Numerical Methods in Civil Engineering

Combining Structural and Non-Structural Measures for Optimal Management of Urban Surface Runoff Collection (Case Study: Ariafar Bridge in Mianroud Canal)

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Abstract:

Today, various structural and non-structural solutions are used to control and reduce the negative effects of floods in investigation and executive projects. But what is certain is that the optimal solution to minimize flood damage is a combination of structural and non-structural methods (planning and response measures). It is essential to provide these solutions in a metropolis like Tehran because the hydrographic network of Tehran runoff is sometimes incomplete during floods and is accompanied by severe flooding. Therefore, in this study, a combination of the mentioned methods were used for a part of Tehran's Mianroud canal (as one of the most important surface water management facilities in the catchment area of west Tehran) called Ariafar Boulevard Bridge. For this purpose, in the first step, severe accident hotspots along the route were investigated and then the capacity of passing on accident-prone routes was evaluated according to hydrological information under different scenarios (discharges with return periods of 5, 10, 25 and 100 -years). The results show the adequacy of channel capacity for a 10-year return period. But for the 25, 50 and 100-year discharge, we will face 8.88%, 28.93% and 50.81% capacity shortages, respectively. In the second step, considering the structural solutions, the methods of eliminating the capacity shortage of bottlenecks, including correcting the route, installing auxiliary routes, or destroying bridges that prevented the transfer of runoff in the canal route were carefully examined. The results showed that the combined use of structural and non-structural methods increases the effectiveness and significantly reduces the risk of flood spreading in the city.

1. Introduction

Concentration of population in urban areas has led to the development of cities, and changes in the natural face of the earth has led to an increase in impermeable levels and transformations in the hydrological cycle, resulting in an increase in urban floods, that have led to numerous drawbacks and damage especially in metropolitan areas in the city.

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Land leveling and encroachment on rivers or canals initiate alterations in the pattern of natural drainage, flooding in urban areas, flooding of roads and increasing maintenance costs of the city. Today, structural and non-structural methods are used to reduce the negative effects and consequences of floods, such as flood mitigation, flood vulnerability reduction, damage reduction and damage preparedness. The expansion of Tehran to an altitude of 2200 meters has caused structural differences in the physical texture of the city and as a result made it prone to natural hazards such as floods. Also, in Tehran, there are several canals and rivers that drain the water of upstream basins and collect water from rainfall in the urban area of Tehran. In some parts of the city where land prices are high, the area of rivers and canals is not considered accordingly and their cross-section is reduced and limited. This can affect the natural regime of the river and the flow path, and cause irreparable damage in the event of heavy rainfall. Furthermore, in order to develop the city of Tehran, in many parts of the city, the urban landscape has been completely transformed.

This development has led to the intersection and interference of the construction of urban thoroughfares with the main surface water network. In some cases, their design has been executed without performing the necessary hydraulic studies or not paying necessary attention to the capacity of canals, which has resulted in bottlenecks in the main surface water network of Tehran. In addition to the above, in some cases, facilities with different uses have changed the cross section of the canal and created bottlenecks. Therefore, in order to promote citizens against the risk of floods and increase urban resilience, it is necessary in the first step to identify flood bottlenecks and in the second step to eliminate the identified capacity shortage. The measures to reduce the negative effects of urban floods is shown in figure 1.

Flood control (Structural measures)	Use of control structures in order to prevent floods in the target areas and reduce direct flood damage
Flood management (Non-structural measures)	All measures taken to keep people and population centers away from flood zones.
Integrated flood management	Development of integrated land and water resources through integrated management of water resources, maximizing the benefits of retention of flood plains, and minimizing flood damage

Fig. 1: Measures to reduce the negative effects of urban floods

During various researches, many measures have been taken to manage floods and risk. Among the structural measures, the following items can be mentioned:

In the past, structural methods were mostly used to control urban floods. Choosing an economically viable structural design necessitates consideration of the benefits and associated costs. On the other hand, the negative outcome of creating a structure is that the environmental consequences must also be considered. Due to the high investment for the construction of flood control structures, non-structural methods were considered. Due to the fact that non-structural solutions are more managerial, flood damage can be greatly reduced by just spending a little time identifying and administering them in the right conditions.

Structural measures research includes the following:

Construction of flood diversion channel to reduce the storage and peak flow [1, 2], Reservoir and detention dam [3-8], Construction of levee and dike to prevent water overflow [9-11], Channel improvement [12, 13] and Installation of feeding wells and artificial feeding [14, 15].

On the other hand, there are non-structural flood control measures that constitute mostly software and management aspects. These methods are much cheaper than structural methods and therefore are preferred over structural methods. Among the non-structural measures taken, the following can be mentioned: Flood insurance [16, 17], Flood zoning [18-20] and Flood warning systems [21-23]. These measures reduce floods and reduce the risk and vulnerability of flood-prone areas.

What makes this research a little different is the identification of critical points in surface water collection canals, especially at the intersection with bridges, which ultimately leads to the presentation of a structural solution.

In this research, we intend to investigate the adequacy of the Mianroud Canal crossing in the Ariafar Bridge area for floods with a return period of 5, 10, 25, 50 and 100 years. If we face a shortage of capacity, we will outline structural measures to address this problem.

