Flood Risk Analysis with Prevention Scenarios for Zeytinli Stream

Zeytinli Deresi için Önleme Senaryoları ile Taşkın Risk Analizi

Cahit Yerdelen(1), Uğur Engin(1), Ebru Eriş(1*)

(1)*Ege University, Engineering Faculty, Civil Engineering Department, 35100, İzmir*

Received date: **13.10.2023**; Accepted date: **28.12.2023**; Published date : **28.12.2023**

Turkish Journal of Hydraulic (Türk Hid. Der.), Vol (Cilt): **7** , Number (Sayı): **2**, Page (Sayfa), **22-29**, **(2023)**

e-ISSN: **2636-8382**

SLOI: http://www.dergipark.org.tr

*Correspondence e-mail: *ebru.eris@ege.edu.tr*

Abstract

Floods are becoming a major problem in many countries because of natural and anthropogenic risks that occur in stream regions. Although the impact of floods cannot be completely eliminated, it is important to develop flood models to minimize them. In this study, one-dimensional hydraulic model was developed for the Zeytinli Stream located in the western part of Turkey using HEC-RAS software. Digital elevation model, stream network, flow paths, and cross-sections of the study region were produced with the help of 1/5000 scale maps on Geographical Information System (GIS) environment. Flood analyses were performed based on the flood discharges for different return periods (5, 10, 25, 50, 100, 500-year) and water surface profiles were obtained. The paper also proposed different prevention scenarios and accordingly repeated flood risk analysis. Changes in water surface elevations and flow areas of the stream were calculated. Based on the results obtained, various evaluations and suggestions were made for the region.

Keywords: Flood risk analysis, Flood prevention scenarios, HEC-RAS, Zeytinli stream.

Özet

Akarsu yakınlarında meydana gelen doğal ve antropojenik riskler nedeniyle taşkınlar birçok ülkede önemli bir sorun haline gelmektedir. Taşkınların olumsuz etkileri tamamen ortadan kaldırılamasa da taşkın modellerinin geliştirilmesi zararlarını en aza indirmek açısından önemlidir. Bu çalışmada, Türkiye'nin batısında yer alan Zeytinli Deresi için HEC-RAS yazılımı kullanılarak tek boyutlu bir hidrolik model geliştirilmiştir. Coğrafi Bilgi Sistemi (CBS) ortamında 1/5000 ölçekli haritalar yardımıyla çalışma bölgesinin sayısal yükseklik modeli, akarsu ağı, akış yolları ve kesitleri üretilmiştir. Farklı dönüş aralıklarına (5, 10, 25, 50, 100, 500 yıl) karşılık gelen akışlar için taşkın analizleri yapılmış ve su yüzeyi profilleri elde edilmiştir. Çalışmada ayrıca farklı taşkın önleme senaryoları önerilmiş ve buna göre taşkın risk analizleri tekrarlanmıştır. Su yüzeyi yükseklikleri ve akış alanlarındaki değişimler hesaplanmıştır. Elde edilen sonuçlara dayalı olarak bölge için çeşitli değerlendirmeler yapılmış ve taşkın önleme önerileri sunulmuştur.

Anahtar Kelimeler: Taşkın risk analizi, Taşkın önleme eenaryoları, HEC-RAS, Zeytinli deresi.

1. INTRODUCTION

Many people have been affected by meteorological, climatological, and hydrological natural disasters compared to earthquakes, volcanic activities etc. during the last quarter of the century over the World. In Turkey, according to a report by the Turkish State Meteorological Service (MGM with Turkish acronym) in 2018, 90% of the recorded large-scale disasters were the weather-related cases such as floods in the last 20 years (MGM, 2018) [1]. Floods are generally large-scale natural disasters that are expected to worsen due to global climate changes. Recently, many model-based studies have been conducted to determine the effects of floods and thus to reduce flood damage [2-9].

