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Hydraulic Simulation to Find Bottlenecks and Potential Flood Points in the Main Runoff Collection Channel by HEC-RAS 5 Model (Mianroud Canal, Tehran)

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ABSTRACT

Currently, floods are one of the biggest threats to social security and sustainable development, and are among the most devastating and costly natural hazards. In recent decades, studies on urban flooding have increased and there has been a leap forward in flood risk management. The management of runoff and floods in the metropolis of Tehran is also more important due to its location at the foot of the mountain, leveling the land, occupying the privacy of the Channels, high relative density of housing and population and improper use of the Channels. For this purpose, in this study, the main Channel collecting surface runoff in the second district of Tehran (known as Flood Diversion Channel of West Tehran) was examined. The HEC-RAS 5 model was used for hydraulic simulation to flood the area and identify critical points in the area. Two parameters, speed and depth, were used as important parameters to assess risk. Studies conducted in this study, as well as a general comparison between flood risk zoning methods, show that the use of combined models with different factors in determining flood risk will have more appropriate results. The use of flow energy in flood risk assessment and considering the two components of depth and speed and their targeted combination will lead to the verification of results. In addition to the above, it seems appropriate to provide appropriate zoning for potential flood hazards, to identify safe areas, to provide relief routes, to economically justify reorganization plans, to flood flood-affected lands, and to manage floods.

Keywords:

Flood risk assessment, flood risk estimation, plain flood management, Mianroud Tehran Channel

1. Introduction

1.2. Background

Floods are one of the most destructive natural hazards. Flood control and management methods are generally divided into structural and non-structural methods. In other words, flood control can be considered as a structural method and flood management methods can be included in the category of non-structural methods. Structural methods such as dam construction on the river, construction of flood dams around flood-prone areas, increasing the height of the walls around the Channels, stabilizing the bed and dredging them try to reduce the amount of flooding, while non-structural methods such as flood forecasting, Seeing flooded areas using satellite imagery, flood control, flood insurance, watershed management, flood warning, flood evacuation, flood management in reservoirs and emergency relief efforts to reduce the effects and consequences of flooding. Many experts believe that combining structural and non-structural methods can reduce flood damage at a lower cost. The world's experience with non-structural methods dates back to the 1980s, and almost all of the above methods have been tested depending on the location of the country and the region in question, but in practice there are four areas for controlling flood plain expansion, flood insurance, flood warning and overfilling. Iqbal has met with success in other European countries, including the United States and Japan. Risk management in different parts of the city is considered as one of the important axes of flood management methods (non-structural methods) in the city. Based on the statistics of annual damages caused by floods in Iran, the study shows the extent of flood damage to natural, human and economic resources in different regions. This risk has far greater effects in cities, which are manifestations of human development, and this reveals the need for management in floodplains. Increasing population growth, land leveling, occupation of rivers and Channels, lack of attention to environmental capacities and improper use of resources along with climatic and physiological factors in large cities have led to the spread of urban floods. Therefore, the issue of floods and financial losses and the resulting casualties in the metropolis of Tehran is of particular importance. The first step in flood management plans and floodplains is to prepare a flood zoning plan. There are different methods for preparing these maps, one of the newest methods is to use GIS geographic information systems and combine them with hydraulic and hydrological models. Flood propagation models are tools that can simulate hydraulic Channels and floodplains. This ability to predict floods is very useful in reducing the potential for flood damage by protecting land use around Channels collecting and transporting surface runoff. Meanwhile, flood zoning maps, considering different return periods, are one of the most common maps that are used to show the potential of hazards in the flood plain. Therefore, according to the above, the implementation of flood control system and efficient drainage mechanism in cities is essential. The purpose of this study is to simulate floodplain areas and identify accident-prone and critical points along the Flood Diversion Channel of West Tehran in the area of District 2 of Tehran.

