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Investigation of Performance and Determination of Optimal Dimensions of Surface Runoff Collection Network Using SWMM Model

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ABSTRACT: Road flooding has always caused many problems in cities due to inadequate networks of the runoff collection. Therefore, it is essential to identify flood-prone areas and canals that have been flooded. In this study, the sufficiency of the Surface Runoff Collection Network in Shahrekord was investigated during 2, 5, and 10-year rainfall returns using the SWMM model. It should be noted that no studies have been conducted on the issue of urban runoff in this area until now. In this simulation, model calibration has been performed based on the discharge index at three and the depth index at two rainfall events. The error coefficients of NSE, RMSE, and BIAS% have been applied to compare the simulated model error with the observed values. The equivalent width index has been found as the most sensitive index of the model by sensitivity analyses. The validation has been performed on two discharge parameters and runoff depth, each in 2 separate rainfall events, in several random canals and nodes. The acceptable values for the error coefficients showed a high accuracy of the simulation. After the validation phase, the model has been run for 2, 5, and 10-year rainfall return periods, and it was found that flooding occurs in 19.4%, 20.68%, and 21.52% of canals, respectively. The locations of the flooded canals indicate that the southwestern part of the city will be flooded. The optimal dimensions of the canals to prevent flooding have been determined during the 10-year rainfall return period, and the volume of concrete needed to modify the dimensions of each canal has also been estimated.

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1- Introduction

In recent decades, the issue of collecting and reducing urban surface runoff has been an important component of urban planning and development [1, 2]. On the other hand, a comprehensive study is needed because of the rapid growth of urban areas, the presence of outdated textures in cities, inadequate drainage and surface runoff collection, and the lack of comprehensive urban flood control plans in most Iranian cities [3-5]. The approach of this study is evaluation of the adequacy of Shahrekord surface runoff collection network, determination of flooded points and canals in 2, 5 and 10-year return periods, and finally determination of the optimal dimensions of the canals to prevent flooding during the 10-year return period. In addition, the volume of concrete needed to modify the dimensions of the surface runoff collection network in Shahrekord has been determined.

2- Methodology

In this study, the simulation of the surface runoff collection network in Shahrekord city has been investigated using the SWMM model. The simulation has been performed in two hydrological and hydraulic sections. The calibration of the model has been performed on two parameters of discharge and depth. The comparison between the observed and simulated hydrographs showed that the results of the model have good accuracy. Figures 1 and 2 show the observed and simulated runoff depth diagrams in two rainfall events.

After ensuring the accuracy of the simulation, the adequacy of the surface runoff collection network has been investigated, and flooded canals have been identified. Finally, the optimum dimensions have been designed for the flooded canals, and the volume of the concrete needed to modify the dimensions of the Shahrekord surface runoff collection network has been estimated.

3- Results and Discussion

The outflow hydrograph has been produced at the outfall point using a 6-hour rainfall with 2, 5 and 10-year return periods. This diagram is shown in Figure 3.

As it can be seen, after the end of the rainfall period, the runoff flow in the outlet canal has been gradually reduced. Providing this hydrograph can help designers to estimate the time, volume, and peak discharge of urban floods.

After this stage, the status of the drainage network of the entire catchment has been investigated, and the location and number of flooded canals have been determined. Figures 4, 5, and 6 show the network status and flooded canals during the 2, 5, and 10-year return periods.

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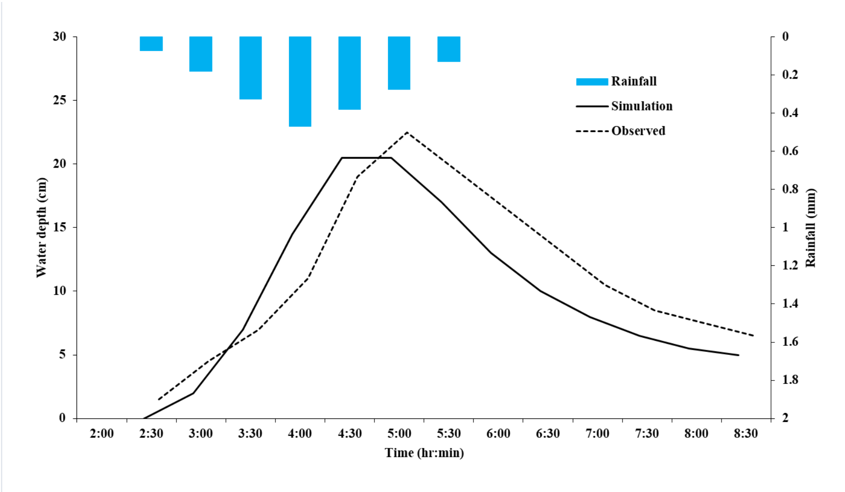