Many studies related to flood modelling and the development of flood dispersion maps for different parts of Turkey are also available in the literature. Akkaya and Doğan (2016) performed 2D flood modeling of the Meriç and Tunca Rivers that passes through Edirne city center and generated flood inundation maps [10]. Based on the study, it was recommended to perform solid material clearance operations particularly during dry seasons, because of the high solid material content carried along with the floods. Dag (2019) used the peak flood rate values at different return periods of years, the water profile along the Altıncay creek route in Antalya has been simulated using HEC-RAS software and the flood risk areas were determined on a station basis. As a result of the study, it was recommended to expand the channel widths. In the study by Celiker et al. (2020), peak flows for return periods of 2, 5, 10, 25, 50, 100, 500 and 1,000 years, flood water depths and inundation areas of Çapakçur, Gayt and Göynük streams passing through Bingöl Province center with the help of HEC-RAS [11]. They proposed reclamation structures such as check dams, grade control structures and afforestation to reduce flood damages. Ogras and Onen (2020) handled the floodplain analysis between Diyarbakır-Silvan Highway and historical Ten-Eyed Bridge and suggested decrease in the roughness coefficient and a tunnel for extracting flooding waters to prevent possible damages [12]. 1D and 2D flood dispersion maps will be established by HEC-RAS software for the Sakarya river in Geyve district of Sakarya Province, Turkey for 100 and 500 years of recurrence flow rates in the study by Ceribasi and Ceyhunlu (2020), [13]. They suggested mostly socio-economic methods to minimize the effect of floods, such as establishment of a flood early warning system, and commissioning of a flood insurance system. As seen from the aforementioned studies, the precautions to reduce flood damage depend on the environmental conditions of the region.

Therefore, the flood risk of the area under consideration should be thoroughly investigated and region-specific methods should be recommended, accordingly. Following the previous investigations, in this study, flood risk analysis is made for the Zeytinli Stream which is located in Edremit; the north-western part of Turkey with the help of HEC-RAS software. Based on written sources, the lowland sections of the Zeytinli Stream have been used intensively in terms of human activities from 1443 BC to the present and continue to be used [14-15].

The agricultural lands previously covered a large area from the coast to the inland. However, these lands are now mostly occupied by summer residences for tourism purposes. Forest areas were destroyed, swamps were drained, and settlements expanded toward these areas. These types of land use put pressure on the natural environment of the region and cause various problems such as flooding (Fig 1). To prevent flooding problems, this study also includes the proposal of different flood prevention scenarios for the study area and comparison of the results.

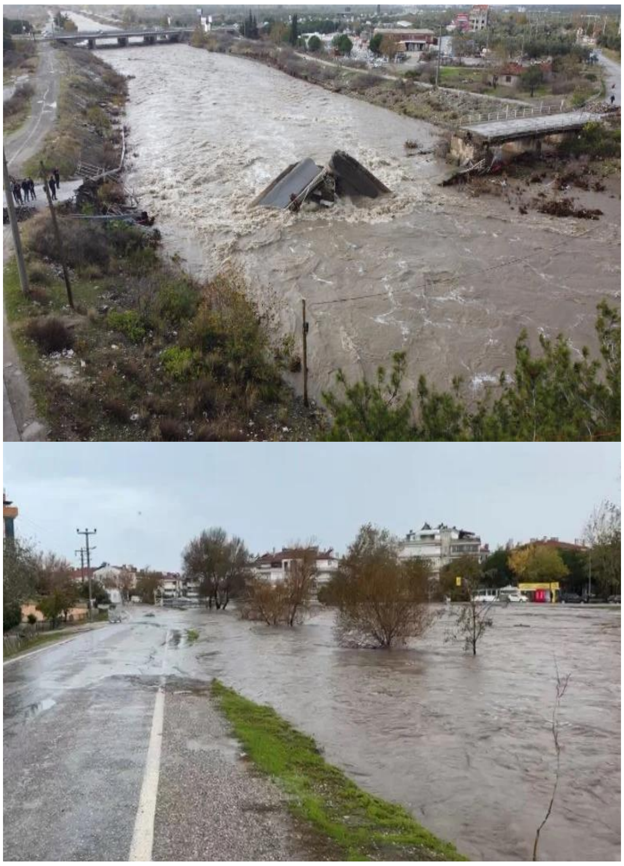

Fig. 1. Floods in the study area [16].

2. STUDY AREA

Zeytinli Stream located in Edremit,Northeastern part of Turkey is selected for flood risk analysis in this study (Figure 2). The river flowing from northwest to southwest is 29.43 km long, and the drainage area of the basin is 119.46 km^2. The average elevation is approximately 784 m and the slope levels are between 6% and 8%. The highest point at1710 m is Kırklar Hill. The total annual precipitation average is 723.5 mm in the Zeytinli Basin. There was an increase in precipitation values in the period between

November and February. The Zeytinli Stream flows throughout the year; there is no period when it is completely dry.