1.2. Overview of the Background Studies

The purpose of flood modeling and storm hydrology in urban basins is to study the occurrence of runoff in these areas and how the drainage system of the region responds to runoff [1]. Floods in most urban areas are caused by the inefficiency of the urban drainage system, which leads to numerous human and financial losses [2]. In this regard, attention to this issue and the study of floods in urban areas has recently received a lot of attention [3-9]. Nearly all research has shown that increasing urban levels and reducing their permeability leads to a decrease in concentration time and an increase in surface water [10, 11]. Also, studies show that due to urban planning activities and construction operations that are carried out on catchment areas, the volume of runoff and the intensity of the flow increases [12]. Many human activities, including the destruction of forests and pastures, changing land use, increase flooding in areas and areas [13]. Many researchers use one-dimensional models to simulate runoff management and surface water collection of the city in channels, tunnels, underground pipes [14, 15]. Also, some modelers use two-dimensional models for junctions or for the entire route to increase their modeling accuracy [16-18]. One of the most common models in this field is the HEC-RAS model [19, 20]. In this research, ASSA (1D) and HEC-RAS 5.0.5 (2D) model has been used to identify bottlenecks or possible urban accident hotspots along the Mianroud channel.

2. Research Method

The first step in reducing the harmful effects of floods is to identify flooding areas and zoning of these areas in terms of risk level so that we can prevent its destructive effects based on the results obtained with integrated management and comprehensive urban planning. Flood risk zoning maps can be considered as an effective tool in planning the future development of the city.

2.1. Problem Theory

In order to study the flooding of the plains of each river or Channel, it is first necessary to prepare a digital map with a suitable scale for simulating it and the surrounding lands.

2.2.1 Preliminary information required to simulate flood zoning

- Hydraulic information (roughness, Channel or river route status, ...).
- Topographic information (longitudinal and transverse profile of the route and marginal lands);
- Flood flow information (flood inlet hydrograph, Discharge curve ...).

The modeling steps in the software are as follows:

- The plan of water transfer sections was defined by determining the coordinates and drawing the sections. To properly implement the model, all obstacles and structures created along the waterway were removed and simulated. These barriers included the bridge, as well as a group of barriers and protective structures along the Channel, such as bridges and stone walls. Mapped area data were used to simulate the existing barriers.
- The roughness coefficient along the main Channel and the floodplain of the plain was determined and calibrated using the suggested tables (n) of the Manning roughness coefficient.
- Primary and boundary conditions are determined by the upstream and downstream water level hydrographs, flow hydrographs, or metering curves. For this purpose, the normal depth method has been used, which requires inserting the slope of the power line as well as the flow given in the desired location. If the Hydraulic Gradient is not available, the slope of the Channel bottom can be used, which is obtained from the longitudinal profile at the top and bottom of the river.
- In order to analyze the flow rate, the required flow rate of comprehensive studies in Tehran was collected and used. Also, the maximum momentary flood values were used during the return period at the study site by Krieger method.

- Water level profile calculations for steady-state variable steady flow in artificial Channels and rivers in subcritical, supercritical and mixed flow regimes in the HEC-RAS model are performed step by step by solving the energy equation by standard method. The two parameters depth and speed of flood are two factors that determine the risk of flooding anywhere. The equation governing flow energy seems to be suitable for analysis because it has both flow velocity and depth criteria.

$$\int_1^2 \frac{\partial V}{\partial t} ds + \int_1^2 \frac{dp}{\rho} + \frac{1}{2}(V_2^2 - V_1^2) + g(z_2 - z_1) = 0 \tag{1}$$

Due to the steady and Incompressible flow, we can conclude:

$$\frac{p_2 - p_1}{\rho} + \frac{1}{2}(V_2^2 - V_1^2) + g(z_2 - z_1) = 0 \tag{2}$$

After simplifying and considering the energy loss, the equation becomes as follows:

$$Z_1 + Y_1 + a_1 \frac{V_1^2}{2g} = Z_2 + Y_2 + a_2 \frac{V_2^2}{2g} + h_e \tag{3}$$

Which is in the above equation, Z is the floor level of the main channel, V is medium deeps, α is speed load correction factor, h_e is total energy loss and g is acceleration of gravity. The momentum equation in the HEC-RAS model also calculated as follow:

$$\frac{Q_2^2\beta_2}{gA_2} + A_2\overline{y}_2 + \left(\frac{A_1+A_2}{2}\right)LS_0 - \left(\frac{A_1+A_2}{2}\right)L\overline{S_f} = \frac{Q_1^2\beta_1}{gA_1} + A_1\overline{y}_1 \tag{4}$$

In the above equation, β is Momentum correction factor, $\bar{y}$ is The measured depth from the water level to the center of gravity of the flow cross section, A is wetland area below the cross section, S is Channel slope, L is distance between sections and Q is flow rates. The following figure shows the study area of District 2 of Tehran.