2. Research Methodology

By examining the topography of the west and north of Tehran, severe accident hotspots were studied. Then, by field study of critical points, the dimensions, length, and capacity of each accident-prone route were determined. Subsequently, different scenarios of discharges with return periods of 10, 25, 50 and 100 years were investigated according to the hydrological information for the safety of the study areas. Next, considering the structural solutions, the methods of eliminating the lack of capacity of the bottlenecks, including amending the route, installing auxiliary routes, or destroying bridges that prevented the transfer of runoff in the canal route were investigated (Fig 2).

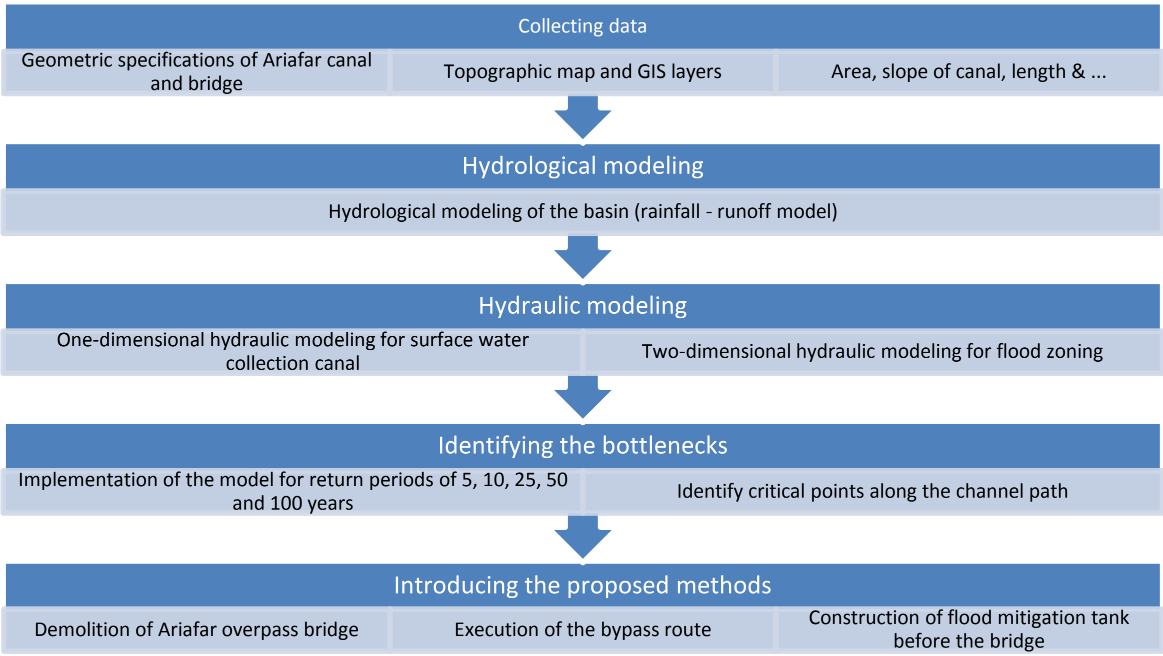

Fig. 2: The process of this research

Non-structural measures

Reducing the risks of urban flooding requires identifying and analyzing the vulnerability of communities to these hazards and the possible consequences. Developing risk reduction strategies, providing appropriate flood management solutions, and a program that implements these strategies are some of the things that should be considered. Therefore, a better understanding of the flood risk phenomenon and its possible outcomes in our society is very important for the development of flood control policies, risk reduction projects and other flood management strategies.

Much progress in the field of computing has led to the development of various softwares and models. The use of these models can be very useful in increasing the accuracy of calculations and obtaining economic design. Obviously, the accuracy of the calculations depends on the dimensions of the design and consequently its implementation costs.

It should not be forgotten that mathematical models are merely an attempt to reflect real conditions with the help of mathematical formulas. Therefore, other factors such as engineering judgment, social and economic conditions should always be considered. In fact, the most important role of computer models of catchment is the possibility of making a logical connection between hydrological, hydraulic, water quality and economic processes at a reasonable cost. From an engineering point of view, urban drainage issues are divided into two main areas: flood volume forecasting and network design. Design models in turn fall into two categories: simulation models and optimization models with hydraulic considerations in the design of networks.

Among the widely used models, we can mention flood zoning with HEC-RAS model, which can be easily implemented in ArcGIS software and is able to calculate water surface profiles in one-dimensional and two-dimensional flow conditions. This model has many applications for the extraction of floodplains along rivers. But the main issue in this field is to build a geometric model for the model.

The HEC-RAS model is designed to perform hydraulic calculations in a complete network of natural and artificial channels .Calculations with flow rate are performed with different return periods, but in terms of increasing the accuracy of calculations and its results, changes in flow along the river and the impact of tributaries should also be considered. Important features of this model include graphical user interface, hydraulic analysis, data storage and management, reporting and communication with GIS. Other issues to be considered in flood zoning with the HEC-RAS model are upstream boundary conditions that include known discharge and water levels or water level slope or critical depth. The rating curve can also be defined as upstream and downstream boundary conditions.