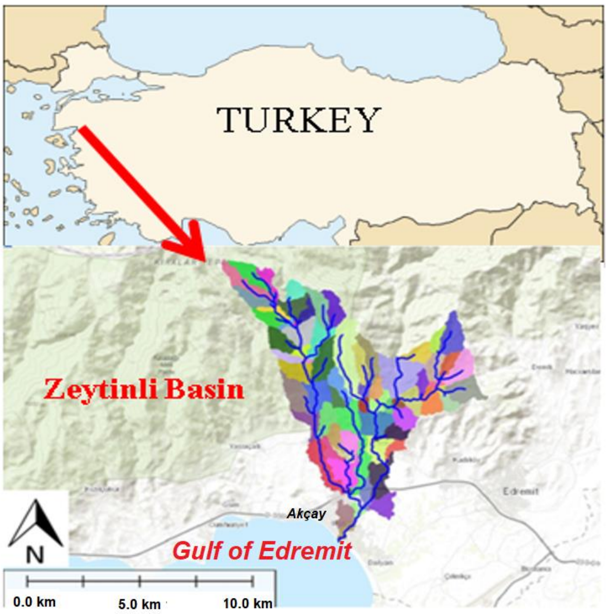

Fig. 2. Study area

The Zeytinli Stream was officially included in the scope of "Flood Water Law of Turkey" in 1958. According to the law, a total of 100 m of the coastline (50 m on each the right and left shores of the stream) from the thalweg line was a risky area.

The first reclamation work at the Zeytinli Stream started in 1963. During the flood that occurred in 1965, the water collected from the bed spilled out as a result of the rivers attached to the Zeytinli Stream, and the houses around were damaged. It was determined that the floodwalls around the sites in the region where the flood occurred were insufficient or even collapsed.

In the 10-year period since 1965, various floods occurred in the Zeytinli Stream. However, the planned and in situ tested reclamation works that were intended to be carried out were removed from the schedule because there was a lack of budget and technical staff. Akçay District, a developing touristic district, has been adversely affected by these disasters and has suffered economic damage.

In 1982, a masonry retaining wall was designed along the left shoreline of the stream to meet the Q100 recurrence flow (210 m^3/s), in order to protect it from any flood. The parts where Zeytinli Stream flows into the Aegean Sea are used as State Hydraulics Works' (DSI with Turkish acronym) reclamation channel and fishermen's shelter. Özşahin (2011) stated that there is severe erosion in the Zeytinli Stream basin every year and more than 10 tons of soil is lost annually. Reclamation works on Zeytinli Stream have progressed slowly until today.

The reason for this is that the zoning plans of the lands to be expropriated cannot be revised in accordance with the improvement project and the land prices increase in value every year [17].

3. METHODOLOGY

3.1. *Flood Hydrology*

The flood discharges used in the study were obtained from DSI. In order to find flood discharges for specific return periods, frequency analysis was performed for 5-, 10-, 25-, 50-, 100- and 500-year return periods using 26 years of data recorded between 1989 and 2014. Nine probability distributions including Normal, Log-Normal (2P), Log-Normal (3P), Gumbel, General Extreme Value, Pearson Type 3, Log-Pearson Type 3, Generalized Logistic and Log. Logistics (3P) were selected for frequency analysis. The compatibility check of distribution were subjected to both Anderson Darling and Kolmogorov–Smirnov tests at 5% significance. The most convenient probability distribution function was found as Generalized Logistic. The flood values calculated for different return periods using General Logistics distribution are presented in Table 1.

Table 1. Flood discharges calculated using Generalized Logistic distribution

Distribution Model	Flood discharge (m^3/s) for different return periods (year)					
	5	10	25	50	100	500
Gen. Logistics	178.42	198.00	219.65	234.12	247.40	274.62

3.2. Hydraulic Model

A Digital Elevation Model (DEM) of the study area was generated using 1/5000 scale maps which were obtained from DSI. Two-dimensional (2D) contour maps were created and then converted into the three-dimensional (3D) format. The 3D contour map was prepared for obtaining the drainage network and processing of terrain data (Figure 3). Geometric data of the study area such as thalweg line, shorelines (right and left coast), flow paths, and river cross-sections required for the hydraulic model were then obtained.

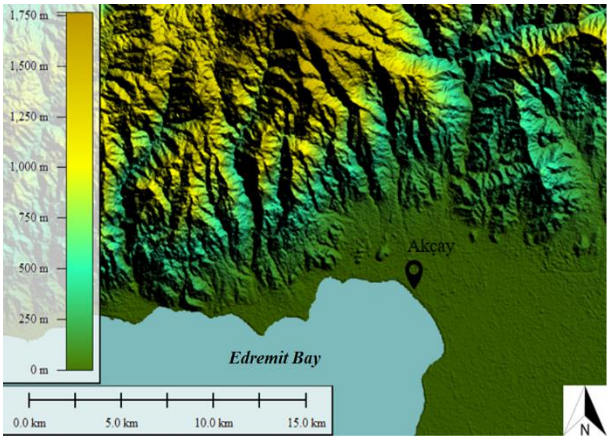

Fig. 3. DEM of the study area

The point where the Zeytinli Stream pours into the Aegean Sea is also the place where the flood model will be established. This area is restricted as at region where the settlements of the Akçay District are dense. For flood analysis, fifteen cross-sections were obtained from the stream bed, which is approximately 1600 m long. The cross-sections of the stream bed on the study area are shown in Figure 4 using the satellite image.

