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EFFECT OF CHANGES IN GEOMORPHOLOGICAL UNITS ON FLOOD AND TORRENT EVENTS DUE TO RAPID URBANIZATION IN BATMAN

ABSTRACT

This study evaluates the change in geomorphological units due to rapid urbanization in the city of Batman and the effect of this change on flood and torrent events. In addition to unplanned development, the rapid expansion of cities also causes significant changes in the geomorphological structure. Batman is a medium-sized industrial city that has rapidly developed within three decades due to the discovery of petroleum. The rapid growth in population has caused the city to expand. Significant changes with regard to geomorphology in the foundation area of the city have occurred due to the rapid and unplanned nature of the development. Satellite images and local field work reveal that these changes primarily include the devastation of stream beds due to their occupation by settlements. The destruction of creeks situated in the foundation area of the city and interventions in the stream bed of Iluh Creek give rise to flood and torrent events following intense precipitations.

Keywords: Batman, Rapid Urbanization, Iluh Creek, Geomorphological Change, Flood and Torrent

BATMAN'DA HIZLI ŞEHİRLEŞMEYE BAĞLI JEOMORFOLOJİK BİRİMLERDEKİ DEĞİŞİMİN SEL VE TAŞKIN ÜZERİNDEKİ ETKİSİ

ÖZET

Bu çalışmada, Batman'da hızlı şehirleşmenin jeomorfolojik birimler üzerinde meydan getirdiği değişim ve bu değişimin sel ve taşkın üzerindeki etkisi değerlendirilmiştir. Alansal olarak hızlı gelişen şehirler plansız gelişme ile birlikte jeomorfolojik yapı özerinde önemli değişikliklere yol açmaktadır. Batman şehri son 30 yılda petrole bağlı olarak hızlı gelişmiş orta ölçekli bir sanayi şehridir. Nüfustaki hızlı artış şehrin alansal olarak yayılmasını sağlamıştır. Bu gelişme çok hızlı ve düzensiz olduğu için şehrin kurulduğu alanda jeomorfolojik açıdan önemli değişiklikler ortaya çıkmıştır. Uydu görüntüleri ve şehir içi arazi çalışmalarında görülen bu değişikliklerin başında dere yataklarının yapılaşmaya maruz kalarak ortadan kaldırılması gelmektedir. İluh Dersi dışında şehrin kurulduğu alandaki diğer derelerin de ortadan kaldırılması ve İluh Deresi yatağına yapılan müdahaleler şiddetli yağışlar sonrasında sel ve taşkınlara neden olmaktadır.

Anahtar Kelimeler: Batman, Hızlı Kentleşme, İluh Deresi, Jeomorfolojik Değişim, Sel ve Taşkın

1. INTRODUCTION (GİRİŞ)

As in many countries across the world, Turkey has also experienced rapid urbanization and economic growth in the last three to four decades. In developing countries like Turkey involved in the process of development, urbanization is an event of demographic character which has gained speed as from the middle of the 20th century. This may be demonstrated by the ratio of urban population to the total population and the number of cities. The rate of urbanization across Turkey was 24% in 1927 and 33% in 1960. However, this rate increased to 71% in 2000 (Yüceşahin et al., 2004). Industrial and trade centers served as a locomotive for the growth and development of cities in Turkey.

Today, urban settlements cover a small part of the earth. However, the expansion of settlements and human activities and especially rapid urbanization in developing countries play an important role on changes in overall land use and surface cover (Masek et al., 2000; Chin, 2006). The impact of major human activities on changes on the surface of the earth was implied many years ago (Marsh, 1877, Thomas, 1956). This impact leads to a change in ecologic processes on a local and general scale. The most important outcome of changes in the natural environment is change in hydrological structure bringing about risk of flooding. Topographical, meteorological, climatic, biological and hydrological factors directly affect the occurrence of flood events. In addition, the changing pattern of land use and changes on the surface of the earth and in hydrological processes may increase the risk of flooding (Brath et al., 2006; Zhang et al., 2007).

Located between the Kıra and Raman mountains in the Southeastern Anatolia Region of Turkey, Batman city was founded on the old meander terraces of Batman Stream (Figure 1). The lower terraces were covered by alluvial fans formed by Iluh Creek and its branches.

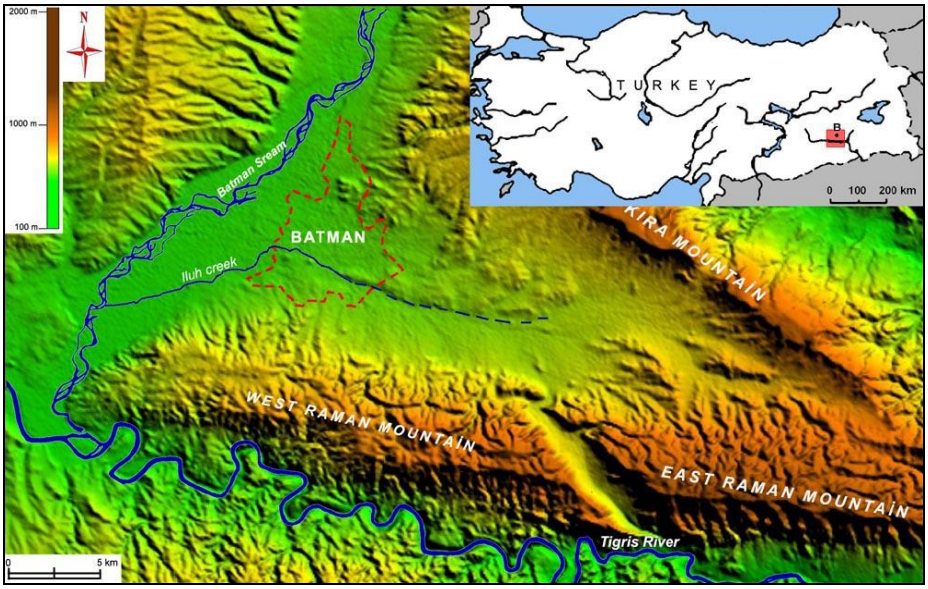

Figure. 1. Location map of Batman city
(Şekil 1. Batman şehrinin lokasyon haritası)

Batman, which was only a village before 1950, rapidly developed due to the discovery of petroleum and gained the status of province in 1990. In the process, significant changes along with unplanned urbanization occurred in geomorphological units in the foundation area of the city, particularly changes in the stream beds.

Urbanization affected the stream systems in an unexpected way (Booth and Jackson, 1997). Some of the stream beds in the city center of Batman

were covered and transformed into streets and avenues while others were occupied by settlements and industrial plants. The section of Iluh Creek in the city was taken into the canal. The risk of floods occurring in stream beds canalled into the main water canal is higher than normal stream beds (Leopold, 1968). Hydrological changes in relation to urbanization have been investigated in several areas. Research clearly reveals that urban development increases the frequency of flood events and expands their coverage area (Leopold, 1968). According to the results of studies; the peak flow, recession time, flood frequency, and total amount of material carried over the surface by the stream also change (Poff et al., 2006).

Due to the change in morphological structure by virtue of urbanization in Batman, an increase in the intensity and frequency of flood and torrent events was observed. The flood and torrent event on the night of October 31-November 1, 2006 resulted in 10 deaths and material damage of 15 million euro.

2. RESEARCH SIGNIFICANCE (ÇALIŞMANIN ÖNEMİ)

This study evaluates the change in geomorphological units due to rapid urbanization in the city of Batman and the effect of this change on flood and torrent events. In addition to unplanned development, the rapid expansion of cities also causes significant changes in the geomorphological structure. Batman is a medium-sized industrial city that has rapidly developed within three decades due to the discovery of petroleum. The rapid growth in population has caused the city to expand. Significant changes with regard to geomorphology in the foundation area of the city have occurred due to the rapid and unplanned nature of the development. Satellite images and local field work reveal that these changes primarily include the devastation of stream beds due to their occupation by settlements. The destruction of creeks situated in the foundation area of the city and interventions in the stream bed of Iluh Creek give rise to flood and torrent events following intense precipitations.

3. METHODOLOGY AND DATA (METOD VE VERİ)

This study utilized field work, topographical analyses, satellite images and geographical information systems (GIS) in order to identify variations and reconstructions of the streams within urban areas. Reference was also made to previous studies (Hooke and Kain, 1982; Graf, 1975; Graf, 2000). The analysis of historical information, old photos and topographic maps, historical methods, aerial photographs and satellite images via GIS may be interpreted as a modern method in such explorations.

Extensive field studies were carried out to demonstrate the change in morphological structure due to the rapid development of Batman city. Field studies were performed over a broad area to cover the basins of creeks affecting the city. Using a portable GPS device with precise measuring capability, profiles were obtained of the stream beds which are apparent outside the city but not apparent inside the city. Geological and geomorphological characteristics of the foundation area of the city were determined by field work, measurements, and satellite images.

A geological map was drawn up with a scale of 1/50,000 and land observations carried out by TPAO (Turkish Petroleum Corporation) while a geomorphological map was prepared according to the method developed by Erol (1979, 1983). Geomorphological units are generally displayed by means of land observations or satellite maps. Geomorphology is of unique importance with regard to administration and planning in the development of urban areas (Guha et al., 2009). Extensive geomorphological studies were carried out in urban areas of Batman. A 1/25,000 scale topographic map was used as the base map for all research. Construction maps and information on city districts were provided by the Municipality of Batman. The distribution of

data collected on the city districts was performed using MapInfo 7.5 program. The construction plan and historical development of the city were then demonstrated by means of a 1/5,000 scale map. Land exploration was carried out again to check that the maps we had developed were accurate.

The determination of the drainage pattern in urban settlements is quite challenging. In such areas, the pattern of streams and canals is established by means of large scale maps, field observations, remote detections and observations by local administrators. Field observations (Downs and Thorne, 1996) are made by stream engineers and administrators (Thorne et al., 1996). Although such methods are generally applicable, they may not always be directly applied in urban areas (Chin and Gregory 2005). It is almost impossible to determine the drainage pattern in dense cities without large scale construction maps and historical topographic maps and satellite images. Taking this into consideration, historical topographic maps and high resolution QuickBird images were used to determine the old drainage pattern in Batman city.