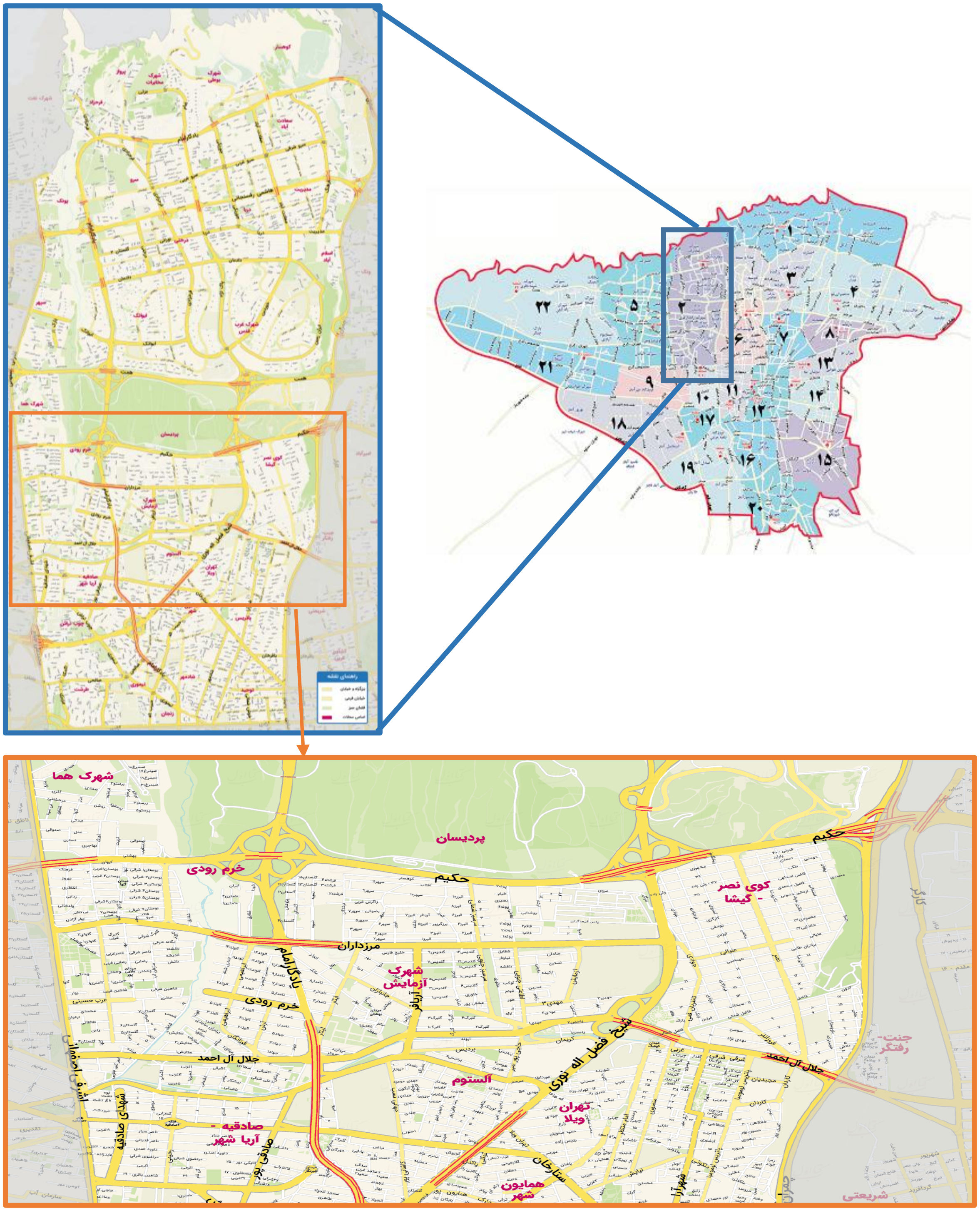


Figure 1. Location of the study basin (Mianroud Canal, District 2 of Tehran).

3. Results and Discussions

3.1. Research Objective

In this study, using ASSA and HEC-RAS models, the adequacy of surface runoff collection system for return periods of 5, 10, 25, 50 and 100 years was evaluated. Also, using flood zoning maps, flooded areas were prepared.

3.2. Findings

Longitudinal view of the bed slope of bottlenecks and potential flood points in this research is given in Figure 2.