Structural mitigation measures:

In this method, the height of the wall above the bottleneck is increased. (If necessary, the upstream side of the bridge deck will be increased). Flood exceeding the capacity of the bottleneck should be trapped above it so that the current passes in its vicinity according to the capacity of the bottleneck. In this method, in connection with the bridges, the bridge must act under pressure and the return of water from the design flood should not be so much that the flow occurs out of the network.

If it is possible to build an auxiliary duct and its entrance partition structures in the vicinity of the bottleneck, the construction of an auxiliary duct can be considered as an option.

One way to moderate flood intensity is to use flood control ponds. Flood storage and containment in the upper parts of the basins is usually implemented by constructing flood control dams and multi-purpose dams, part of which is dedicated to flood control. However, in flat areas and plains, it is usually not possible to build these dams. Therefore, flood storage in artificial ponds and pools or diversion of flood current into natural wells can be considered.

The presence of drops in the bridge area is a condition for the feasibility of this method. By deepening the channel floor or modifying the drop effect, the depth or the passage capacity of the duct increases. This method is usually used in channels with a longitudinal slope.

If none of the above methods are feasible, or do not have full effect in eliminating the lack of capacity of the bottleneck, it is necessary to remove the bottleneck from the flow path, then its reconstruction should be located, designed and executed by the designer of the bridge and the device in charge of the matter in a way that the minimum geometry required for passing the design flood is observed.

3. Case Study

Districts 2 and 5 of Tehran Municipality in the northwest of Tehran are exposed to flood instability due to Proximity to Darkeh, Farahzad, and Kan basins, High relative share of constructions, relatively high density of housing and population, change of use and entering the river area and Improper use of channels. West flood diversion canal (Mianroud canal) is one of the most important surface water management facilities in the West Tehran catchment area, adjacent to important infrastructures such as the Tehran-Karaj freeway and the 4th and 5th metro lines. The west flood diversion route or Mianroud canal, is one of the most important water collection routes in the west of Tehran, which directs the flood collection of Darkeh, Farahzad, Tappeh Neyzar and Hesarak rivers and flows into the Kan River. Therefore, its critical points are among the high priority flood bottlenecks.

This bridge has been constructed in Ariafar Street for vehicles to cross the Mianroud canal (35°43'N 51°21'E). The deck of this bridge has reduced the useful cross section of the canal by 61%. In addition to this bridge, a few meters ahead, there is a diagonal bridge with a canal as an access bridge with a width of 13 meters and a height below the deck of 2.1 meters. Figure 3 shows a view of the Ariafar Street Bridge and its geometric features.

Roughness coefficient of this section is 0.027, bed slope is 0.004, canal width is 7.3 meters, and canal height is 4.5 meters.

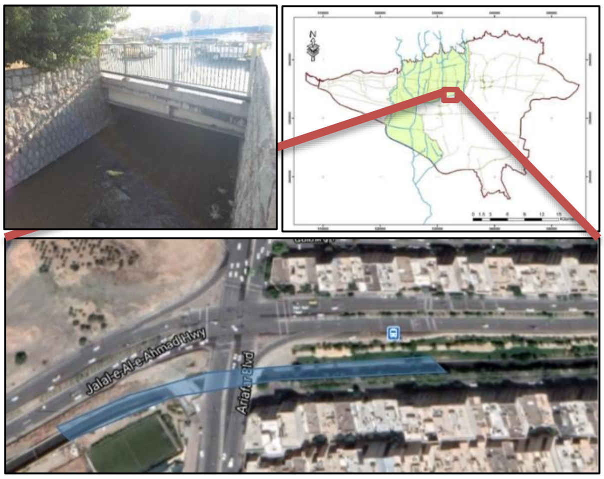

Fig. 3: Study area (Ariafar Boulevard Bridge)

4. Results

Hydrological studies

The steps and information used in each step are as follows:

- Use of information layers with height points, range of streets and alleys (SRTM (2008) data was used in the construction of the digital elevation model of the city)
- Determining the direction of water movement and the manner of accumulation and movement of runoff in the streets and alleys of the city by WMS software
- Defining the flood network for the study area to WMS software
- Determining the physiographic characteristics of sub-basins (characteristics such as area, slope lands of the basin, length, and slope of flood on each sub-basin, position of center of gravity and average height of the basin, percentage of impermeable land surfaces and the like)
- Controlling and inspection of sub-basins, modification of runoff movement on surfaces
- Integrating the areas smaller than 1 km^2 into adjacent areas and break down areas larger than 20 km^2 or areas with heterogeneous use into smaller areas
- Obtaining hydrological results

Time of concentration: Time of concentration is one of the most important physiographic parameters of the sub basin. Experimental relations such as Kirpich formula, SCS velocity method can be used. Basically, the Kirpich method is extracted for small and steep non-urban areas and its application for urban areas is recommended in a situation where a correction factor of 0.4 is used in the formula. Undoubtedly, for suburban areas without vegetation, there is no need to apply a correction factor. The SCS Delay Time Formula developed by the US Soil Conservation

Organization, has been modified and used for use in small urban areas with less than 800 hectares. Although this formula gives good results on perfectly covered surfaces, it exerts more focus time on composite surfaces. Considering the average speeds of 0.8, 0.9, 1.0 and 1.1 m / s, the concentration time was obtained under the spheres and plotted against each other. The results show the higher accuracy of the calibrated SCS latency method. To calculate the flow time in the canals, the results of hydraulic modeling of the surface water collection network in Tehran were used. According to the preliminary results obtained from the hydraulic model, the average flow velocity in a channel with a slope of 1% is between 4 $\frac{m}{s}$ to 5 $\frac{m}{s}$. Therefore, considering the velocity of 4.5 m/s for the flood flow in the canal with a slope of 1%, the time of water flow in the canals was calculated.