4. GEOLOGICAL AND GEOMORPHOLOGICAL CHARACTERISTICS OF FOUNDATION AREA OF BATMAN CITY (BATMAN ŞEHRİNİN KURULDUĞU ALANIN JEOLOJİK VE JEOMORFOLOJİK ÖZELLİKLERİ)

Batman city was founded on units of Quaternary and the Şelmo Formation comprising mudstone, sandstone and conglomerate belonging to the Upper Miocene to Pliocene erea (Yılmaz and Duran, 1997). Other than the above-mentioned units, those of Eocene to Oligocene which outcrop to the west of Mount Raman are the oldest ones in the area of investigation (Figure 2). Basalts, found in small quantities within the area of investigation to the northeast, form the structure of Mount Kıra and overlap the units of Pliocene to Quaternary age. These basalts are therefore of Quaternary age. Quaternary units present throughout the valley of Batman Stream correspond to the alluvial terraces, alluvial fans and flood plains of Batman Stream.

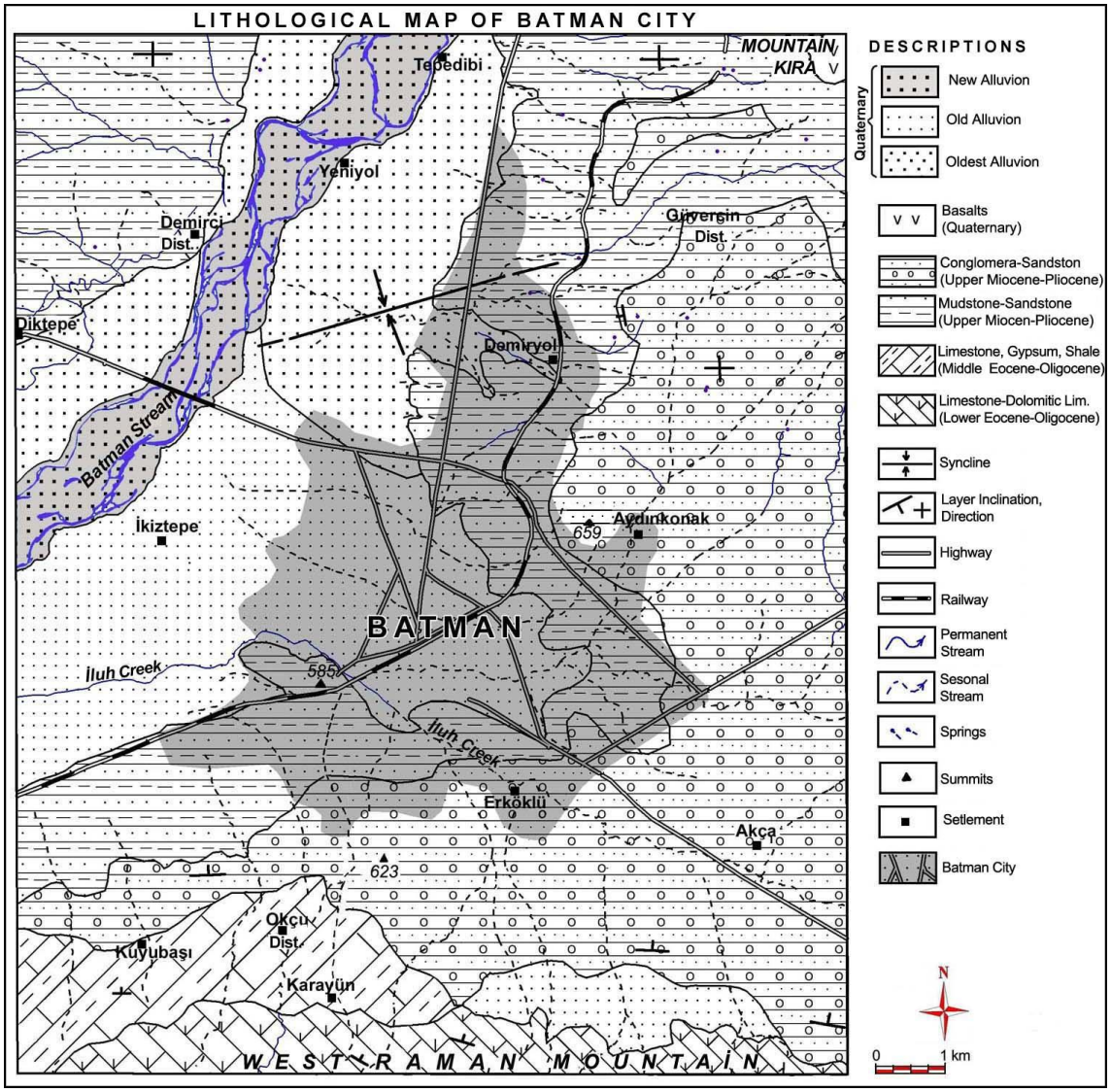

Figure. 2. Lithological map of Batman city
(Şekil 2. Batman şehrinin litoloji haritası)

Batman city was founded on the old meander terraces and the new alluvial fans of Batman Stream. These terraces are split by Iluh Creek in the area where the city was founded (Figure 3).

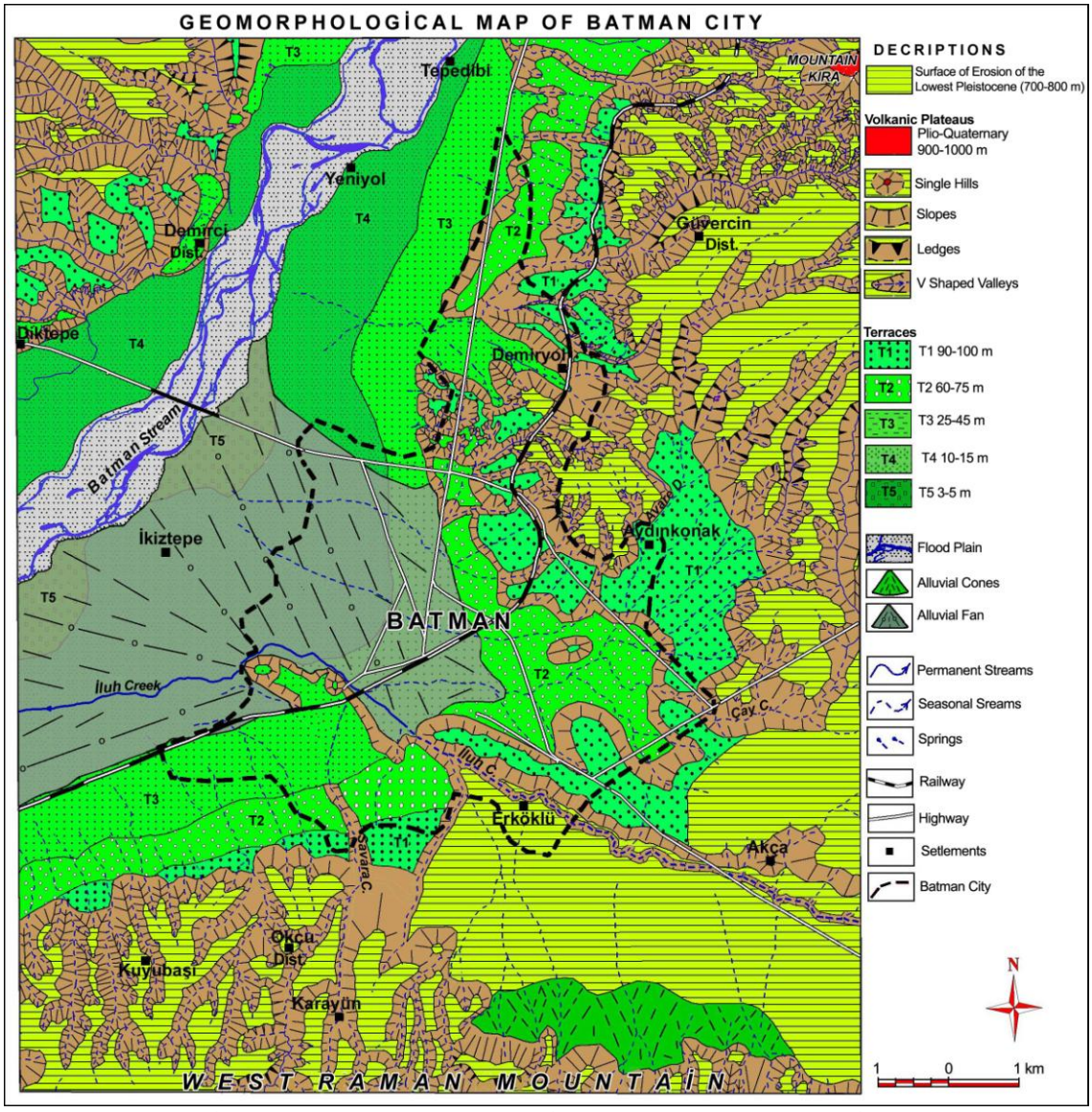

Figure. 3. Geomorphological map of Batman city
(Şekil 3. Batman şehrinin jeomorfoloji haritası)

There are broad plains of 700-800 m altitude to the north and south of Batman city (Tonbul and Sunkar, 2008). These plains are broad and not split in the southeast part of the city while the splits are apparent in the northeast. These surfaces correspond to old surfaces of Lowest Pleistocene according to the model developed by Erol (1983). The above-mentioned surfaces and the surfaces of Lowest Pleistocene age observed by Erol (1979) around the district of Silvan (Province of Diyarbakır) have the same altitude. These plains are higher and split in the east part of the city and this is due to the existence of conglomerates on the upper levels of the Şelmo Formation, which comprises the structure in this area. In transition from these surfaces to the terraces of Batman Stream, one can observe escarpments 50 to 60 m high comprised of ledges in some areas. In the south, the northern slopes of west Mount Raman correspond to surfaces of the Lowest Pleistocene age, which are not split by valleys. To the east of Batman city, there is a large area which is not included within the scope of this investigation. This area comprises slightly rolling plains on the north piedmonts of Mount Raman and was referred to as Tilmis Plain by Ardel (1961).

In addition to these general morphologic characteristics, the valleys of creeks affecting the area where Batman city was founded are quite apparent and have a deep structure in the upper basins. The stream beds in the foundation area of the city were destroyed due to low inclination as a result of urbanization (Figure 3). As the pattern of settlement is sparse and the process of urbanization is slow in the area neighboring the city, the stream beds are apparent at the entrance of the city during the period of stream flow.

