}$$

$$C_2 = \frac{(2k - 2kx - \Delta t)}{(2k - 2kx + \Delta t)} \tag{8}$$

Which in the above relations k stands for hydrograph temporal steps, x is the weight factor for location and values of these two factors have been determined by Al-Humoud *et al*. (2006) to be between 0 to 0.5 which its mean is considered to be 0.2. An important and fundamental issue in the Muskingum procedure is that x and k parameters have no physical meaning and they can only be estimated provided inflow and outflow hydrographs are expressed of a flood incident in the channel or river interval. This problem has been solved in the Muskingum–Cunge method in which x and k parameters have been expressed according to the physical properties of the channel interval (Chow *et al*., 1988 and Chow, 1982). Moradi *et al*. (2008) attempted flood routing through Muskingum and Muskingum Cauge in the Lighvan River and observed that result obtained of the routed flow by two models has a significant difference with the real results registered in the downstream hydrometer station.

The reason was mentioned to be the region being mountainous, existence and downstream stations. Also Schultz *et al*. (2008) employed the cinematic wave model for flood routing. One of the objectives of this research is that through change of river width and length, study the outflow hydrograph and then employing the genetic algorithm compute coefficients of the Muskingum nonlinear model. Then the change trend of these coefficients, along with the channel width and length will be studied, and the possibility of expressing a mathematical relation between these fluctuations will be investigated. In this research, first regarding data on several national rivers, a schematic plan of a river with all details is drawn n the HEC-RAS software and following entering data on the inflow hydrograph into the planned river, its outflow hydrograph is obtained and then by assistance of the genetic algorithm, relevant coefficients are extracted via the nonlinear Muskingum method. The genetic algorithm method has been frequently used in the hydraulic methods. Some researchers have studied the problems concerning subsurface waters using the genetic algorithm. Ritzel *et al*. (1994) employing the genetic algorithm studied the problems concerning pollution of sub surface waters. Employment of genetic algorithm method for solving rather complex equations in the flood routing procedures, can lead to precise and easy solution of high volume of these equations with no need to high time consumption. Following determination of outflow hydrograph and the model coefficients, in case of hydrograph being rational, outflow and coefficients computed of this hydrograph are used as the reference hydrograph and in the next software runs, physical properties of waterway are changed, such properties include length and width of the waterway. Figure 1 depicts the diagram of the reference inflow hydrograph. After entering the various data and obtaining the model coefficients, the trend of modifications of the above said values are drawn against each other and the expected results are deduced.

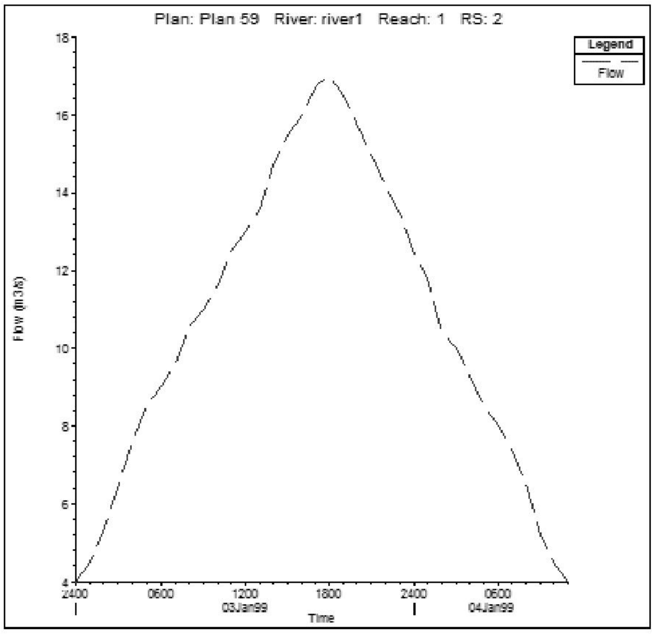


**Figure 1. Inflow hydrograph**

## Computations

Following entering the river data and specifications of the inflow hydrograph into the river, the outflow hydrograph is obtained. Figure 2 depicts this hydrograph which is drawn considering the 3000m length and 8m width of the river. Then length and width of the water way are changed are the Muskingum nonlinear model coefficients considering the working method explained in the task performance stages will be computed. Table 1 reveals the modified values of the waterway length and the Muskingum nonlinear model coefficients. Table 2 as well, depicts the modified values of the water way's width and the Muskingum nonlinear mode coefficients.