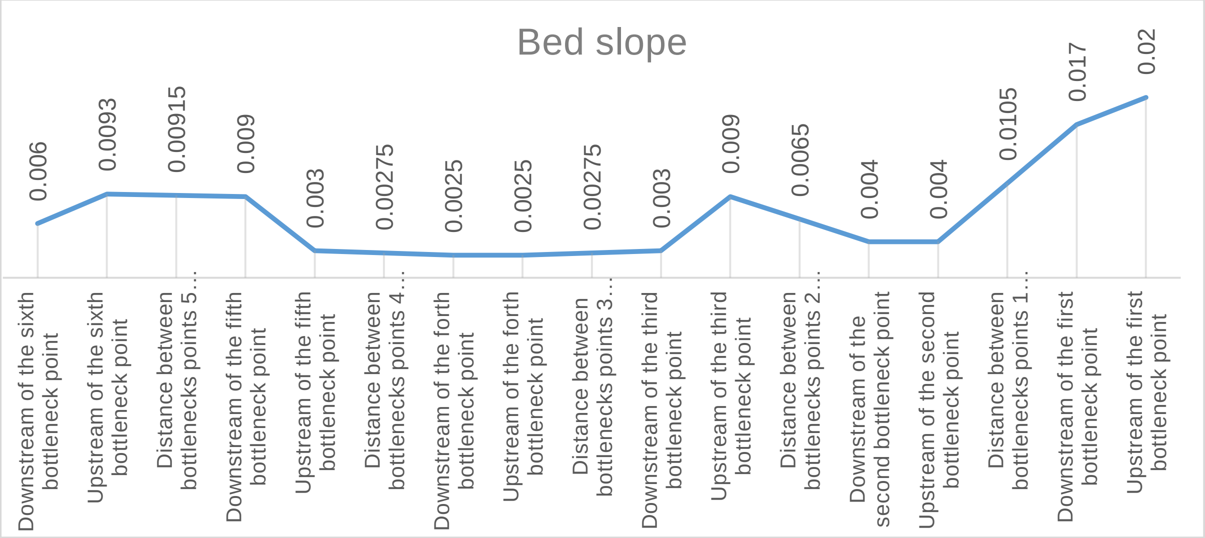
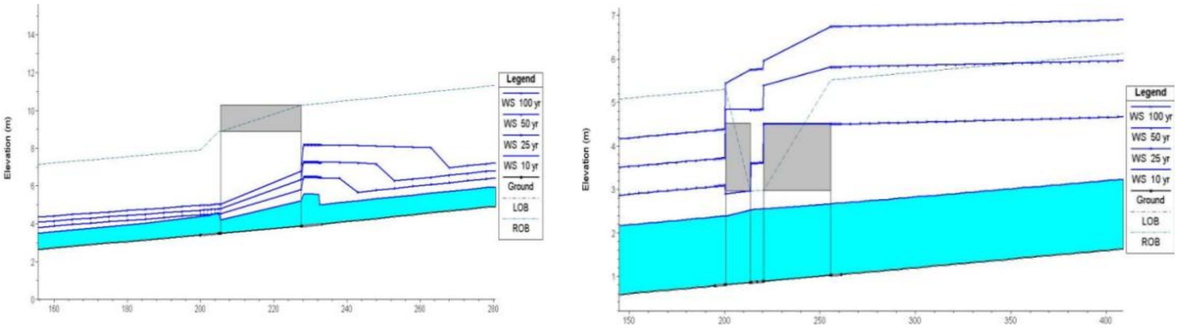


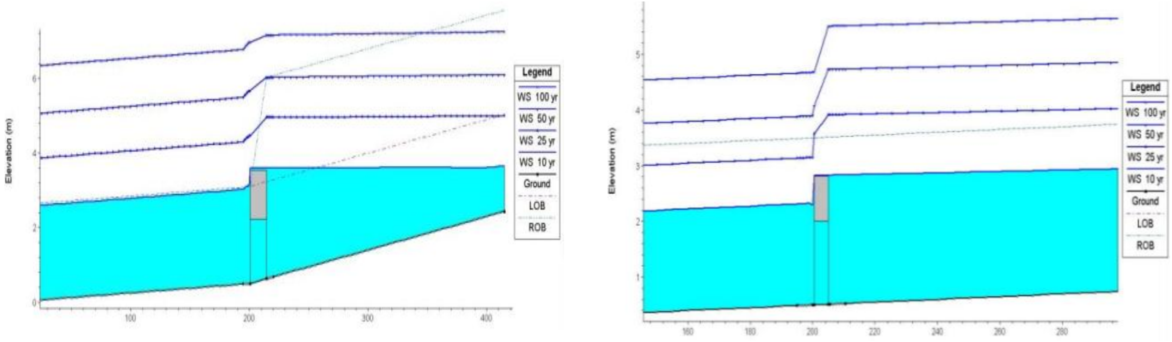
Figure 2. Longitudinal view of the slope of the bed of bottlenecks and potential flood points in the study area.