5. FOUNDATION AND DEVELOPMENT OF BATMAN CITY (BATMAN ŞEHRİNİN KURULUŞ VE GELİŞMESİ)

The foundation and development of Batman city are closely related to events occurring in its immediate surroundings. El-Medine, whose date of foundation is not known but which was made the center of the district of Beşiri (Batman) in 1894, experienced a great flood event in 1926. In this flood event, occurring due to the overflow of Batman Stream, a large part of El-Medine was damaged. A large proportion of the population living in El-Medine moved to the villages of İkiztepe and Iluh in the immediate surroundings of this area (Zengin, 2005; Acar, 2008). According to general censuses (SIS), the population of this settlement was 401 in 1935, 269 in 1940, and 196 in 1945. The censuses also reveal that the settlement was completely abandoned in 1950. Iluh village, which grew with the wave of migration, entered a process of rapid development once petroleum was discovered in the period 1940 to 1950 and the railway between Haydarpaşa and Kurtalan was commissioned. Iluh was a municipal borough in the period 1940 to 1957. After 1957, it became a country town with the name of Batman which was affiliated with the province of Siirt. Eventually, it gained the status of province on May 16, 1990 (Zengin, 2005). Batman rapidly developed and is now a city with a population of 298,342 (Photo 1, 2). The rapid growth and development of the city can be attributed to the discovery of petroleum as well as migrations from its immediate surroundings. Geomorphological characteristics in the process of development were ignored and areas unsuitable for settlement were zoned for settlement. As Batman city was not founded on an area suitable for settlement, it is under risk of natural disasters, especially flood and torrent events.

It is possible to divide the development process of Batman city into two main periods. The first period is from 1945 to 1980. The city received labor migration with the construction of the railway in 1942 and the start of petroleum exploration on Mount Raman in those years. With the establishment of a modern refinery and the increase in industrial investments after 1966, the city entered a period of rapid development in which the city grew in an unplanned manner. Despite the unplanned development of the city in this period, flood and torrent events did not constitute a high risk as the city had not yet expanded to a considerable degree.

Photo 1. Batman (Iluh) and Petroleum Refinery in 1966. At this date, only the districts of Iluh and Çarşı existed in the area where Batman city was founded (http://www.batman.gov.tr/fotograflar/Nostalji/index.html 11.12.2009)
(Foto 1. 1966'lı yıllarda Batman (İluh) ve Petrol Rafinerisi. Bu tarihte Batman şehrinin kurulduğu alanda sadece İluh ve Çarşı mahalleleri bulunmaktadır. (http://www.batman.gov.tr/fotograflar/Nostalji/index.html 11.12.2009))

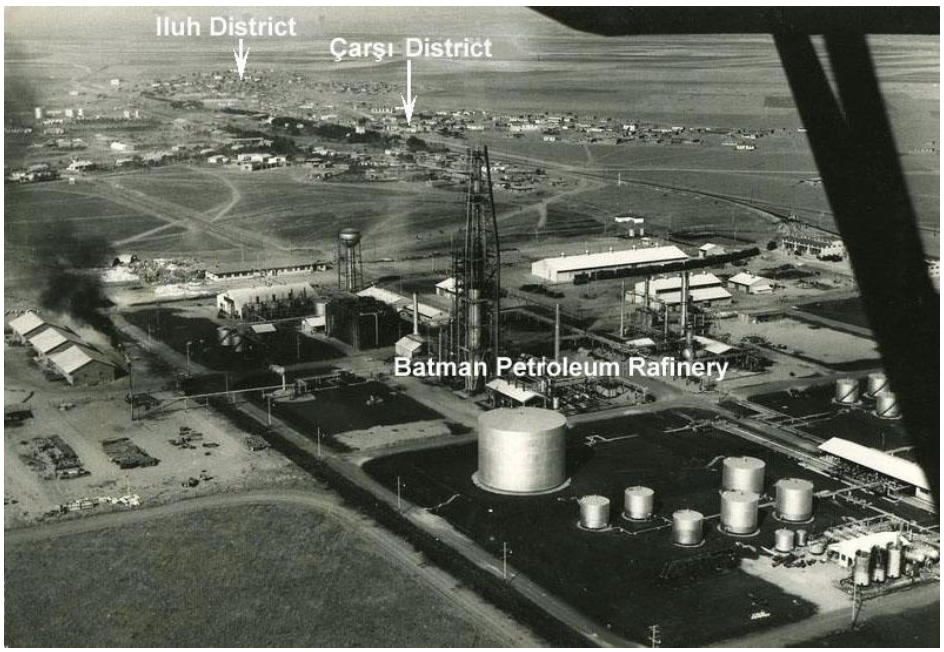

Photo. 2. General view of Batman city, from north to north-west (Directorate of Press, Governorship of Batman)
(Foto 2. Batman şehrinin kuzey-kuzeybatıya doğru genel bir görüntüsü (Batman Valiliği Basın Müdürlüğü))

The period from 1980 to the present constitutes the second period, when a new wave of migration from rural or small settlements to urban areas took place. However, the problems caused by migrations in the 1950s were

overcome whereas problems in city districts receiving migration after the 1980s escalated and became unavoidable. Cities in Turkey at this time resembled villages harboring large masses of population (Avcı, 2003). The rapid population growth and urbanization in Batman also reached a peak from 1980 onwards. The urban population increased by more than 200.000 in this period. The rapid population growth in Batman city was due to industrialization based on petroleum as well as migrations from the immediate surroundings for reasons of safety. The expansion of the city around the old districts after 1980 caused considerable changes on the geomorphological units (Figure 4).

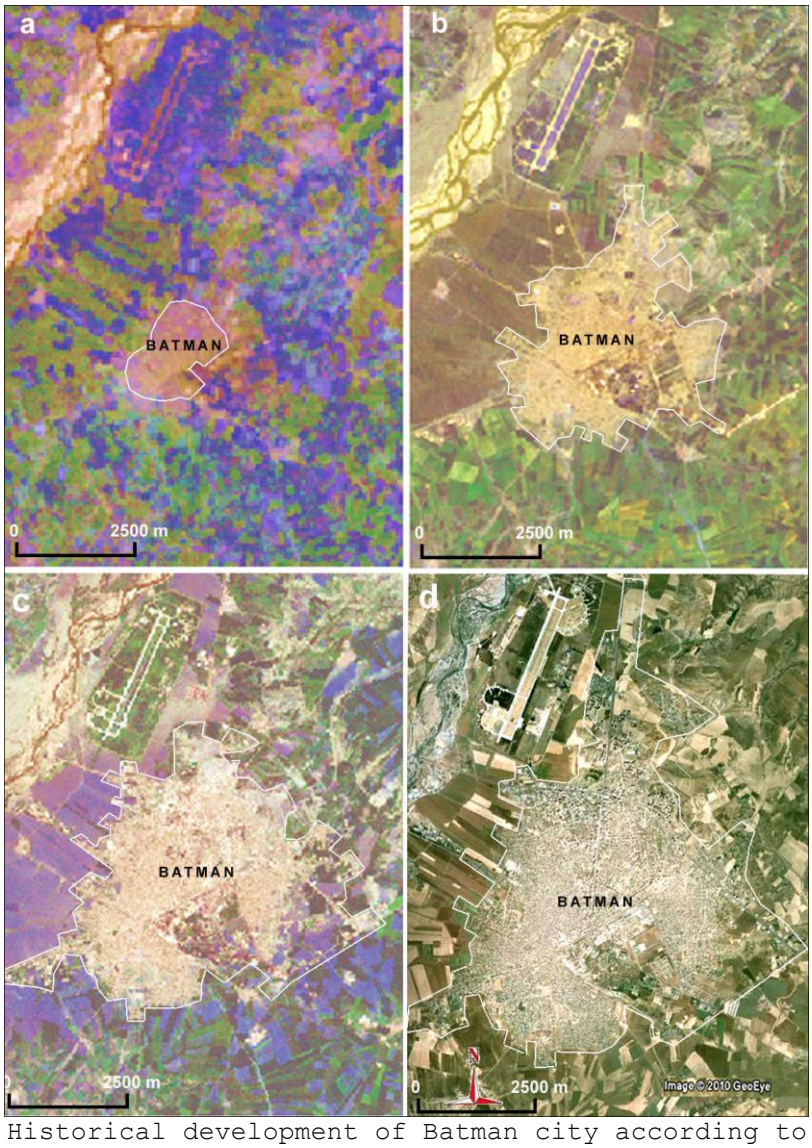

Figure 4. Historical development of Batman city according to satellite images. a, b, c) Landsat images (1,2,3 bands), d) Google Earth image, a) 1975, b) 1990, c) 2002, d) 2009 images
(Şekil 4. Uydu görüntülerine göre Batman şehrinin tarihi gelişimi. a, b, c) Landsat görüntüsü (1,2,3 bandlar),d) Google Earth görüntüsü, a) 1975, b)1990, c) 2002, d) 2009 görüntüleri)

Batman consisted of 15 city districts until 1980. It first developed around Iluh district, which is the oldest district of the city, then expanded towards neighboring areas (Figure 4). Afterwards, it grew towards Çarşı district, located in the west. Thereafter, the districts of Kısmet

and Aydınlıkevler were established and the city expanded towards the area where the refinery was built. Following these, the districts of 19 Mayıs (especially through migrations from Kozluk region) and Petrol (especially through migrations from Gercüş, Hasankeyf) were established. These districts are relatively old, having been established in the 1980s. From these, the districts of Sağlık, Bağlar and Gap were set up due to the migration of Köçer nomads. In the past, the Köçer nomadic tribes in the area spent their summers in Muş and Bitlis and their winters in the surroundings of Batman. Over time, the Köçer tribes settled in the city center of Batman and today a large part of the Köçer group are still engaged in animal breeding. This being the case, adverse environmental conditions emerge in these districts that affect public health.

- **Settlement Characteristics of Batman City (Batman Şehrinin Yerleşme Özellikleri)**

In order to demonstrate the change in geomorphological units due to urbanization in Batman, the characteristics of settlement and local land use were evaluated. When the density of population and houses in Batman were compared, a definite coherency was observed. Namely, the districts with a dense population are also districts with a high density of houses (Figure 5). The districts of Aydınlıkevler, Beşevler, İluh, Karşıyaka, Kısmet, Raman and Yeni are located in the city center and the density of population in these areas is high, parallel to the density of houses. The high density of population and houses in these districts is due to their small coverage area. The density of population and houses decreases from the city center towards the outskirts. The outer districts primarily include Bayındır, Gültepe, Çamlıtepe, Güneykent and Cumhuriyet (Figure 5), however, housing has increased considerably in these districts in recent years.

The denser the pattern of settlement, the more the risk of erosion increases. The amount of sediment carried by streams in the surroundings of small cities is 10 times more than that in normal stream beds. This rate may increase up to 250 times in the development period of large cities (Guy and Ferguson, 1962). As a human activity, urbanization directly or indirectly changes some elements of the natural structure and affects the flow rate of streams and amount of sediment carried by these streams (Kang and Marston, 2006). The primary criterion of urbanization in a stream basin is the existence of impervious surfaces (May et al., 2002). The surface of an impervious cover prevents the infiltration of water into the soil (Arnold and Gibbson, 1996).