Rainfall: Rainfall is one of the important and main parameters in rainfall-runoff modeling and determining flood design. For this purpose, it is necessary to determine four precipitation characteristics including depth, total continuity, temporal distribution, and spatial distribution. For design purposes, especially in urban land drainage studies, rainfall depth can be obtained from the intensity-duration-frequency curves of rainfall. Also, using these curves, the temporal distribution of precipitation can be determined. Equation 1 is used to analyze the information of general rainfall intensity curves in Tehran.

$$\mathbf{i = C_{Alt}\, D^{-0.645}} \qquad (1)$$

In this regard:

i: Rainfall intensity (mm / h)

D: Continuation of precipitation (minutes)

C_{Alt}: Equation coefficient that is proportional to the design return period and the average height of the catchment (Fig 4)

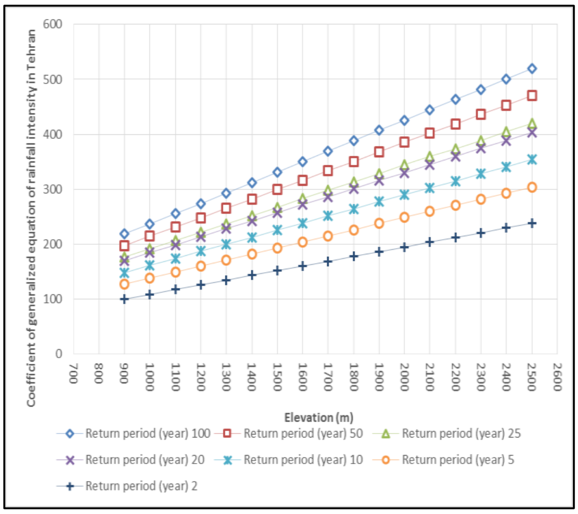

Fig. 4: Calculation chart of C_{Alt} coefficients using altitude (m) and return period (year) for Tehran

The fitted equations for calculating C_{Alt} coefficients based on altitude and return period are given in Table 1.

Table1: Fitted equations for calculating C_{Alt} coefficients based on altitude and return period

Return Period (Year)	Coefficient
100	y = 0.1892 (Elevation) + 47.24
50	y = 0.1709 (Elevation) + 42.953
25	y = 0.1527 (Elevation) + 38.282
20	y = 0.1468 (Elevation) + 36.787
10	y = 0.1286 (Elevation) + 32.275
5	y = 0.1109 (Elevation) + 26.953
2	y = 0.0865 (Elevation) + 21.471

To calculate the total rainfall continuity, it is necessary that the minimum design rainfall duration is equal to or greater than the concentration time of the entire basin, so that we can consider the impact of all components of the catchment in the production of outflow floods. Examination of the concentration time of the constituencies in Tehran shows that in any case, the total concentration time of the constituencies until reaching the exit point is not more than 3 hours. Figure 5 shows the selected model to describe the temporal distribution of design precipitation in the study area .

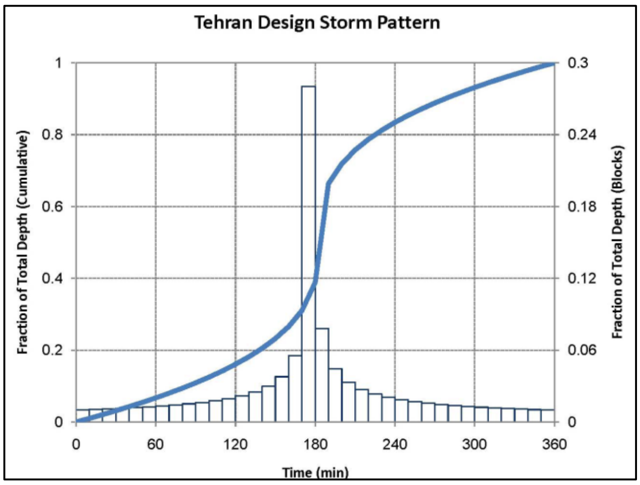

Fig. 5: Diagram of the selected model to describe the temporal distribution of design precipitation in the city of Tehran

Spatial distribution of precipitation: To determine the total depth of precipitation in each sub-basin, the average height of each sub-basin was considered. Then precipitation with a total duration of 6 hours related to a point with the same height was extracted from the intensity-duration-frequency curves of short-term precipitation in Tehran. The obtained value was applied as precipitation with continuities of 30 minutes to 24 hours on the whole surface of the basin. In this study, for sub-basins with an area of more than 25 square kilometers, a reduction coefficient was extracted from the diagram and applied to the rainfall of the same sub-basin.