HEC-RAS is a graph-based, multitasking software developed to perform hydraulic calculation of flows in natural rivers. Open channels were then built. The software can calculate the water surface profile, sediment transport, moving base calculations, water quality analysis and many hydraulic structure calculations in steady and unsteady flows (USACE, 2016). The HEC-RAS software calculates water surface profiles for subcritical, supercritical and mixed regime flows. The calculation of the water surface profiles was performed using the standard step method for gradually varied flow. The standard step method is an implementation of the Bernoulli equation. The distance (Δx) between the two selected sections is usually taken at a standard length. If the standard steps are chosen sufficiently small by determining the geometric and physical properties of the cross-section at these determined distances, accurate results can be obtained in natural streambeds. The energy equation is defined as:

$$z_2 + Y_2 + \propto_2 \frac{V_2^2}{2g} = z_1 + Y_1 + \propto_1 \frac{V_1^2}{2g} + h_e \tag{1}$$

In Equation (1), z_1 and z_2 represent the bottom slope of the channel, Y_1 and Y_2 represent the depth in the cross-section, V_1 and V_2 are the average velocity (discharge/flow area), $\propto_1$ and $\propto_2$ denote the velocity coefficient, g is the acceleration due to gravity, and h_e represents the head loss. Head loss between back to back cross-sections (h_e) consists of friction loss and sudden changes in cross-section. Energy head loss is defined in the following equation:

$$h_e = LS_f + C \left| \propto_2 \frac{V_2^2}{2g} - \propto_1 \frac{V_1^2}{2g} \right| \tag{2}$$

In Equation (2), L is the length of the channel, S_f is the slope of the energy line between two cross-sections and C is the energy loss due tothe change in the instant cross-section. The length of the channel, L, can be calculated using the following equation:

$$L = \frac{L_{lfp}\, Q_{lfp} + L_m Q_m + L_{rfp} Q_{rfp}}{Q_{lfp} + Q_m + Q_{rfp}} \tag{3}$$

L_{lfp}, L_m and L_{rfp} define the length of the flow path and correspond to the left floodplain, main floodplain and right floodplain length of the channel, respectively. Q_{lfp}, Q_m and Q_{rfp} define average flow rates in the cross-section and correspond to the left floodplain, main floodplain and right floodplain flow rates, respectively.

Fig. 4. Flow path and cross-sections

1D flow model of the study area was created using HEC-RAS software and the observed cross-sections were shown in Figure 5a. The main, right and left bed widths defined as 30 m in the hydraulic model, in which the natural flow bed was modelled before the reclamation works were started. One of the cross-sections taken on the model is shown in Figure 5b. The region between the red points in Figure 5b represents the main bed, and the areas to the left and right of the red points represent the left and right coast flow limits, respectively.

Because of its simple structure and easy applicability, the Manning formula is the most widely used formula in open channel studies [18]. The HEC-RAS software uses the Manning roughness coefficient when calculating head losses due to friction. The Manning coefficient changes with the roughness of the surface, vegetation, channel irregularity, channel curvature, accumulation in the channel, wear, obstacles and seasonal changes. The guide prepared by DSI was considered while determining the Manning roughness coefficient in the streambed of Zeytinli Stream, and the roughness value of n was determined as 0.030 [19]. Although the Zeytinli Stream starts from Mount Kaz, the part where the hydraulic model of the river is established is a distance of 1600 m from the place where it pours into the sea to the region where the urbanization level is high. Therefore, the bottom slopes of the streambed studied are low. The average bed slopes vary between 0.1% and 1% along the stream's flow route. The characteristics of the flow conditions are shown in Table 2.