The creeks causing flood and torrent events in Batman carry a considerable amount of sediment due to urbanization, lithological structure in the environment, and soil characteristics. It is observed that the denser the pattern of settlement, the greater the amount of sediment carried by these creeks. Thick sediment aggregations were observed in a large part of the city in flood and torrent periods. In the flood event experienced on 31 October 2006, an aggregation of mud higher than 1 m was observed in the gardens of houses in the districts of Hürriyet, Karşıyaka and Petrolkent (Photo 3).

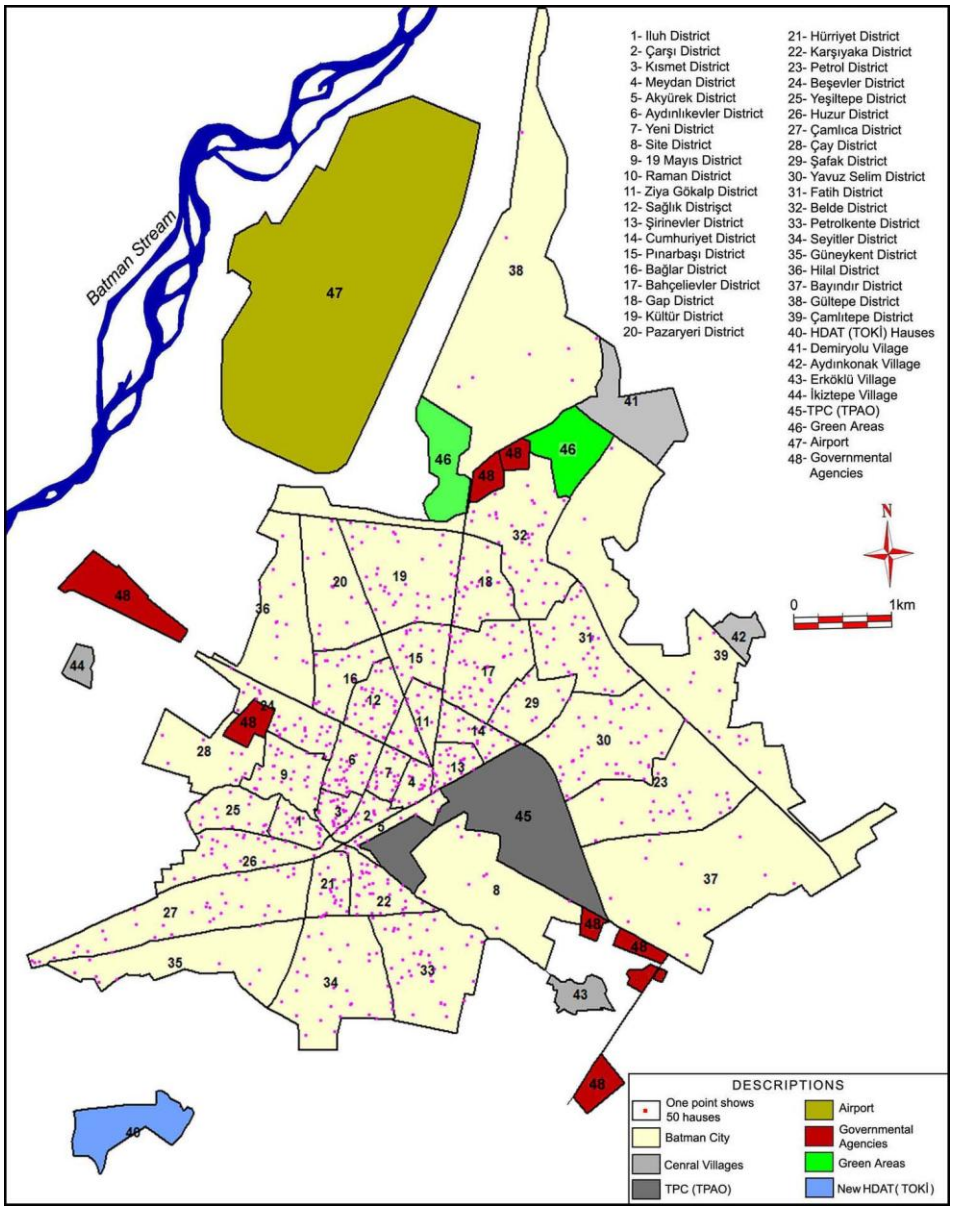

Figure 5. Density of houses by district in Batman city (Housing census data 2005, Municipality of Batman
(Şekil 5. Batman şehrinde mahallelere göre konut yoğunluğu (Batman Belediyesi 2005 yılı sayım verilerine göre oluşturulmuştur))

Batman is still developing rapidly and the process of urbanization is continuing. Furthermore, it is observed that the authorities are not yet conscious of the need for population planning and there is a lack of infrastructure in this regard

Photo 3. Aggregations of mud up to 1 m high observed in the gardens of some houses as a result of the flood and torrent event in Batman on October 31-November 1, 2006.
(Foto 3. 31 Ekim – 1Kasım 2006 tarihinde Batman'da yaşanan sel ve taşkın sonucunda bazı meskenlerin bahçesinde 1 m'yi bulan çamur birikmiştir)

6. EFFECT OF CHANGES IN GEOMORPHOLOGICAL UNITS DUE TO RAPID URBANIZATION ON FLOOD AND TORRENT EVENTS (BATMAN'DA HIZLI ŞEHİRLEŞMEYE BAĞLI JEOMORFOLOJİK BİRİMLERDEKİ DEĞİŞİMİN SEL VE TAŞKIN ÜZERİNDEKİ ETKİSİ)

Geomorphologic impacts, especially due to human activities, may be observed in cities and in their surroundings. The development, population growth, and economic growth of cities include a series of processes with geomorphologic outcomes. Excavations over a large area, extensive transportation networks, and large storage areas comprise the new environment and land use characteristics. Although these activities start new anthropogeomorphological processes, they should not be confused with other environmental processes. Such activities affect the impacts of natural denudation and the amount of sediment (Wolman and Schick, 1967; Wolman, 1967; Sowa et al., 1990; Trimble, 1997; Rawat et al., 2000; Lu, 2005; Rivas et al., 2006).

Cities are settlements constructed by human beings and one or a number of environmental processes may be effective on their foundation and development. However, people make changes to the natural environment for the purpose of developing cities (Dow, 2000). Important problems emerging in the center of cities may result from negative changes to the natural environment in the process of urban development. With the rapid urbanization in Batman city, significant changes occurred in the natural environment and especially in the geomorphological units. The change in the natural environment caused natural events to be transformed into natural disasters. The most important change in Batman was the occupation and destruction of stream beds in the city center by settlements and industrial plants (Figure 6).

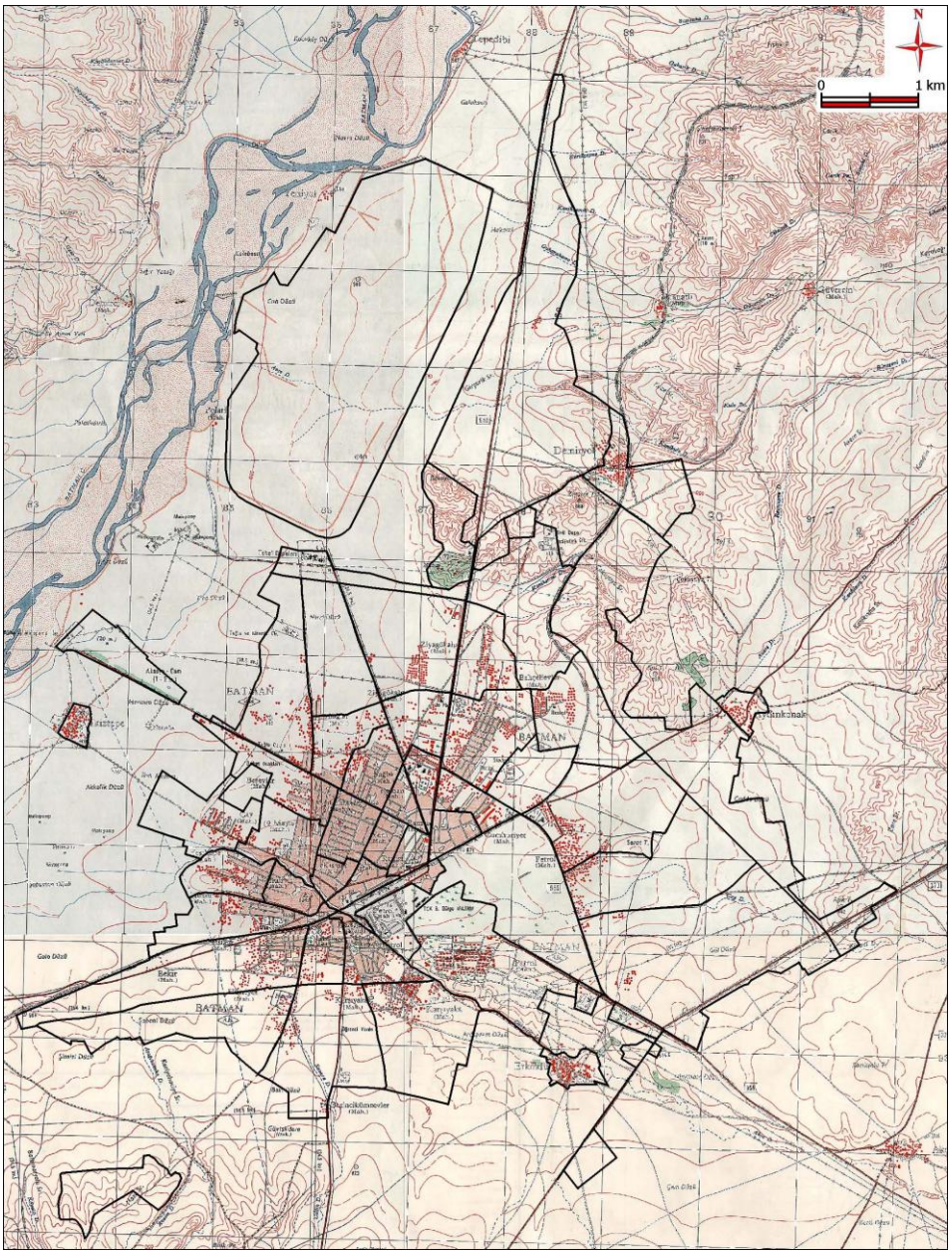

Figure 6. Expansion areas of Batman city according to 1986 topographical map and coverage areas of the city according to 2008 construction plan. It is seen that the coverage area of the city was small in 1986 and the stream beds located inside the city were destroyed in the process of development after 1986.
(Şekil 6. Batman şehrinin 1986 yılında hazırlanmış topografya haritası üzerindeki yayılış alanları ile 2008 yılı imar planına göre kapladığı alanlar. 1986 yılında şehrin dar alanlı olduğu ve bu dönemden sonraki gelişmede şehir içinde kalan dere yataklarının ortadan kaldırıldığı görülmektedir)

The development, size and functional characteristics of city centers are largely based on natural conditions. One or a number of characteristics such as elevation, climate, geographical formations, exposure, soil and hydrography are primarily effective on the selection of settlement areas (Özdemir and Karadoğan, 1996). The most important geomorphological factors affecting the process of urbanization comprise the geomorphological

formations and soil structure of the area where the city was founded (Bilgin, 1989). Natural disasters due to ignorance of geomorphological characteristics in the selection of settlement areas greatly affect the population. Likewise, when geomorphological characteristics are underestimated as risk factors, unplanned and unguided urbanization occurs. On the other hand, the rapid expansion of cities gives rise to significant changes in the geomorphological structure. These changes distort the natural structure and cause geomorphological problems.