Hydraulic Results

According to the classification and definitions, if the canal is not able to transmit floods with a return period of 50 years, it is considered a critical route. The figures 6 to 9 show the water level profile diagram for the desired range for 10, 25, 50 and 100-year return periods. According to the results obtained for the 10-year return period, we do not see a lack of capacity and the flow is transmitted freely with a filling percentage of 36% upstream channel. But for 25-year return period, the flow is under pressure and we encounter an 8.88% capacity shortage. In 50-year-discharge, we see outflows due to a shortage of 28.93%. In discharge, with a 100-year return period, we will have 50.81% outflow.

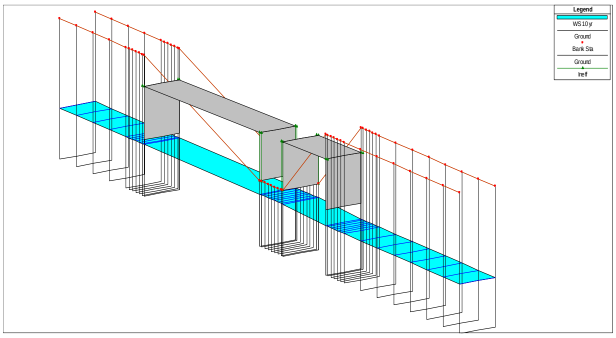

Fig. 6: Diagram of surface water profile at the junction with the bridge (discharge 10-year return period)

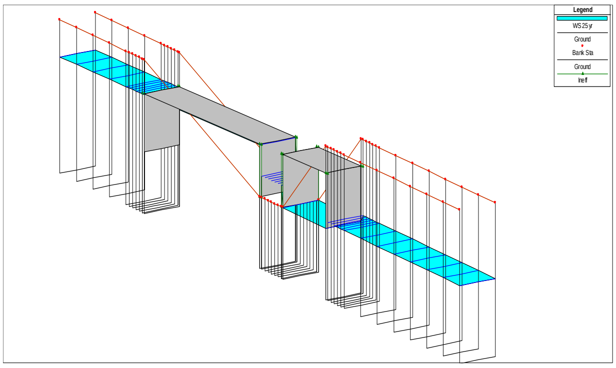

Fig. 7: Diagram of surface water profile at the junction with the bridge (discharge 25-year return period)

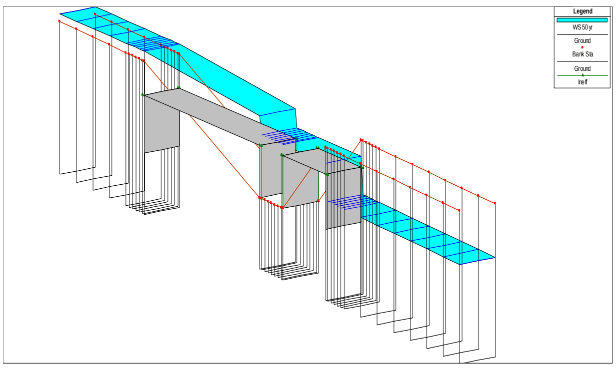

Fig. 8: Diagram of surface water profile at the junction with the bridge (discharge ۵۰-year return period)

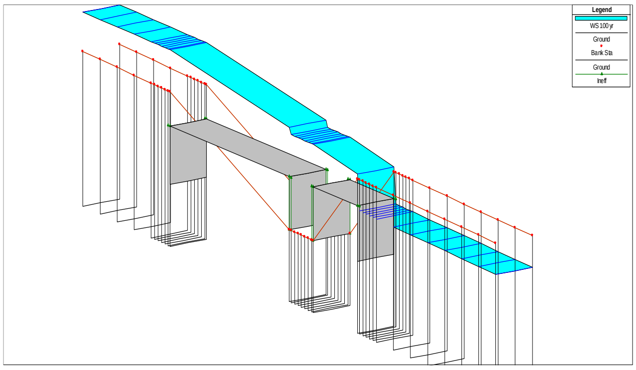

Fig. 9: Diagram of surface water profile at the junction with the bridge (discharge 100-year return period)

The uncontrolled development of Tehran and the reduction of infiltration levels by urban levels have increased the risk of floods. This has made urban textures vulnerable to this environmental hazard.

Areas adjacent to rivers or surface water collection canals are always exposed to the dangers of floods. Therefore, in these areas, determining the rate of flood progression and its height relative to the surface cultivar, and determining the characteristics of floods in different return periods, is of great importance.

In this regard, with the aim of reducing the risk of possible floods, a two-dimensional HEC-RAS hydraulic model was used around the Ariafar highway bridge. In this study, which used different digital maps, the extent of floods in the lands along the bridge for floods with return periods of 2, 5, 10, 25, 50 and 100 years was calculated. According to Fig 10, it was observed that the combination of GIS with HEC-RAS model in the analysis of floodplains facilitates calculations and reduces field operations and can determine the map of critical areas before floods.