Table 2. Zeytinli streamflow characteristics

Flow Regime	Subcritical
Flow conditions	Regular, Non-uniform and Gradually changing flow
Average bed slope	0.04704
Manning Coefficient	0.030
Cont.- Exp. Coefficient	0.1-0.3

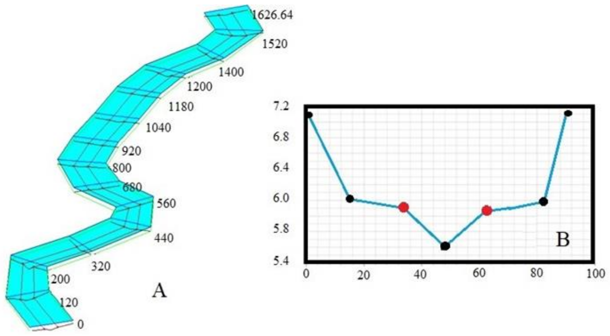

Fig. 5. (a) Observed cross-sections and (b) Natural streambed cross-section (200 m)

4. RESULTS

As of 2019, there is a gabion-style reclamation work on the right and left plain coast of Zeytinli Stream. It has been observed that rocks have been eroded, and vegetation has damaged the existing structure. The right and left coast plains are used as piers and ports for small and fishing boats. Considering the previous reclamation works, in situ measurements, and DEM created in the computer environment of the region, the typical cross-section of the stream is as seen in Figure 6.

The crest elevation of the stream (based on flood level, the wall built on edges of the stream, the top elevation of the ground or the raised ground) is 5.05 m above the thalweg line as shown in Figure 6. It has been reported that the reclamation works of the stream are carried out according to the peak flood for the 500-year return period [19]. The current water flow area is 48.77 m^2, and the channel cross-section is 137.20 m^2 (which is defined as control volume area). The water levels in the stream sections vary between 2.13 and 2.18 m.

The hydraulic model of the natural streambed before reclamation activities was observed in 15 cross-sections between 0 m (downstream) and 1626.64 m (upstream) in HEC-RAS software. Water surface profiles for various return periods (i.e. Q_5, Q_{25}, Q_{50}, Q_{100} and Q_{500}) at the cross-sections along the study area and the path were calculated (Figure 7a). The water surface profiles of flows for different return periods obtained from the cross-section at 320 m of the riverbed are given in Figure 7b, as an example. Starting from the thalweg line of the streams, the elevations reached by the water surface profiles for various flows were determined.

As seen in Figure 7a, the thalweg elevation of the longitudinal section from 1280 to 1160 m increased from 8.65 to 8.82 m. The increase in the thalweg level caused a reverse slope. It was observed that the flow regime of the stream became subcritical; cross-sectional flow areas decreased, and flow velocities increased. The minimum slope values can be seen at cross-sections of 1140 and 680 m. Accordingly, the water surface profile in these sections showed the minimum changes in the longitudinal cross-section.

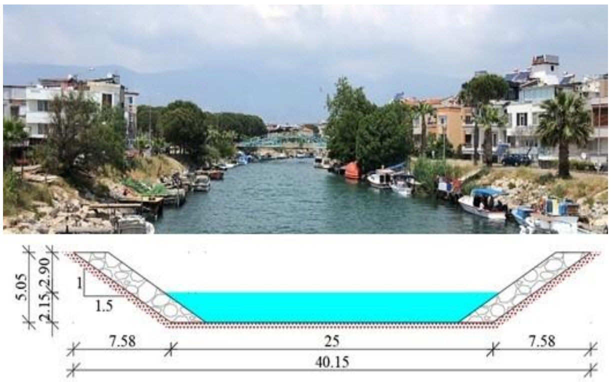

Fig. 6. Current situation of the Zeytinli Stream and typical cross-section of the stream

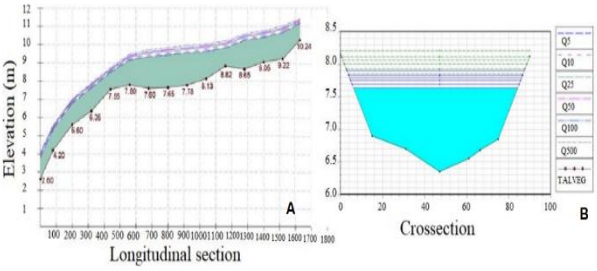

Fig. 7. Water surface profile for the longitudinal cross-section and water surface profiles on a typical cross-section (320 m)

The minimum energy losses in the streambed were seen in these parts. In the sections mostly seen subcritical regime, the flow velocity was low, cross-sectional flow areas were high and the Froude numbers were less than 1. Considering the typical cross-sectional area (137.20 m^2; formed as a result of the reclamation works), it was determined that the cross-sections of 1140 and 680 m are the riskiest parts of the stream. There was a reverse slope again based on the increment of the thalweg elevation at cross-sections of 680 to 560. The flow velocities increased, and the cross-sectional areas decreased. Although the slope of the energy line increased, energy losses were low.