Human beings have affected geomorphology for quite a long time (Goudie, 1993), generally in a distortive and destructive manner. The impact of human beings on geomorphological units started with industrialization and reached a peak with rapid urbanization. This situation can be clearly observed in Batman, a medium-sized city which has developed in the last three decades (Photo 1,2; Figure 4,6). As a result of rapid urbanization without considering construction practices, the stream beds located in urban areas were largely destroyed. The seasonal character of the creeks located in the settlement centers and the low inclination of their stream beds facilitated the destruction of these beds (Table 1). Due to these morphologic characteristics, the valleys of creeks in the city center were destroyed. Therefore, only the creeks located in the city center and affecting the city were evaluated in this study with regard to morphological change. Important changes also occurred in other morphological units besides stream beds. For instance, terraces and slopes were distorted as a result of rapid urbanization. However, this change is not as significant as that on stream beds.

Table 1. General characteristics of creeks affecting Batman City
(Tablo 1. Batman şehrini etkileyen derelerin genel özellikleri)

Creeks	Area (m^2)	Length (km)	Maximum difference in elevation (m)	Inclination %
Iluh	316.793.	33,84	390	1,1
Savaro	9.807.69	8,52	270	3,1
Şakuli	22.457.2	11.33	370	3,2
Avare	18.315.2	6,56	200	3,0
Çay	23.221.3	8,65	290	3,3
Aşağıko	4.736.58	4,88	260	5,3
Şikeste	10.813.5	7,39	270	3,6
Kanikae	543.596	1,21	60	4,9
Guharoh	382.164	1,14	50	4,3
Kanikul	950.684	1,52	100	6,5
Demiryo	735.956	1,41	70	4,9
Kaniker	268.112	1,39	50	3,5

According to 1/25,000 scale topographic map

6.1. Iluh Creek (İluh Deresi)

Iluh Creek drains the waters of an area of 316.793,423 m^2 which is located between Kıra and Raman mountains (Figure 7). This creek is seasonal and poor in terms of catchment characteristics due to climatic conditions and the lithological structure of its basin. The basin of Iluh Creek is broad-based and triangular-shaped and the stream pattern is dendritic. The longitudinal profile of Iluh Creek is aslope and there is no knick point at this profile. This is due to the low inclination and simple character of its lithologic and tectonic structure.

The inclination increases and the lithological structure changes in transition from the bottom of the basin to the mountainous areas. Therefore, the stream bed of Iluh Creek is apparent and quite broad in the

upper basins. The stream bed of Iluh Creek in the upper basin is three times larger than the lower basin (Figure 7). As a result of decreasing inclination in the lower basin and agricultural activities, the stream beds became narrower over time and their valleys became smaller (Figure 3). This change was random and unplanned. However, morphological arrangements in the stream system may be performed by means of changes to the section, length and plan of the canal, stream pattern, and basin of the creek (Gregory, 1987a,b). The construction of a reservoir and dam in an area where the population becomes denser, changes in land use in the basin, or construction of a canal and urbanization significantly alter the nature of the environment (Gregory, 1987a,b; 2006).

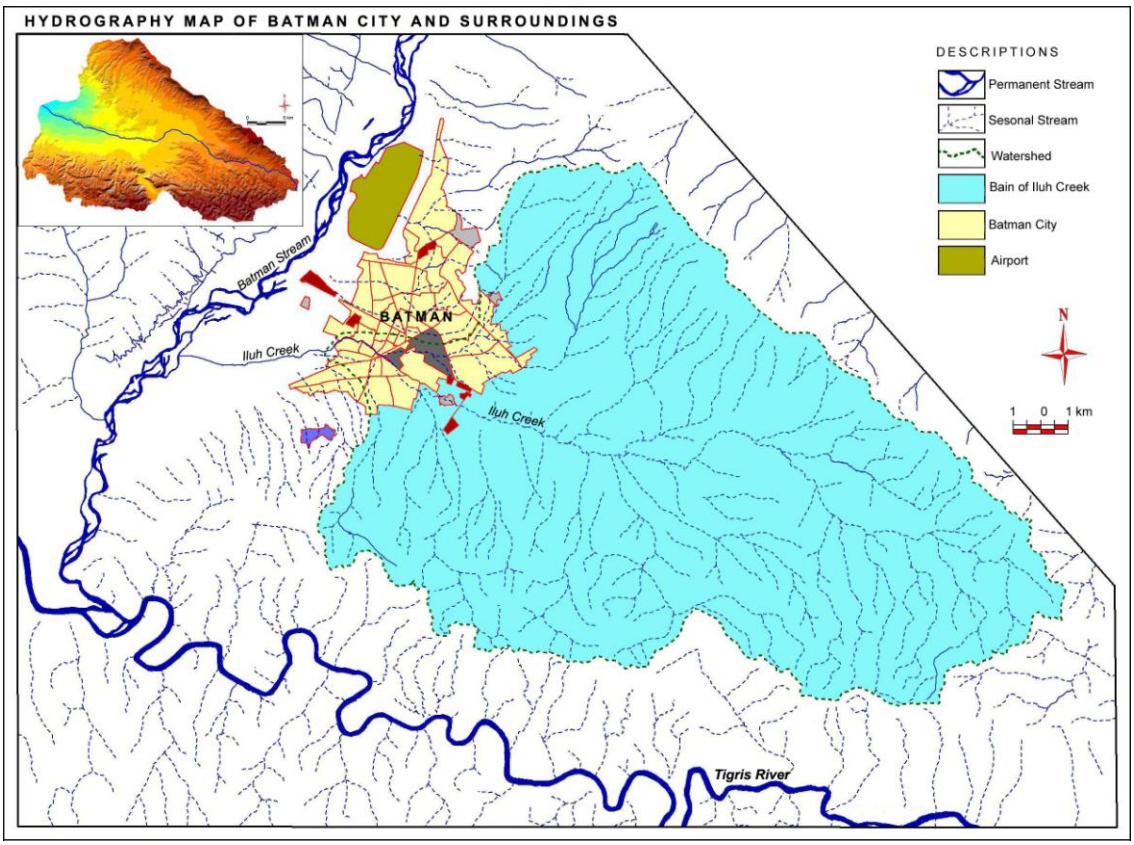

Figure 7. Hydrographical map of Batman city and its surroundings
(Şekil 7. Batman şehri ve çevresinin hidrografya haritası)

The part of Iluh Creek located in Batman was filled with excavations that caused the creek to grow narrower and shift then be displaced by settlements. This alteration on the main stream bed of Iluh Creek is more apparent in profiles taken at the entrance of the city (Photo 4). It is this change that causes flood events in the city.

Photo 4. Morphological status of valley of Iluh Creek a) Valley of Iluh Creek east of Binaltlı. b) Canal of Iluh Creek in city center. c) Valley of Iluh Creek east of Erköklü before flood event on October 31-November 1, 2006. d) Earth-lined canal of Iluh Creek constructed east of Erköklü before the flood event.

Foto 4. İluh Deresi Vadisi'nin morfolojik durumu (a-Binaltlı doğusunda İluh Deresi Vadisi, b-Şehir merkezinde İluh Deresi Kanalı, c- 31 Ekim-1Kasım 2006 tarihindeki taşkından önce Erköklü doğusunda İluh Deresi Vadisi, d- Taşkından sonra Erköklü doğusundaki yapılan İluh Deresi toprak kanalı)

The canal constructed according to the distorted stream bed of Iluh Creek is of importance in the occurrence of flood events (Figure 8, Photo 4). The basin area of the canal, with a depth of 4.3 m and width of 7 m at the entrance of the city, was designed according to the maximum flow rate. There are many sinuous on this canal, which was completed in 2005 (Figure 9). In addition to the frequent expansion of canals during the urbanization process, alterations to canals such as the removal of sinuous, reduction of materials in the river bed, and increase in drainage density have also been identified as other urban-induced issues and effects (Mosley, 1975; Fox, 1976; Arnold et al., 1982; Pizzuto et al., 2000; Finkenbine et al., 2000; Chin, 2006). For example, it was revealed that flood plains might expand by 270% due to sedimentation (Graf, 1975) and the drainage density might initially be reduced by 58% (US Department of Interior, 1968) once the small canal has been removed during urban development (Meyer and Wallace, 2001). However, the construction of roads (Gregory and Park, 1976) and drainage of stormy precipitation (Hannam, 1979) might increase the drainage intensity by 50% (Graf, 1977) and this rate may sometimes rise to 80% (Whitlow and Gregory, 1989).