As you can see in Figure 3 the capacity of the first critical point (bridge) is sufficient for floods with a return period of 10, 25, 50 and 100 years, and it crosses the upstream channel flow as a free surface flow. The capacity of the second critical point (bridge) is sufficient for floods with a 10-year return period and for floods with a 25-year return period, the bridge operates under pressure. Also, for floods with a return period of 50 and 100 years, the flow overflows the channel and the deck of the bridge, and as a result, this bridge is not suitable for the passage of 50 and 100-year-old floods. Among the features of the third critical point (bridge no #3) are the reduction of the cross section of the channel by 30.76% by the bridge deck, the higher right wall of the channel compared to the left wall of the channel above the bridge and also the reduction of the cross section of the channel at a distance of 5 meters after the bridge. From 6.7 meters to 5.2 meters. So, the capacity of this bottleneck point of channel is not sufficient for floods with a return period of 10, 25, 50 and 100 years. During the flood, the water flow will pass through the bridge deck due to the increase in the water level, and some of the flow will flow out of the upper channel. For the fourth bottleneck point of the channel the deck of this bridge has reduced the useful cross section of the Channel by 43.33%. It is presented in the form of its hydraulic specifications. This is not enough for floods with a return period of 10, 25, 50 and 100 years. In a flood with a return period of 10 years, the stream passes over the deck and some of the passing flood returns to the downstream

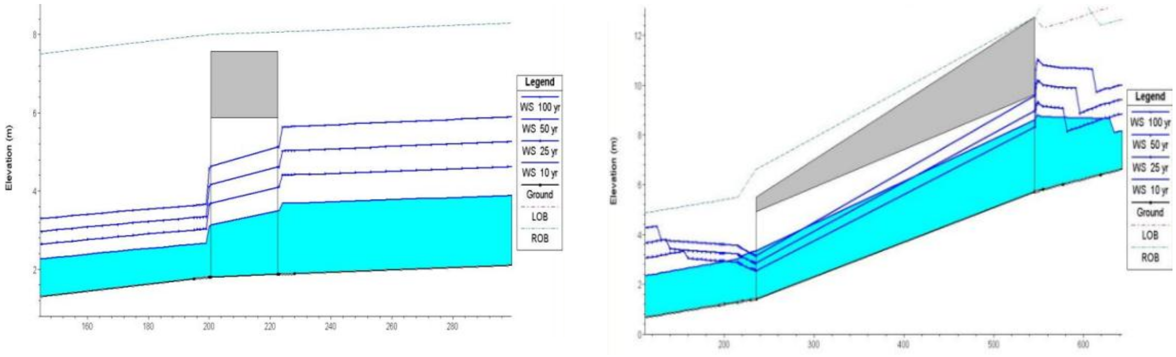
Channel, and some overflows around the deck. In the floods with a return period of 25, 50 and 100 years, in addition to the flooding of the bridge deck, water also flows out of the upper channel.



Bottleneck Point #1 Bottleneck Point #1



Bottleneck Point #3 Bottleneck Point #4



Bottleneck Point #5 Bottleneck Point #6

Figure 3. The longitudinal profile of bottlenecks and potential flood points in the study area.

The fifth critical point of the Mianroud channel was built to cross North Ninth Street from the channel on the Flood Diversion Channel of West Tehran, and its deck has reduced the useful cross-section of the upstream Channel by 45.08 %. With the return periods of 10, 25, 50 and 100 years, the flow passes through the sub-bridge as a free surface and with respect to the free board. The capacity of the sixth bottleneck point of the mentioned channel (6th bridge), On the upward side, the cross-sectional area of the duct is reduced by 59.80% compared to the upper channel level. It should be noted that since there is a bridge 20 meters after the channel is opened, which affects the flow passing through the channel. Therefore, this part has been modeled in two modes, considering the effect of this bridge and regardless of its effect, both cases are presented below:

The results of the mentioned modeling alone, without considering the effect of the next bridge, show that this range can cross the flood channel of the west with the return periods of 10, 25, 50 and 100 years.