It was observed that the flow regime reached critical and passed into the supercritical regime between the cross-section at 560 m and 440 m. The slope of the energy line increased, and the head losses were higher than those in the previous cross-section. Flow velocities increased, and accordingly, cross-sectional flow areas decreased. A subcritical flow regime was observed in the section at 320 m. Compared to the previous section, flow velocities decreased, cross-sectional flow areas increased, but not at a dangerous level. At the 200 m-section, the flow regime turned into supercritical. Flow velocities and the slope of energy line increased, and cross-sectional flow areas decreased. Critical regime conditions were observed from 200 m- to 80 m-sections. At the 0 m-section (downstream), the flow regime was observed to be subcritical. Based on the decrement in the flow velocity, it was observed that cross-sectional flow areas increased but remained below the control volume (137.20 m^2).

5. PREVENTION SCENARIOS

The flow regime was generally subcritical considering the study region along the stream path. Based on the distances between cross-sections and increase/decrease in the thalweg elevations, it was observed that the flow regime was critical in some cross-sections and passed into supercritical. The flow velocities were not excessively high at the cross-sections along the flow. The reason of low velocities at the cross-sections is that the natural streambed is suitable for the water to spread together with the increasing flow values for different return periods. Accordingly, Froude numbers were less than 1 at most cross-sections.

Table 3. Results of the analysis after reclamation (current situation and the first and second scenarios)

		Current state			1st scenario					2nd scenario				
Section (m)	**Stream Crest Elevation (m)**	**Thalweg Elevation (m)**	**Water surface elevation (m)**	**Flow area (m^2)**	**Thalweg Elevation (m)**	**Water surface elevation (m)**	**Flow area (m^2)**	**Water surface elevation change (%)**	**Flow area change (%)**	**Thalweg Elevation (m)**	**Water surface elevation (m)**	**Flow area (m^2)**	**Water surface elevation change (%)**	**Flow area change (%)**
1280	10.33	8.65	10.59	153.81	8.65	10.5	149.9	-0.85	-2.54	7.5	9.98	116.54	-5.76	-24.23
1160	10.45	8.82	10.19	116.17	8.35	10.22	121.08	0.29	4.23	7.3	9.66	97.78	-5.20	-15.83
1040	9.7	8.13	10.05	162.46	8.13	10.03	159.84	-0.20	-1.61	7.2	9.53	123.99	-5.17	-23.68
920	9.33	7.78	9.95	179.49	7.78	9.91	176.25	-0.40	-1.81	7.1	9.25	133.27	-7.04	-25.75
800	9.17	7.65	9.83	176.95	7.65	9.79	172.63	-0.41	-2.44	6.9	8.91	129.45	-9.36	-26.84
680	8.92	7.6	9.72	177.45	7.6	9.66	171.9	-0.62	-3.13	6.8	8.72	131.87	-10.29	-25.69
560	9.41	7.8	9.48	140.96	7.45	9.41	138.09	-0.74	-2.04	6.6	8.46	115.07	-10.76	-18.37
440	9.15	7.55	8.73	89.15	7	8.67	92.01	-0.69	3.21	6.4	8.37	78.55	-4.12	-11.89

In this study, it was aimed to reduce the flow areas and flood water levels in the natural streambed by performing reclamation in the cross sections to have flood risk potential. Therefore, two different channel regulations were proposed. The streambed level was first lowered at the cross-sections between 1280 and 116 m and 680 m and 440 respectively, which have the reverse slopes (Figure 8a).

In the second case, the bottom elevation was reduced between the cross-sections of 1280–440 m (Figure 8b). The hydraulic models considering Q_{500} flow value were performed again, and the results compared with those of the current situation (Table 3).

As a result of the bottom regulation studies for the risky cross-sections of the stream, the water surface elevations and flow areas mostly decreased in the first analysis, with the reduction of the reverse slope base elevations, but flood risk still existed in most sections. In the second regulation, an average of 1 m of excavation was proposed for the risky areas of the stream, and the hydraulic analysis was repeated. In Figure 9, the current state of the streambed and the changes in the water surface elevations and thalweg line formed as a result of the reclamation works are shown. Surface profiles and stream crest lines are compared for the 500-year return period flow. As seen from Table 3, all water surface elevations and flow areas decreased for the second scenario.