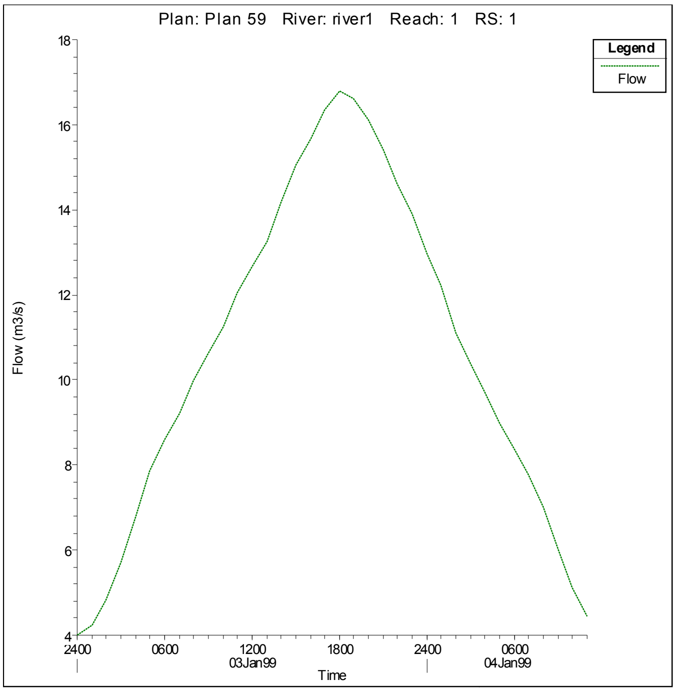


**Figure 2. Output hydrograph for the river length and width**

**Table 2. The channel width change and Muskingum nonlinear coefficients model**

| River length (m) | Coefficient (x) | Coefficient (k) | Coefficient (m) |
|---|---|---|---|
| 8 | 0.002 | 0.271 | 1.64 |
| 9 | 0.004 | 0.469 | 1.424 |
| 10 | 0.011 | 0.747 | 1.248 |
| 11 | 0.035 | 0.773 | 1.245 |
| 12 | 0.052 | 0.788 | 1.24 |
| 13 | 0.068 | 0.831 | 1.228 |
| 14 | 0.07 | 0.861 | 1.224 |
| 15 | 0.078 | 0.873 | 1.232 |
| 16 | 0.085 | 0.547 | 1.429 |
| 17 | 0.089 | 0.306 | 1.679 |
| 18 | 0.097 | 0.853 | 1.271 |
| 19 | 0.107 | 0.753 | 1.319 |
| 21 | 0.109 | 0.812 | 1.288 |
| 22 | 0.11 | 0.759 | 1.314 |

## RESULTS AND DISCUSSION

Following performing the above computations, values for the first column are drawn against the values present in the next columns. Figure 4 depicts such diagrams. Values employed in each diagram are observable Figure 4. Diagram of length modifications with coefficients (up) and diagram of width modifications with coefficients (below).