Fig. 1. Diagram of the observed and simulated runoff depth on 2019-10-4

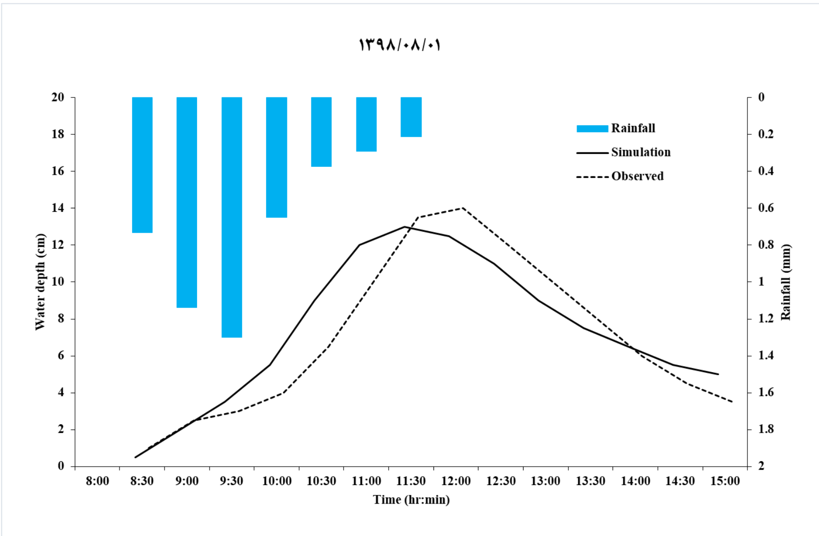

Fig. 2. Diagram of the observed and simulated runoff depth on 2019-10-23

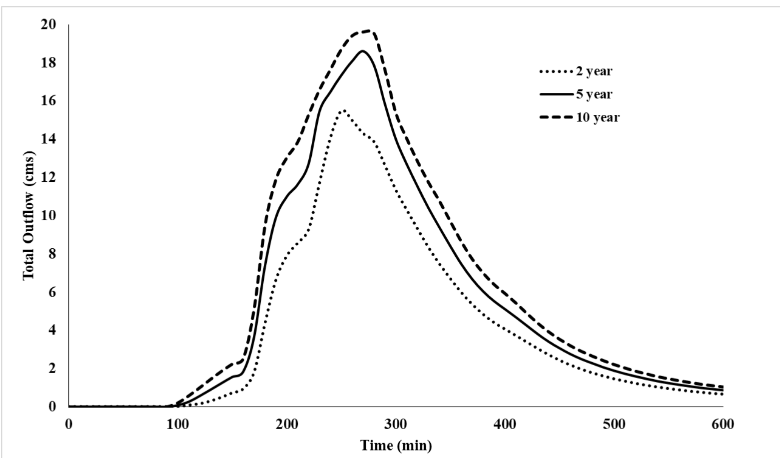

Fig. 3. Catchment outfall hydrograph during 2, 5 and 10-year return periods

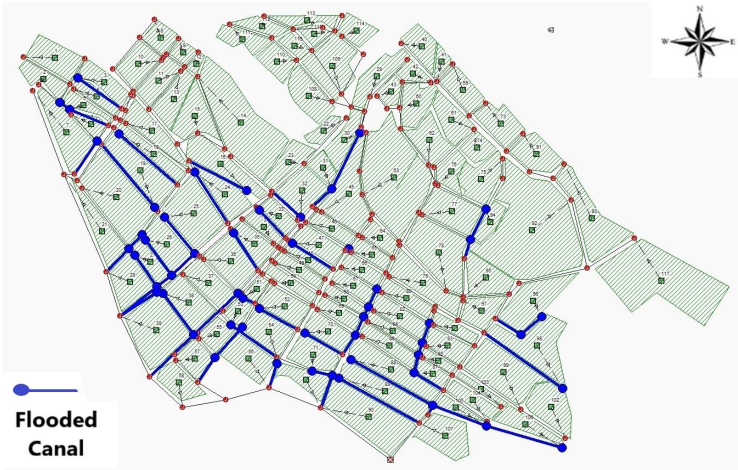

Fig. 4. Network status, flooded canals and flooded points in Shahrekord, during 2-year return period