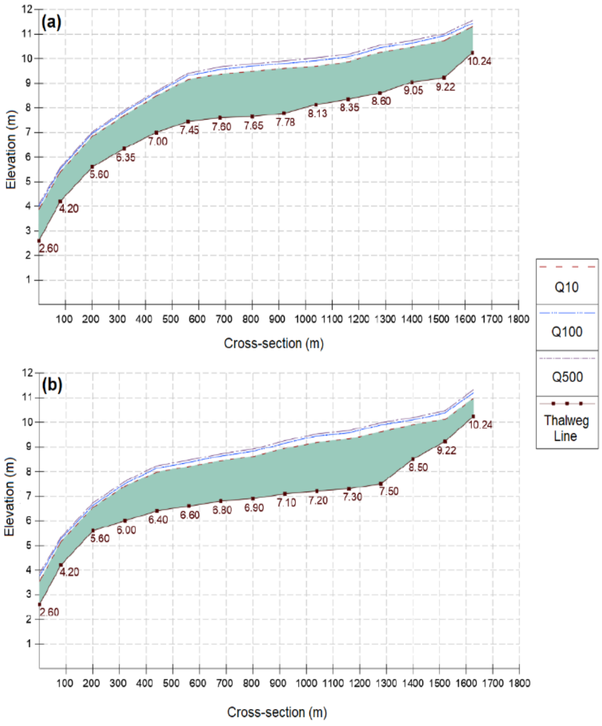

Fig. 8. Longitudinal cross-section after the (a) first and (b) second reclamation

On the other hand, a flood detention reservoir can be constructed on unoccupied and non-agricultural land in the region. With this solution, maximum flows can be prevented from entering the stream channel directly, and flow in then downstream can be reduced. The soil volume extracted in the proposed solution is calculated as 29450 m^3. In this context, the capacity of the flood detention reservoir to be built is determined to be 30000 m^3. The detention reservoir can be designed with a depth of 1.5 m and a width of 100 × 200 m as shown in Figure 10. In addition, the flood detention reservoir can be used for agricultural purposes other than the flood season. As an alternative to the second scenario, a part of flood water may be transferred to the flood channel to mitigate flood damages. However, as mentioned before, settlements on the right and left coastlines of the region are dense.

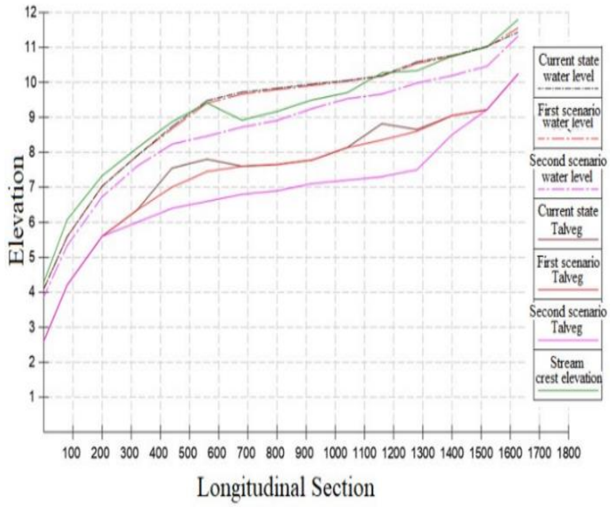

Fig. 9. Longitudinal cross-sections for the current situation and after reclamation (for Q$_{500}$)

Fig. 10. Location of the flood detention reservoir

For this reason, it is difficult to regulate streamflow by constructing a flood channel. In addition, people in the region use the right and left coasts of the stream as piers for fishing boats. A bank and/or floodwall structures to be constructed to prevent floodwater will adversely affect the pier usage and they are also economically disadvantageous. For these reasons, the reclamation activities that can be done in the city center are limited. In highly urbanized areas, it is more probable to access more data and use new methods in flood analysis. On the other hand, in rural areas where the population is sparse and/or increases and decreases seasonally, flood studies and precautions may be insufficient. Therefore, flood risk analyses for small settlements will serve as a guideline for new constructions and will enable urbanization to develop in a healthier way. The results obtained in this study can be developed and used as a generalized reclamation method for similar scale towns. Moreover, all flood reclamation works for both urban and rural areas should be region-specific [20-21].

References

[1] MGM (Turkish State Meteorological Service) (2018), Meteorological Character of 2017 Natural Disasters Assessment, Research Department of Meteorological Disasters Branch Office, Ankara, 156p (in Turkish).

[2] Dasallas, L., Kim, Y. and An, H. (2019), Case Study of HEC-RAS 1D–2D Coupling Simulation: 2002 Baeksan Flood Event in Korea, Water, 11 (10), 2048, https://doi.org/10.3390/w11102048.