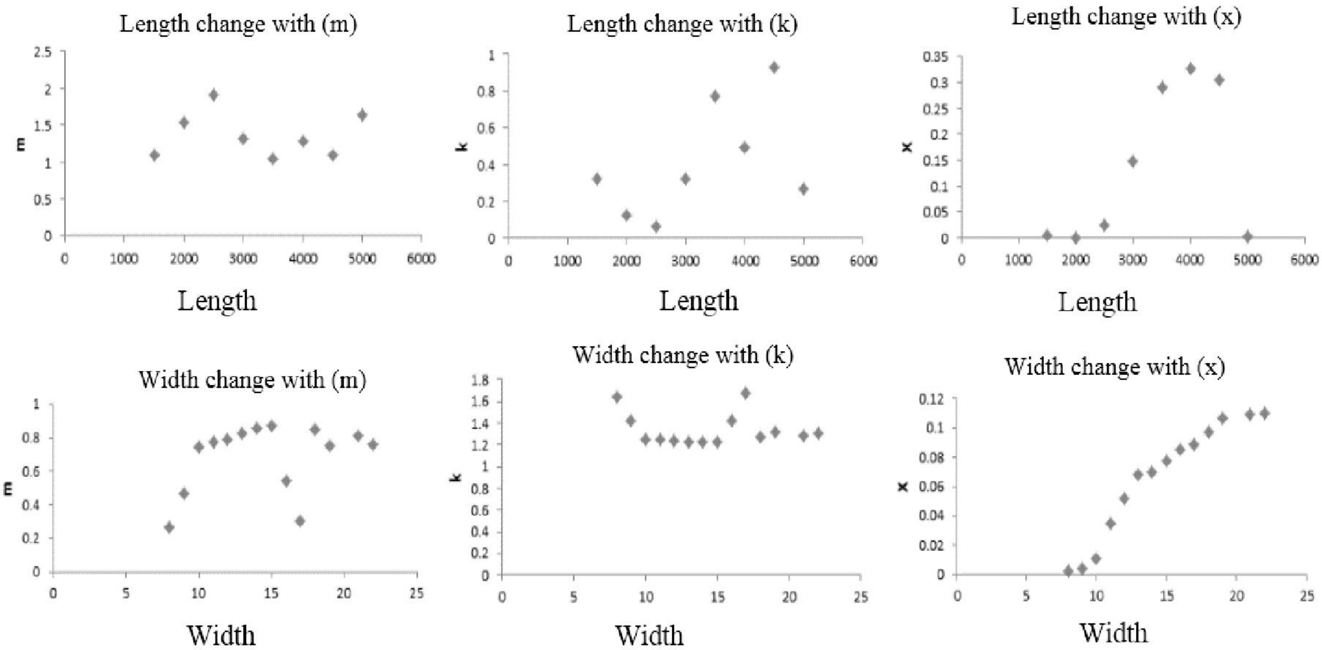


**Figure 4. Length (above) and width (bottom) variation diagram with the coefficients**

**Table 1. Different values of channel length and Muskingum nonlinear coefficients model**

| River length (m) | Coefficient (x) | Coefficient (k) | Coefficient (m) |
|---|---|---|---|
| 1500 | 0.005 | 0.324 | 1.098 |
| 2000 | 0.001 | 0.122 | 1.542 |
| 2500 | 0.025 | 0.062 | 1.912 |
| 3000 | 0.148 | 0.319 | 1.31 |
| 3500 | 0.291 | 0.769 | 1.049 |
| 4000 | 0.326 | 0.491 | 1.278 |
| 4500 | 0.304 | 0.929 | 1.099 |
| 5000 | 0.002 | 0.271 | 1.64 |

As depicted in Figure 4, along with the increased river length, an increasing terendis seen n values of the x coefficient however, along 5000m, such values has experienced a severe decrease. To study this decrease, further data concerning 5000m of the river length are needed but, generally it can be concluded that through increased length of the river, the coefficient x value is also increased but in the case of k and m coefficients such modifications do not follow an increasing or decreasing trend but are sinuous which nearly follow a particular model. As it can be seen, k modifications are the reverse of the m modifications however, the rate of k modifications it more, therefore, the k coefficient shows more sensitivity to modifications of the river length. Regarding modifications of the river width it is observed that along with increased width, value of the x coefficient increases as well and that this increase follows a particular model. As it can be seen however, once again the k and m coefficients have a non-ascending or absolute descending trend. These two values thus accordingly fluctuate contrary to each other; through m increase, k decreases and vice verse but sensitivity and the rate of m modifications relative to width modifications is much more than those seen for k. As a conclusion, it can be pointed to the following results:

1. The x coefficient increases along with increased length and width of the river.
2. The trends of k and m modifications are opposite to each other; along with the k increase, m is decreased and vice versa.
3. Trend of k and m modifications relative to increased length is sinuous with a rather identical alternation.
4. Trend of k and m modifications relative to increased width is similar to increased length in a alternative form however, compared with the length increase fluctuations, it experiences sudden and more intensive fluctuations.
5. The k coefficient is sensitive to the river width, therefore, through width modifications, m coefficient experiences more modifications compared with the m coefficient.
6. Regarding the trend of modifications of the coefficients, through increased magnitude of data it will be possible to provide a mathematical formula for expressing such modifications in relation to length and width modifications of the river.

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