Fig. 10: 100-year flood zone map in the area of Ariafar Bridge

The results show that the most sensitive parts of the city's vulnerability to floods and runoff are affected by structural factors, climate, topography, geology, hydrology, vegetation, population density and land value.

5. Discussion

Flow velocity:

Flow velocity considerations include minimum and maximum velocities. The minimum flow velocity must be ensured in such a way as to prevent the deposition of material on the floor of the floodplain as much as possible. For channels that do not contain sediment load, a rate of 0.6 to 0.9 m/s is recommended.

The maximum flow velocity should not be such as to cause corrosion and erosion of the floor and walls of the floodwaters and damage the system. Various sources have suggested a maximum speed of 3.6 to 6 meters per second for concrete-covered canals.

According to the fig 11, the flow velocity before the Ariafar Bridge has a constant value and decreases as soon as it crosses the bridge. After the bridge, we see a decrease in speed in the return periods of 25, 50 and 100 years by 1.01, 1.27 and 1.3 meters per second, respectively. In other words, before the bridge, there is a direct relationship between the return period and the flow velocity. (The longer the return period, the faster the flow). But after the bridge, the speeds increase and converge towards a fixed numerical value.

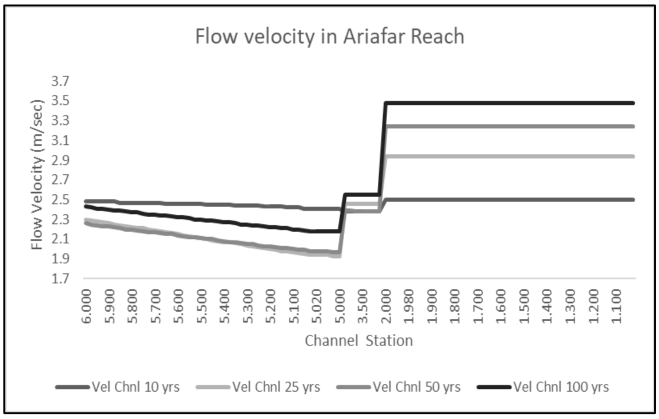

Fig. 11: Flow velocity obtained by hydraulic simulation for Mianroud canal (Ariafar Bridge)

Water Surface Elevation:

According to the figure, we see an overall increase in Water Surface Elevation along the flow path in the canal. The lowest change is in the 10 years return period and the highest change is in the return period of 100 years. In other words, in the return periods of 10, 25, 50, and 100 years, we see an increase in Water Surface Elevation of 1.84, 2.43, 3.07, and 3.36 meters, respectively. (Fig 12)

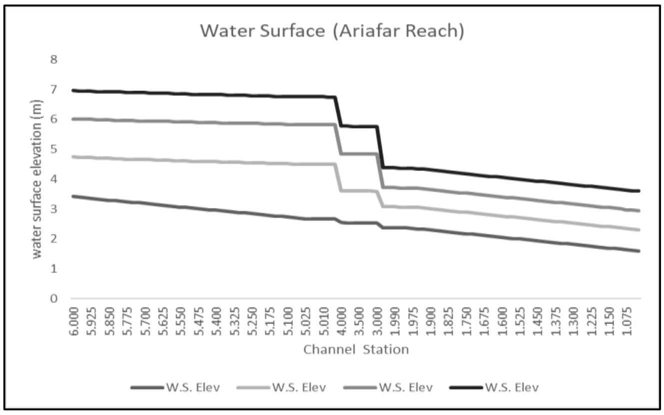

Fig. 12: Water surface profile obtained by hydraulic simulation for Mianroud canal (Ariafar Bridge)

Froude number:

As we know, this dimensionless number expresses the ratio of inertial force to weight force. This number is very important in free-flowing flow such as open channels to classify the type of flow. According to the picture, the Froude number before the Ariafar Bridge had a fixed value, which demonstrates a significant decrease in the Froude number as soon as it intersects the bridge at the beginning and end. But after the bridge, the Froude number gradually increases. It should be noted that the value of the Froude number along this channel indicates a subcritical current. (Fig 13)

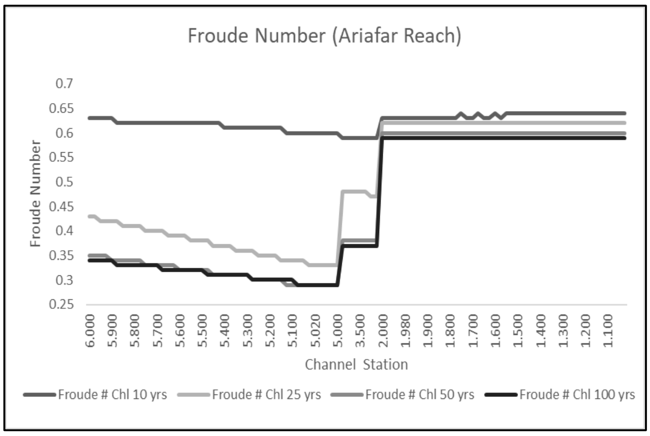

Fig. 13: Froude number profile obtained by hydraulic simulation for Mianroud canal (Ariafar Bridge)