[3] Rangari, V.A., Umamahesh, N.V. and Bhatt, C.M. (2019), Assessment of inundation risk in urban floods using HEC RAS 2D, Modeling Earth Systems and Environment, 5, 1839 – 1851, https://doi.org/10.1007/s40808-019-00641-8

[4] Zeleňáková, M., Fijko, R., Labant, S., Weiss, E., Markovič, G. and Weiss, R. (2019), Flood risk modelling of the Slatvinec stream in Kružlov village, Slovakia, Journal of Cleaner Production, 212 (6), 109-118, https://doi.org/10.1016/j.jclepro.2018.12.008

[5] Huţanu, E., Mihu-Pintilie, A., Urzica, A., Paveluc, L.E., Stoleriu, C.C. and Grozavu, A. (2020), Using 1D HEC-RAS Modeling and LiDAR Data to Improve Flood Hazard Maps Accuracy: A Case Study from Jijia Floodplain (NE Romania), Water, 12, 1624. https://doi.org/10.3390/w12061624

[6] Ongdas, N., Akiyanova, F., Karakulov, Y., Muratbayeva, A. and Zinabdin, N. (2020), Application of HEC-RAS (2D) for Flood Hazard Maps Generation for Yesil (Ishim) River in Kazakhstan, Water, 12, 2672, https://doi.org/10.3390/w12102672.

[7] Desalegn, H. and Mulu, A. (2021), Mapping flood inundation areas using GIS and HEC-RAS model at Fetam River, Upper Abbay Basin, Ethiopia, Scientific African, 12, e00834, https://doi.org/10.1016/j.sciaf.2021.e00834

[8] Salman, A., Hassan, S.S., Khan, G.D. et al. (2021), HEC-RAS and GIS-based flood plain mapping: A case study of Narai Drain Peshawar, Acta Geophysica, 69, 1383–1393, https://doi.org/10.1007/s11600-021-00615-4

[9] Tamiru, H. and Dinka, M.O. (2021), Application of ANN and HEC-RAS model for flood inundation mapping in lower Baro Akobo River Basin, Ethiopia, Journal of Hydrology: Regional Studies, 36, 100855, https://doi.org/10.1016/j.ejrh.2021.100855

[10] Akkaya, U. G. and Doğan, E. (2016), Generation of 2D flood inundation maps of Meriç and Tunca Rivers passing through Edirne city center, Geofizika, 33, 15-34, https://doi.org/10.15233/gfz.2016.33.7

[11] Çelikler, M., Koçer, N., and Yildiz, O. (2020), Bingöl İl Merkezinde Taşkın Yayılım Alanlarının Coğrafi Bilgi Sistemleri ve HEC-RAS ile Belirlenmesi, Doğal Afetler ve Çevre Dergisi, 6(2), 354-365. https://doi.org/10.21324/dacd.647877 (in Turkish)

[12] Ogras, S. and Onen, F. (2020), Flood Analysis with HEC-RAS: A Case Study of Tigris River, Advances in Civil Engineering, 13, Article ID 6131982, https://doi.org/10.1155/2020/6131982.

[13] Ceribasi, G. and Ceyhunlu, A.I. (2020), Generation of 1D and 2D flood maps of Sakarya river passing through Geyve district of Sakarya city in Turkey. Natural Hazards, 105, 631-642, https://doi.org/10.1007/s11069-020-04327-8

[14] Yetkin, G. (1947). *Edremit Tarihinden Yapraklar*. İstanbul: İstanbul Kâğıt ve Basım İşleri AŞ, 28s.

[15] Durak, M. (2019), Edremit ve Zeytinli Çayı Havzalarının (Balıkesir) Ekolojik Koşullara Göre Arazi Kullanım Kabiliyet Sınıflandırması, Yüksek Lisans Tezi, Balikesir Üniversitesi, Sosyal Bilimler Enstitüsü (in Turkish)

[16] Url-1 (2023) https://gazetemerhaba.com/edremit-zeytinli-cayi-tasti

[17] Özşahin, E. (2011), Erosion analysis of Zeytinli Creek basin (Balikesir), Nature Sciences, 6, 42–56.

[18] Chow, V.T. (1959), Open Channel Hydraulic, McGraw-Hill, New York.

[19] DSI (Turkish State Hydraulics Works) (2015), Roughness Coefficient Determination Guide for Stream Beds, Ministry of Forest and Water Management of Turkey, Ankara (in Turkish).

[20] Dag, I. (2019), Flood Analysis Using Hec-Ras for Antakya Altıncay Creek, MSc Thesis, Hatay Mustafa Kemal University (in Turkish).

[21] USACE (United States Army Corps of Engineer) (2016), Hydraulic Reference Manuel (Version 5.0), Institute for Water Resources Hydrologic Engineering Center, 609 Second Street, Davis, CA., 95616. USA.