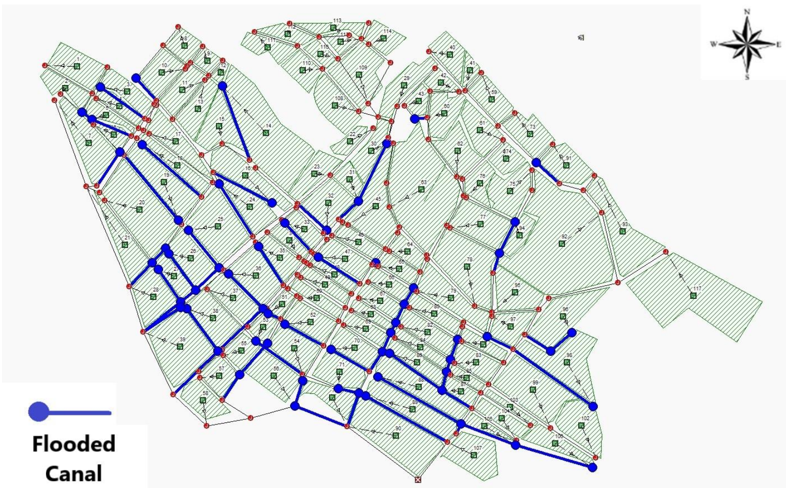

Fig. 5. Network status, flooded canals and flooded points in Shahrekord, during 5-year return period

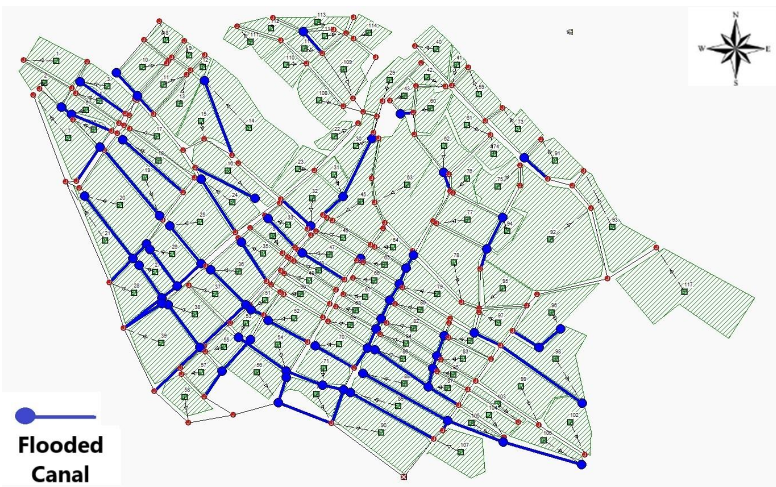

Fig. 6. Network status, flooded canals and flooded points in Shahrekord, during 10-year return period

According to Figures 4-6, most of the flooded points and canals are located in the southwestern part of the city, which is less elevated than the northeastern part. Most of the outlets leading to the city's southern drainage canal are also flooded. Besides the southwestern and outfall canals, the canals in some northeast and northwestern parts of the city have also flooded with increasing rainfall return period from 2 to 5 years (Figure 5). Finally, it has been found that during the 2, 5 and 10-year return periods, 19.4%, 20.68% and 21.52% of the city's canals have been flooded, respectively. After this stage, the optimum dimensions of the surface runoff collection canals have been determined during the 10-year rainfall return period. Then, the volume of the concrete needed to modify the dimensions of these canals has been estimated to be about 7929 cubic meters for the whole city.

4- Conclusion

In this study, the SWMM model was used to simulate surface runoff in 114 sub-catchment of Shahrekord city using 6-hour rainfall over 2, 5, and 10-year return periods. The simulation results showed that in most nodes and canals of the southwest of the city, flooding occurred so that during the 2, 5 and 10-year return periods, 19.4%, 20.68% and 21.52% of the city canals have been flooded, respectively. Then, the optimal dimensions of the canals for the 10-year return period were determined, and the concrete volume needed to correct them was estimated.

The results of this study, which are presented separately for all city canals, could be implemented in a fully applied manner and can significantly help to overcome the problem of flooding of roads due to the inadequacy of the surface runoff collection network in the Shahrekord urban area.

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