Energy Gradeline for calculated water Surface Elevation:

As expected, the energy line for long-term return periods is longer than the short-term. Along the channel path, we also see an increase in the energy gradeline linearly. These changes in the cross-section of the bridge (at the beginning and end of the bridge) are tangible changes. (Fig 14)

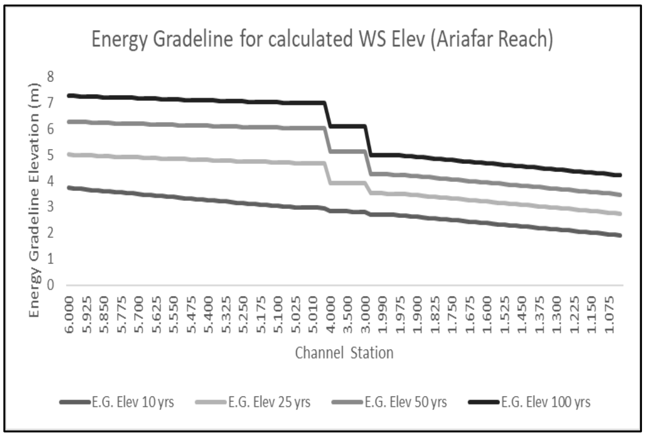

Fig. 14: Energy Gradeline profile obtained by hydraulic simulation for Mianroud canal (Ariafar Bridge)

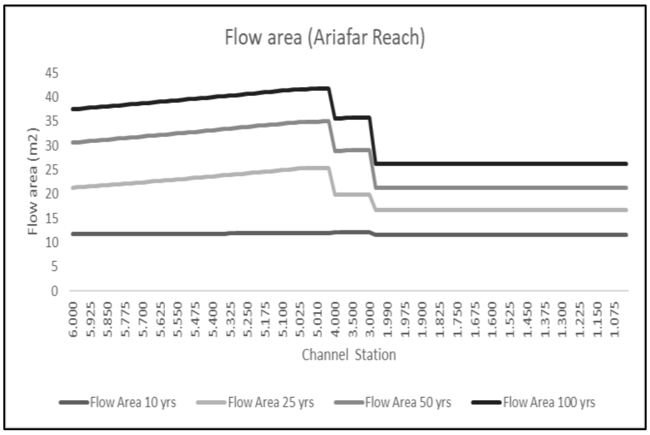

Fig. 16: Flow area profile obtained by hydraulic simulation for Mianroud canal (Ariafar Bridge)

Slope of the energy grade line:

As seen in figure 15, at the junction with the bridge, the amount of the slope of the energy grade line decreases for different return periods. After the end of the bridge, we notice a sudden and gradual decrease in the amount of return periods of more than ten years. This value increases along the path. This slope with the 10-year return period has values much higher than other return periods.

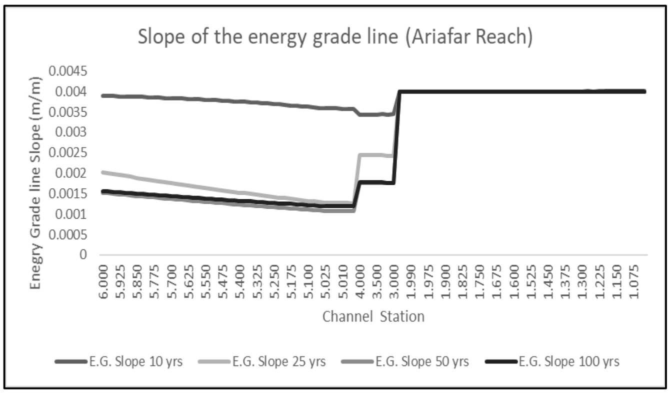

Fig. 15: Slope of the energy gradeline profile obtained by hydraulic simulation for Mianroud canal (Ariafar Bridge)

Flow area:

According to figure 16, the value of this parameter is constant before the Ariafar Bridge and as soon as it crosses the bridge, we see a significant increase in the flow level in a gradual manner. After the bridge, the amount of current level gradually decreases. These changes are not very noticeable for the 10-year return period.

6. Conclusion

In this study, the optimal management of surface water collection (structural and non-structural flood control solutions) was investigated around the Ariafar Bridge located in the Mianroud Canal. Given the large differences between catchments in terms of climatic conditions, future development conditions and topography of the region, a standard approach to use these methods in general cannot be proposed. But what is certain is that the combination of structural and non-structural methods is less costly and more effective than either method independently. The results of this study showed that the construction of Ariafar Bridge on Mianroud canal reduces the canal capacity in case of floods with return periods of more than 25 years. The solution of demolition or construction of a bypass flood channel can solve this problem in a structural way. The results also show a slight difference between one-dimensional and two-dimensional models in simulating hydraulic parameters such as flow velocity, water surface elevation, Froude number, energy gradelines, slope of the energy gradeline and flow area in surface water collection channels. The difference between one-dimensional and two-dimensional results in flood zoning is more pronounced, and a two-dimensional HEC-RAS 5 model was used to simulate flood zones more accurately.