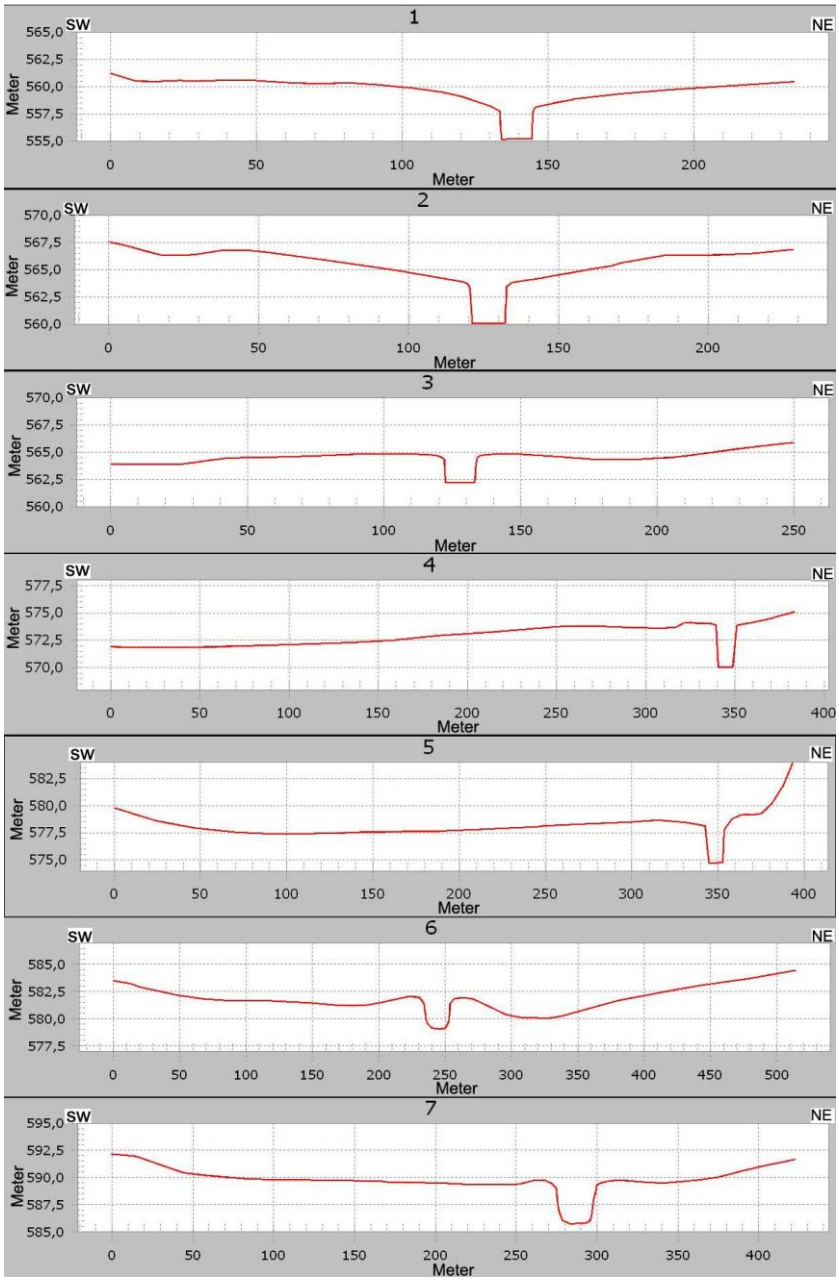

Figure 8. Series of transverse profiles taken from entrance to city center towards the west over Iluh Creek.
(Şekil 8. İluh Deresi'nin şehir merkezi girişinden batıya doğru İluh Deresi üzerinden alınan enine profil serileri)

The Iluh canal was constructed according to its probable flow rate (150 m^3/s) when in flood over a period of 200 years by the State Hydraulic Works. This rate is relatively low considering the area and climatic conditions of the basin of Iluh Creek. The flood experienced on 31 October 2006 was three times more than the above-given flow rate. Despite the deficiencies of this project, the canal built on Iluh Creek prevented further loss of life and property in the flood event of 2006.

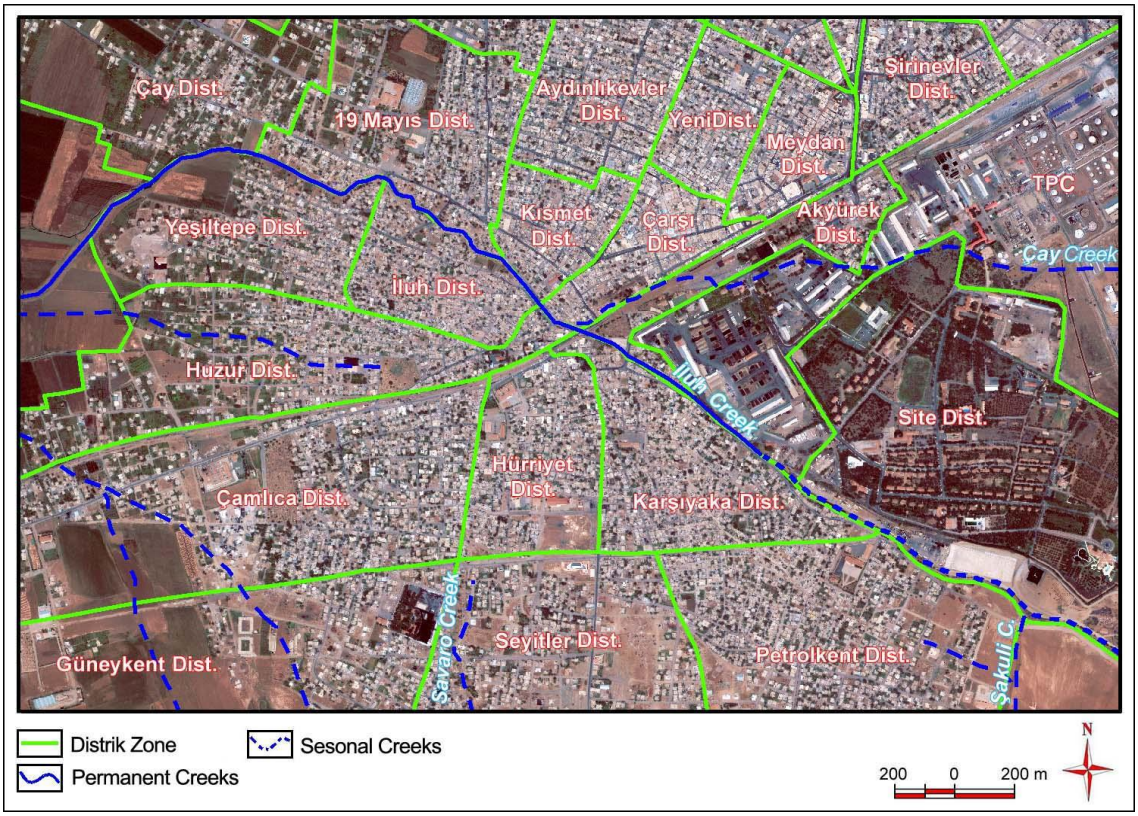

Figure 9. Canal with sinuous constructed on Iluh Creek flowing through Batman city.
(Şekil 9. Batman şehrinin içerisinden geçen İluh Deresi üzerinde yapılan kanal ve bu kanal üzerinde yer alan kıvrımlar)

The stream beds of side branches linked to Iluh Creek in the foundation area of Batman city have been completely destroyed at the entrance of the city. The disappearance of valleys at the entrance to the city, which were broad and apparent in the upper basins, is due primarily to urbanization and secondly to their low inclination and lithological structure. The seasonal character of these creeks is another reason for their disappearance in the lower basins.

6.2. Savaro (Dodik) Creek (Savaro (Dodik) Dere)

Savaro creek, which takes its source from the western slopes of Mount Raman to the south of Batman city, collects the waters from an area of 9.807,690 m^2. This creek has a stream bed with an inclination of 3.1% and a length of 8.52 km. This value is higher in the source area and lower in the lower track.

On mountainous areas and plateaus, the stream bed of Savaro creek is deep on the limestone while shallow and wide on basin depositions comprised largely of mudstones. Due to climatic and hydrographic characteristics, there may not be water in the stream bed in all seasons. However, stream flow occurs if extreme precipitation falls in the rainy period. Due to this characteristic of Savaro creek, its stream bed was destroyed in the city (Figure 10). As high stream flow did not occur for many years, the settlements in the upper basin were not affected. Therefore, people settled around and even on the stream bed of the creek, as in Hürriyet district (Photo 5).

Figure 10. Creeks affecting settlements in the south of Batman city. The connection of these creeks to Iluh Creek was cut
(Şekil 10. Batman şehri güneyinde yerleşmeleri etkileyen dereler. Şehrin güneyinde yer alan bu derelerin İluh Deresi ile olan bağlantısı kesilmiştir)

Photo 5. Savaro creek, affecting the south of Batman city. a) Stream bed of Savaro creek, wide and shallow up to the entrance to the city. b) Valley of Savaro creek at entrance to city. c) Valley of Savaro creek in Seyitler district. d) The stream bed of Savaro creek completely disappears in Hürriyet district.
(Foto 5. Batman şehrini güneyden etkileyen Savaro Deresi (a- Savaro Dere'nin şehir girişinden önceki yatağı geniş ve derinliği azdır. b- Savaro Dere'nin şehir girişindeki vadisi, c- Savaro Dere'nin Seyitler Mahallesi'ndeki vadisi, d- Savaro Dere'nin yatağı Hürriyet Mahallesi'nde tamamen kaybolmaktadır)

In conclusion, the stream bed of Savaro creek, which is apparent and wide until the entrance of the city, becomes narrow at the entrance of the city and completely disappears in the inner districts. Rapid urbanization and the absence of flood events caused these areas to be zoned for settlement.

6.3. Şakuli Creek (Şakuli Dere)

Şakuli creek takes its source from the mountainous area to the south. The longest branch of the creek, which collects the waters from an area of 22.457,225 m^2, has a stream bed with a length of 11.33 km and an inclination of 3.2%. Like Savaro creek, Şakuli creek also has a stream bed which is deep in mountainous areas and shallow and wide at the bottom of the basin. The valley of Şakuli creek is apparent until the entrance to the city with wide bridges and road crossings. The stream bed of Şakuli creek then completely disappears at the entrance of the city (Photo 6).

Photo 6. Şakuli creek, affecting the south part of Batman city. a) Stream bed of Şakuli creek on the alluvial fan to the south of west Mount Raman. b) Bridge on Şakuli creek before entrance to the city. c) Stream bed of Şakuli creek before the entrance of the city became narrow due to land use. d) Stream bed of Şakuli creek occupied by dwellings in Petrolkent district. (Foto 6. Batman şehrini güneyden etkileyen Şakuli Dere (a- Şakuli Dere'nin Batı Raman Dağı güneyinde birikinti yelpazesi üzerindeki yatağı, b- Şehir girişinden önce Şakuli Dere üzerindeki köprü, c-Şakuli Dere'nin şehir girişinden önceki yatağı arazi kullanımı sonucu daralmış, d-Petrolkent Mahallesi'nde şakuli Dere yatağı meskenler tarafından işgal edilmiştir)

Şakuli creek accumulates materials carried by erosion from mountainous areas in the area where it opens into the basin. Due to this accumulation, the stream bed of the creek at the bottom of basin was continuously filled and became indistinct in some areas. However, the creek uses its old stream bed in flood periods. The valley of this creek is deep on mountainous areas, slightly apparent in transition to the bottom of basin, and has been destroyed in the city center.