The results of the simultaneous modeling of 6th Bridge and the subsequent bridge show that the capacity of the bridge is sufficient for flooding with a 10-year return period. The flow passes through the bridge as a free surface, observing the free board. However, for floods with a return period of 25, 50 and 100 years, the return of water from the construction of the second bridge will lead to the outflow from the lower channel.

The following diagrams (Figure 3) are the results of the hydraulic modeling of the bottleneck points.

4. Conclusion and Suggestion

The results of water level calculations in different return periods and flood zones in each period were determined. As can be seen in the figure below, the discharge rate has increased with respect to the longer return period, and the flood zone has expanded. The difference in the expansion of the flood zone is primarily due to the topographic features around the channel. This feature is well illustrated in the Figure 4.

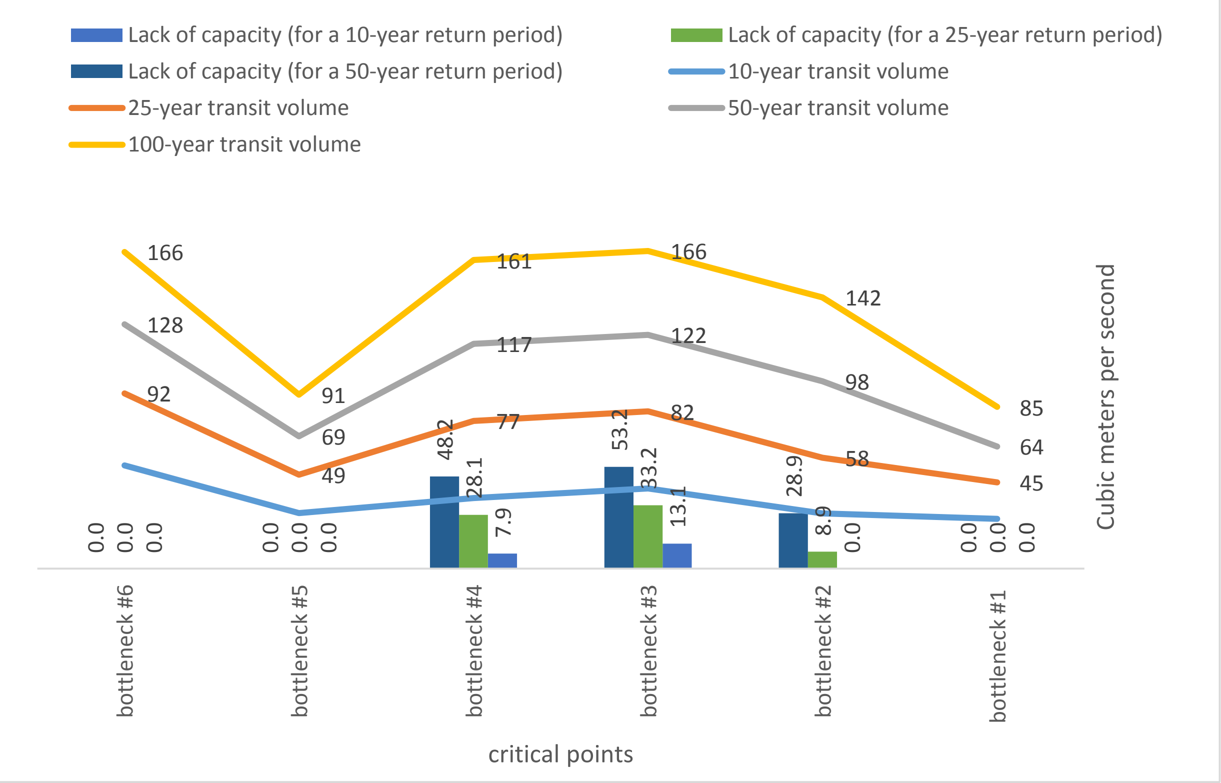


Figure 4. Bottlenecks and potential flood points in the study area.

Floods are a natural hazard that can cause great damage to city dwellers each year. Preparing flood zoning maps for different return periods is one of the common methods used to show the potential of flood hazards. It is recommended that important points be identified and that sensitive points be identified at different return periods after the implementation of the model. To this end, it is recommended that city managers avoid over-developing building and population density in areas with medium to high risk. Also, using engineering and management solutions to create conditions for creating open spaces in order to provide relief in cases of natural hazards, to create a network of high-width passages in vulnerable areas.

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