As it was observed, due to the insufficiency of the capacity of passing the bottleneck point in the route introduced in this research, the next step is to provide a suitable structural solution such as constructing an auxiliary duct or removing the bottleneck from the flow path in the network. The results of the simulation with the hydraulic model can also help in short-term and long-term planning of modification and reconstruction of the existing collection system. In this way, after defining various scenarios, they are simulated in order to evaluate its efficiency and effectiveness before implementation.

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References:

[1] Nugroho, J., I. Soekarno, and D. Harlan. Model of Ciliwung River flood diversion tunnel using HEC-RAS software. in MATEC Web of Conferences. 2018. EDP Sciences.

[2] Peng, G., X. Junqiang, and C. Qian, A mechanics-based model of flood risk assessment and its application in a flood diversion zone. Advances in Water Science, 2017. 28(6): p. 858-867.

[3] Heydari, M., F. Othman, and M. Noori, Optimal Operation Of Multiple And Multi Purpose Reservoirs Systems Using Non-Dominated Sorting Genetic Algorithm (Nsga-Ii). Feb-Fresenius Environmental Bulletin, 2016: p. 2935.

[4] Heydari, M., F. Othman, and K. Qaderi, Developing optimal reservoir operation for multiple and multipurpose reservoirs using mathematical programming. Mathematical Problems in Engineering, 2015.۲۰۱۵ .

[5] Heydari, M., F. Othman, and M. Taghieh, Optimization of multiple and multipurpose reservoir system operations by using matrix structure (Case study: Karun and Dez Reservoir Dams). PloS one, 2016. 11(6): p. e0156276.

[6] Mohammed, H., Optimization of multipurpose reservoir operation using evolutionary algorithms/Mohammed Heydari. 2017, University of Malaya.

[7] Othman, F., et al. Preliminary Review of the Optimal Operation of Reservoir Systems using Optimization and Simulation Methods. in International Conference On Water Resources "Sharing Knowledge Of Issues In Water Resources Management To Face The Future. 2012.

[8] ShahiriParsa, A., et al., Introduction to linear programming as a popular tool in optimal reservoir operation, a review. Advances in Environmental Biology, 2015. 9(3): p. 906-917.

[9] Islam, M.F., B. Bhattacharya, and I. Popescu, Flood risk assessment due to cyclone-induced dike breaching in coastal areas of Bangladesh. Natural Hazards and Earth System Sciences, 2019. 19(2): p. 353-36.۸

[10] Kundzewicz, Z., et al., Opinion: Flood-risk reduction: Structural measures and diverse strategies. Proceedings of the National Academy of Sciences, 2018. 115(49): p. 12321-12325.

[11] Sivakumar, S., Flood mitigation strategies adopted in Sri Lanka a review. International Journal of Scientific and Engineering Research, 2015. 3(6.(

[12] Yufanga, H. and L. Chuantenga, Process research on estuarine turbidity maximum and mouth bar of Yangtze Estuary after the improvement works. Procedia Engineering, 2015 :۱۱۶ .p. 80-87.

[13] Yujing, Y. and L. Zhiming, River Channel Improvement and River Ecological Restoration. Journal of Landscape Research, 2019. 11(4.(

[14] Booth, E.G., et al., Is groundwater recharge always serving us well? Water supply provisioning, crop production, and flood attenuation in conflict in Wisconsin, USA. Ecosystem Services, 2016. 21: p. 153-165.

[15] Masoud, A.A., Runoff modeling of the wadi systems for estimating flash flood and groundwater recharge potential in Southern Sinai, Egypt. Arabian journal of Geosciences, 2011. 4(5-6): p. 785-801.

[16] Burby, R.J., Flood insurance and floodplain management: the US experience. Global Environmental Change Part B: Environmental Hazards, 2001. 3(3): p. 111-122.

[17] Michel-Kerjan, E.O., Catastrophe economics: the national flood insurance program. Journal of economic perspectives, 2010. 24(4): p. 165-86.

[18] Heydari, M., M.S. Sadeghian, and M. Moharrampour. Flood Zoning Simulation byHEC-RAS Model (Case Study: Johor River-Kota Tinggi Region). in International Postgraduate Seminar, Organized by Faculty of Civil Engineering. 2013.

[19] ShahiriParsa, A., et al., Floodplain zoning simulation by using HEC-RAS and CCHE2D models in the Sungai Maka river. Air, Soil and Water Research, 2016. 9: p. ASWR. S36089.

[20] ShahiriParsa, A., et al. Introduction to floodplain zoning simulation models through dimensional approach. in International Conference on Advances in Structural, Civil and Environmental Engineering-SCEE2013, Kuala Lumpur, Malaysia. 2013.

[21] Chang, L.-C ,.et al., Building an intelligent hydroinformatics integration platform for regional flood inundation warning systems. 2019, Multidisciplinary Digital Publishing Institute.

[22] Chang, M.-J., et al., A support vector machine forecasting model for typhoon flood inundation mapping and early flood warning systems. Water, 2018. 10(12): p. 1734.

[23] Lamichhane, N. and S. Sharma, Effect of input data in hydraulic modeling for flood warning systems. Hydrological sciences journal, 2018. 63(6): p. 938-956.