The above-mentioned morphological structure of Şakuli creek causes great flood events, especially in the city center following intense precipitations. Petrolkent district located in the south part of the city was affected by the last and greatest disaster experienced in the autumn of 2006 (Photo 6). Great damage occurred to infrastructure and superstructures. Furthermore, Şakuli creek swept away the thick soil cover on the bottom of its basin and accumulated this cover in the inner parts of districts as the creek gained the character of a flood at the bottom of its basin (Photo 3).

6.4. Avare Creek (Avare Dere)

Avare creek, which affects the east part of Batman city, collects the waters from an area of 18.315,227 m^2 and has a stream bed with a length of 6.56 km and an inclination of 3%. The valley of the creek is quite apparent until Aydınkonak district due to the existence of conglomerates in the basin and its depth varies from 30 to 60 m. As the inclination decreases on basin depositions comprised of mudstones in the east of Aydınkonak district, the stream bed of Avare creek widens and the depth of its valley decreases. Even though the stream bed widens in this area, it is apparent until the entrance of the city. However, the stream bed completely disappears in Petrol district due to the expansion of the bed and road constructions (Photo 7, Figure 11).

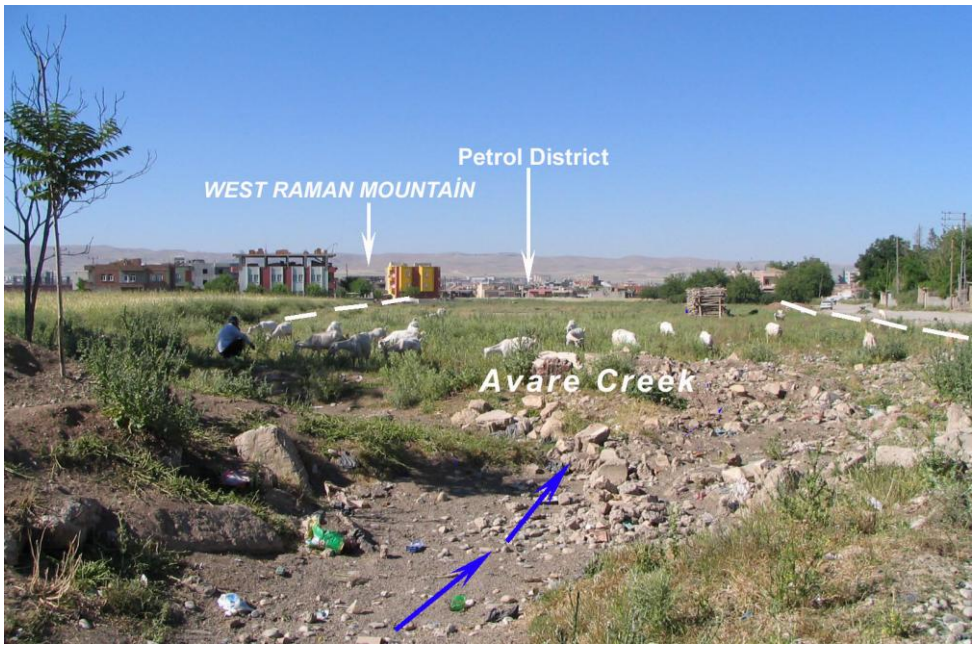

Photo 7. Avare creek, which affects Petrol district at the exit of Aydınkonak district, and its flood plain.
(Foto 7. Aydınkonak çıkışında Petrol Mahallesi'ni etkileyen Avare Dere ve taşkın yatağı)

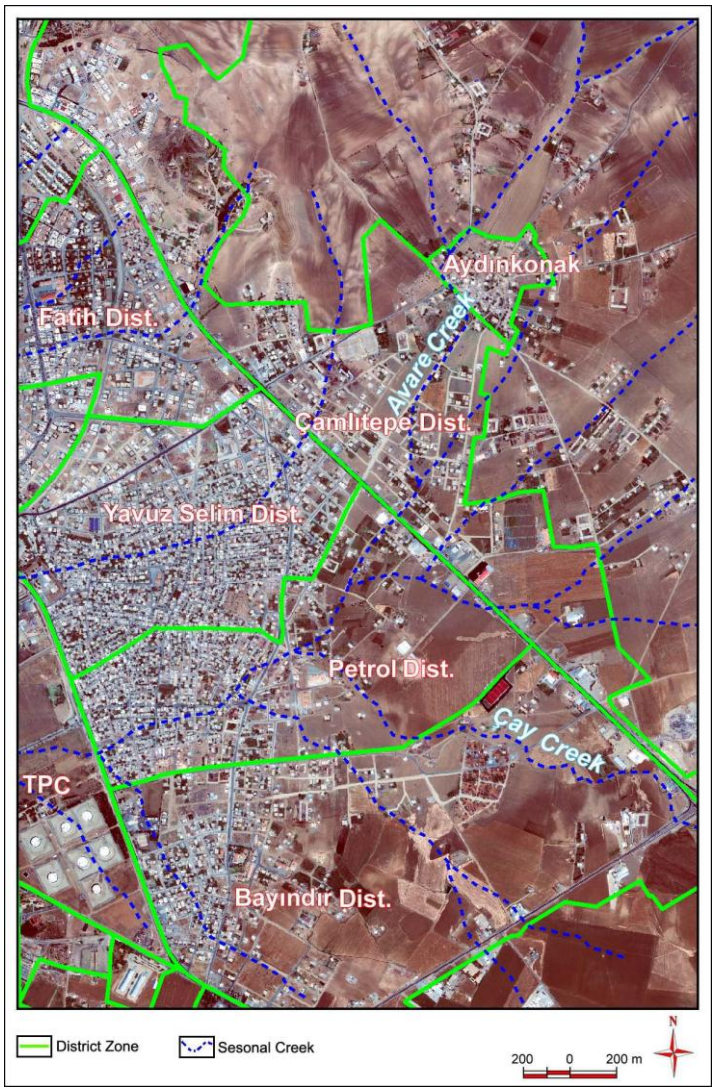

Figure 11. Creeks affecting districts located in the east part of Batman city according to a QuickBird image. These creeks have apparent stream beds until the entrance of the city but these beds disappear at the entrance of the city. The occupation of stream beds by settlements causes flood and torrent events in rainy periods.
(Şekil 11. Quikbört görüntüsüne göre Batman şehri doğusunda yer alan mahalleleri etkileyen dereler. Şehir girişine kadar belirgin bir yatağa sahip olan bu dereler şehir girişinde kaybolmaktadır. Dere yataklarının yerleşmeler tarafından işgal edilmesi yağışlı dönemlerde sel ve taşkınlara yol açmaktadır)

The above-mentioned change in the morphological structure of Avare creek causes the waters which start to runoff following intense precipitations to affect the eastern part of Batman city. This does not cause much damage in the Districts of Aydınkonak and Çamlıtepe as these areas are relatively undeveloped. However, Petrol district is considerably affected by flood events arising from Avare creek.

6.5. Çay Creek (Çay Dere)

Çay creek, which has the widest basin in the eastern part of Batman city collects the waters from an area of 23.221,388 m^2 up to the entrance of the city. This creek has a stream bed with a length of 8.6 km and an average inclination of 3.3%. Çay creek, which is linked to Avare creek in

Petrol district, constitutes a high risk for the eastern part of Batman city and for the refinery area. The connection of Çay creek with Iluh Creek was cut once the road between Batman and Midyat was constructed and the plants of Turkish Petroleum Corporation (TPC) and Turkish Petroleum Refineries Corporation were built (Figure 11).

The valley of Çay creek shows various morphologic characteristics until the entrance to the city. The creek exhibits a valley character, which is young from the source area until east of Kösetarla village and broad-based from Kösetarla village to the entrance of the city. Before entering the city, the creek loses its valley character due to its inclination and lithological structure (Photo 8).

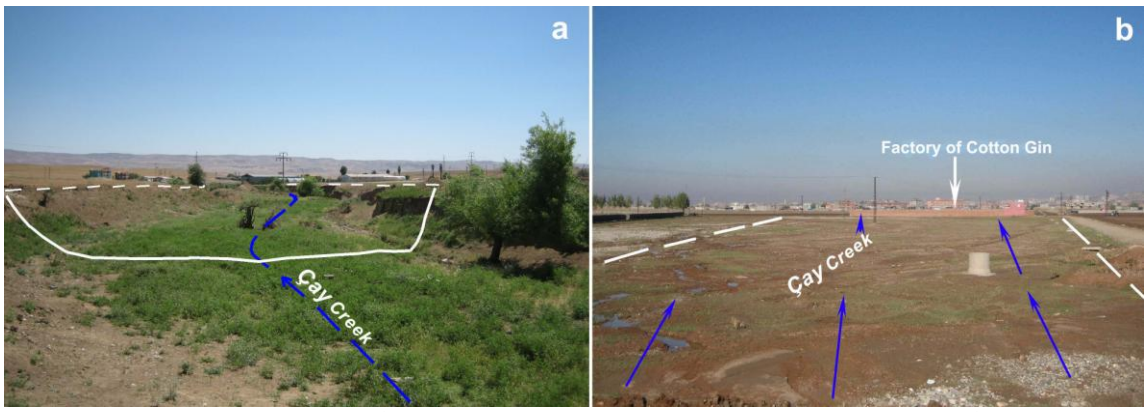

Photo 8. Çay creek, which affects the east part of Batman city. a) Stream bed of Çay creek, 4-5 m deep and 15-20 m wide south of Kösetarla village. b) Stream bed of Çay creek at entrance of the city.
(Foto 8. Batman şehrini doğudan etkileyen Çay Dere (a-Kösetarla güneyinde Çay Dere yatağı 4-5 m derinliğinde ve 15-20 m genişliğindedir, b-Şehir girişinde Çay Dere yatağı)

The stream bed of Çay creek, which is apparent up to the highway in the eastern part of Batman city, disappears at the entrance of the city. The stream bed of Çay creek, which enters the city by means of the wide bridge on the highway, disappears after passing this bridge (Photo 8, 9). The changes in the morphological structure of the stream bed as a result of human activities in Kösetarla village and at the entrance of the city cause Çay creek to overflow and greatly damage its environment following downpours. The creek gains the character of flood at the entrance of the city and affects the basement and ground floors of houses.

Photo 9. Bridge over Çay creek at entrance of Batman city and areas where water accumulates in times of flood.
(Foto 9. Batman şehir girişinde Çay Deresi üzerindeki köprü ve taşkın dönemindeki suyun biriktiği alanlar)

6.6. Other Creeks (Diğer Dereler)

Other than the above-mentioned creeks (including Savaro, Şakuli, Avare and Çay creeks), some small creeks whose basin areas are not so large also affect Batman city following intense precipitations. These include Aşağıkonak creek to the south and Şikestek, Kanikaemin, Guharohamo, Kanikulo, Demiryolu and Kanikermil creeks to the east (Photo 10,11). The stream beds of these creeks, which have small basins, have also been destroyed due to rapid urbanization.

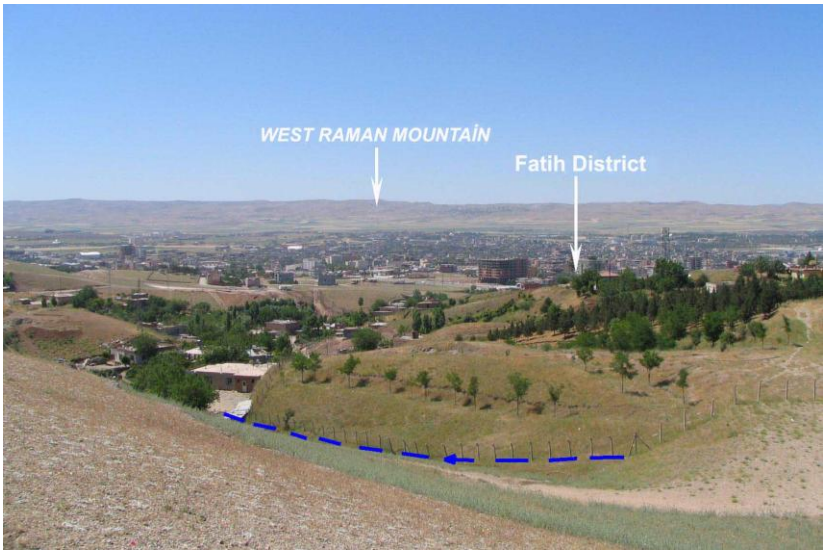

Photo 10. Stream bed of Kanikermil creek, seen completely occupied by illegal settlements. Dwellings built on this stream bed have rural characteristics and most of them are made of briquette.
(Foto 10. Kanikermil Dere yatağı tamamen kaçak yapılaşma ile doldurulmuştur. Bu dere yatağında yapılan meskenler kırsal karakterli ve çoğu biriketten yapılmıştır)

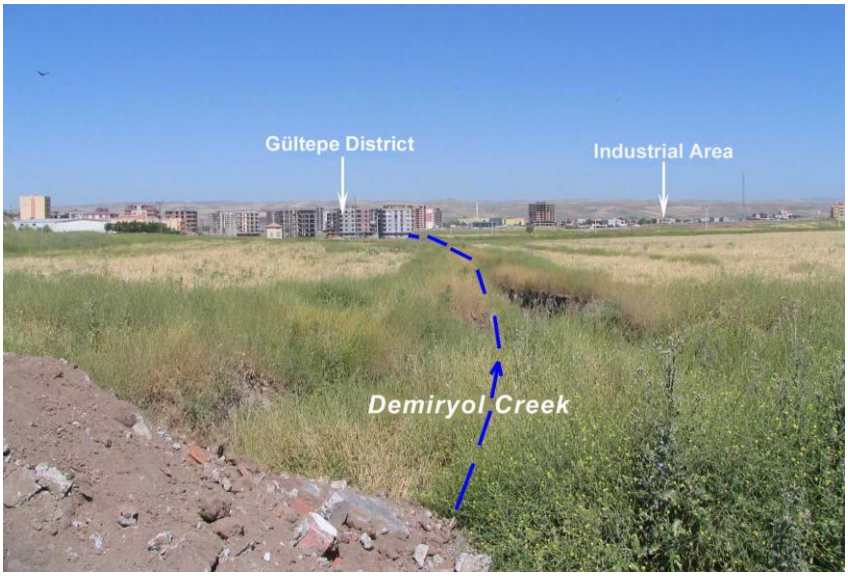

Photo 11. Morphological change continues due to the occupation of the stream bed of Demiryol creek, located in the east part of Batman city, and the construction of modern dwellings.
(Foto 11. Batman şehri doğusunda Demiryol Dere yatağının doldurulması ve modern konutların yapılmasıyla morfolojik değişim devam etmektedir)

7. DISCUSSION (TARTIŞMA)

Significant changes occur in the morphological structure of the foundation areas of cities due to urbanization and urban-induced structures. Changes in some geomorphological units, especially valleys, are clearly seen following large-scale excavations for roads, bridges and foundations. These changes are more rapid in areas experiencing rapid urbanization. Over time, changes in morphological structure due to urbanization may cause important problems, such as flood and torrent events.

The stream beds in all urban settlements experiencing rapid development in the last two to three decades in the southeastern part of Turkey have been destroyed. The devastation of stream beds in the area may be associated with inclination and especially climatic characteristics. Seasonal streams have caused fallacies with regard to urbanization across the region where arid and semi-arid climate conditions prevail. The impact of urbanization on arid region streams is another result of hydroclimatological events. Especially, dynamic streams in arid areas may cause fallacies with regard to urbanization. The streams in these areas are more effective than those in tropical areas. Temporary streams also carry a considerable amount of sediment similar to tropical streams (Reid and Frostick, 1987; Laronne and Reid, 1993). At the same time, arid areas exhibit maximum change with regard to the amount of precipitation and associated mechanisms (Graf, 1988). Due to these characteristics, the morphological structure of canals is subject to a rapid and irregular change (Rendell and Alexander, 1979). In such cities, stream beds located in the city center should be converted into canals as soon as possible to eliminate the risk of flood and torrent events.

8. CONCLUSION (SONUÇLAR)

Batman is a medium-sized city with a population of 293,024 which rapidly developed and urbanized due to the discovery of petroleum. The city exhibited urban characteristics in the 1980s and gained the status of province in 1990. After this period, the city experienced rapid and unplanned development as a result of migrations from rural areas. Due to the unplanned development of the city over stream beds and the fan formed by Iluh Creek and its branches, the morphological structure changed. The indistinct stream beds were transformed into streets and avenues by means of excavation works. Some of these stream beds were occupied by settlements and industrial plants. Due to rapid urbanization in Batman, the parts of creeks which are located inside the city were completely destroyed except for the stream bed of Iluh Creek. The size of the stream bed of Iluh Creek inside the city was reduced by a ratio of 1/3.

Iluh Creek, which was incorporated into the canal in the city center, also shifted out of its natural bed. Based on morphological change due to rapid and unplanned development in Batman, the frequency of flood and torrent events increased. Consequently, Batman was considerably affected by the flood event in the Southeastern Anatolia Region in the autumn of 2006.

As a consequence of urbanization, the stream beds of Savaro, Şakuli, Çay and Avare creeks disappear in the districts located at the entrance of the city (Figure 12). This change in stream beds is a direct result of rapid and unplanned urbanization. In addition, the low inclination and small amount of cleavage in the foundation area of the city facilitated changes in morphological units. Furthermore, the flow of creeks in rainy seasons and absence of flow in arid periods hampered preservation of the natural balance.

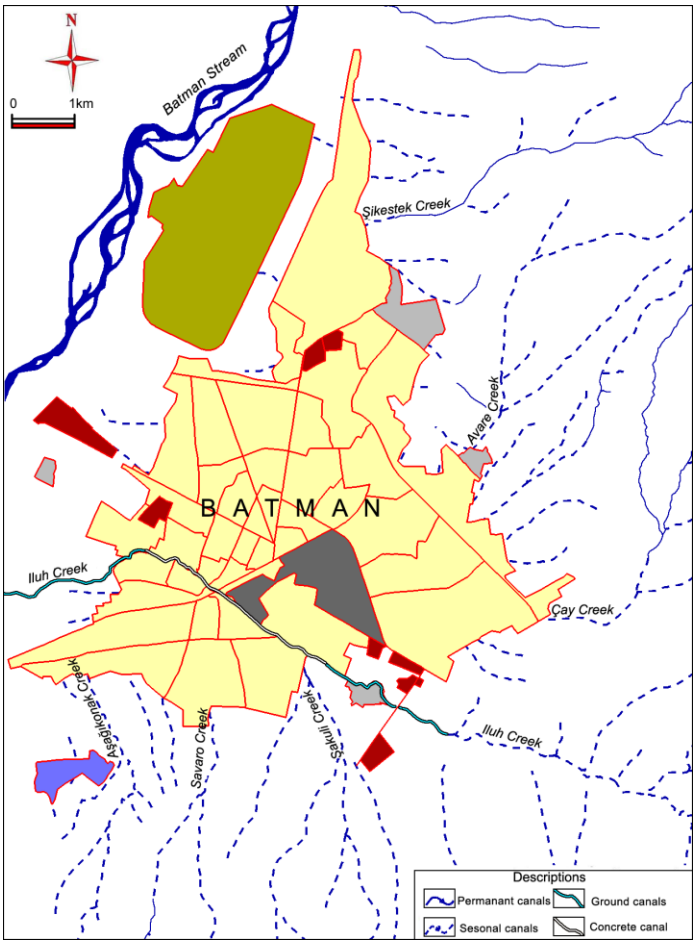

Figure 12. Changes in stream beds due to urbanization in Batman.
(Şekil 12. Batman'da şehirleşme sonucu akarsu yataklarında meydana gelen değişmeler)

Urbanization and the resulting rapid population growth increased the value of agricultural lands in the area neighboring the city. Consequently, people living in rural areas were forced to increase production. The necessity of obtaining more produce from the land gave rise to the farming of fertile flood plains. Agricultural usage of stream beds for many years caused the destruction of these beds.

In conclusion, significant morphological changes occurred in the foundation area of Batman city due to urbanization. Changes in morphological structure increased the frequency of flood and torrent events and contributed to the escalation of these events to catastrophic levels. In order to provide protection from such disasters, in addition to soil explorations conducted as part of normal construction practices, hydrographic analyses also need to be requested before the construction of dwellings.

It is vital that hydrographic and hydrologic explorations of areas newly zoned for construction should be carried out. The creeks which were ignored during the foundation process of cities should be designed and converted or incorporated into canals according to their basin areas and maximum flow rates. Sinuous must be avoided in the construction of canals.

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