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Floods, geodynamic environment and human intervention. The case of Corinth (Greece)

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Abstract

The town of Corinth (N. Peloponnessos, Greece) and the broader area suffered extensive damage and human life loss, when Xerias torrent burst its banks during extreme rainfall on 12 Jan. 1997. The results of this type of shower, which has a return period of 100 years, were aggravated by a number of factors, namely (i) topography, with frequent alternations between areas of high and low relief, (ii) catchment area and (iii) widespread occurrence of impermeable deposits. However, the most crucial factor was human intervention, in the form of waste and debris disposal along the course of the river, wrongly designed constructions (bridges, artificial canals) and finally the position of the city itself, which has been rebuilt on the mouth of the torrent. Design and prevention of such environmental hazards is all-important for the broader area, as it is prone to frequent and extensive floods.

1 Introduction

Floods are a global common geo-environmental hazard and can have consequences on the social and economic structure, on local or regional scale. In Greece they occur as flash floods and stem from heavy and showers in areas with high morphological relief. In the present decade many regions in Greece have suffered the catastrophic effects of such flooding phenomena as in the recent case of January 1997, where heavy rainfall in various areas in Greece caused extensive floods in northern

Peloponessos, in the town of Argos, the drainage basin of Sperchios river and elsewhere.

The area that was affected mostly by the intense rainfalls January 1997, was the broader region of the basin of Xerias torrent, in the mouth of which the new town of Corinth is built (northeastern Peloponessos). The toll was high: six people killed, extensive damage of houses, cultivations, and bridges while tens of cars were drifted away by the torrent.

It was not the first time that the town of Corinth was hit by such phenomenon. In 1972 the same stream flooded and drowned four people, while in August 1990 it just coped with a common heavy downpour where the torrent waters reached the highest level, but did not burst the banks.

The main factors that control the flooding vulnerability of an area, besides precipitation, are the following:

- ***Topography:*** intense and abrupt alternations of the relief result in the decrease of water velocity in areas of low gradient and the consequent accumulation in short time of vast volume of waters where the present stream-beds cannot discharge.
- ***The drainage network*****:** the area of the drainage basin, highest stream order and stream frequency.
- ***Geological conditions,*** especially permeability of the geological formations and the occurrence of flood deposits.
- ***Land use,*** that is urban areas, cultivated land, grasslands and densely planted or forested areas.
- ***Human interventions,*** mainly along the river beds, in the form of reduction of flow capacity of streams and accumulation of debris and waste in the river bed.

The aim of this paper is the investigation of the influence of the above factors in the occurrence of the floods in the area of Corinth on 12 January 1997. For this purpose, a detailed report on rainfall intensities will be presented and after all relevant factors have been listed, a discussion on the significance of each one in flood generation will follow.

Finally, the significance of prevention and/or action that must be taken after the occurrence of such phenomena, will be discussed, taking into account the particularities of area of Corinth.

2 Intensity of rainfall of 12/Jan. /1997

The meteorological station of Velou in Corinth gave the most reliable data, since it is the closest one in the area. The storm initiated at 21.00 on the 11th January 1997 and finished at midnight of the next day. In this period the hourly height of rainfall did not remain constant but increased in six periods with hourly height of rain output exceeding 20 mm, in the half of which there was extreme precipitation with hourly height of rain output above 30 mm.

The first hourly maximum was recorded between 23.00 and 24.00 (24mm); after an hour followed the peak (60mm in 2hrs). Between 04.00-05.00 and 06.00-08.00 on the 12th January 1997 the hourly heights exceeded 15 mm. After a four-hour period, the second and crucial maximum of hourly height of rain was recorded (37mm), while in three hours it added up to 87 mm.

The total height of rain output for the interval between the onset the storm and the first pause was 177mm, while in the crucial following 12 hours it was 141mm. Note that for that 12-hour period 61% of the rain fell in three hours. The total height of rain output between 9.00 on the 11th/Jan./97 and the 24.00 on 12th/Jan./97 was 320mm, while the average height of rain output for the month of January in the area is just 57 mm.

Oikonomou and Migardou,[1], analysing the above data and combining these with the barometric data from four other automated meteorological stations, they estimated that the storm was a rain episode with a return period of 100 years. They also pointed out that the occurrence of two extreme and successive downpours maximised surface runoff.

3 Morphology

The Xerias catchment (Fig. 1) can be distinguished in three areas. A southern one, of highest altitude and high relief, with the mountains of Trapezona (1137 m) and Psili Rahi (1078 m). An intermediate area where other smaller mountain ranges with a general E-W orientation exist, separated by areas of smoother relief. These mountain ranges form the Oneia Mountains to the east (max elevation 562m) and the hills of Profitis Ilias and Tsouba (701 m and 621 m respectively). The third area lies north, after Examilia and up to the mouth of Xerias with lower heights and generally smoother relief.

The catchment has intermediate gradients, varying between 15-20% in half of its area. Higher and gradients occur in the southern mountainous part (Fig. 1).

4 Drainage network

The total area of Xerias catchment is 1600 km^2 and a total stream length (combined) of 143km (Kalliris,[2]) (Fig. 1). The main stream that issues from the mountain range of Trapezona has length of 30 km. A major tributary is Klissoura torrent (16km long), which converges with Sousana (next to the railway station into the main stream at Sousana).

There is a high upstream gradient while from Athikia village until the confluence at the two main streams, the gradient is much lower. The latter area is the discharge domain of the Voukina and Klissoura torrents. In this area, the torrent shows gentle morphology, with bed width of > 80m and small depth. Low gradients are also observed beyond Examilia and after cutting through the Oneia Mountains, however in this area the bed is naturally incised.

5 Geology

Xerias catchment occupies the southern part of the neotectonic graben of "Eastern Corinth" and the northern part of the tectonic horst of "Arahnaio-Trapezona" (Papanikolaou,[3]). The outcrops in the hydrogeological basin of Xerias consist of alpine sediments which occupy areas of tectonic horsts, and post alpine ones which occur in tectonic grabens. The alpine formations belong to the Sub-Pelagonian unit and consist of thick-bedded to non bedded limestones, intensively deformed with the result of exhibiting enhanced secondary permeability and karstification. The post alpine formations comprise from the oldest to the youngest: the Eastern Corinth basin formation (marls, sandstones and polymictic continental conglomerate), the Sikiona-Ancient Corinth formation (marls, sandstones and conglomerates), the Ellinohorio formation (marine terraces consisting of cohesive conglomerates, sands and marls) and alluvial formations, coastal deposits and alluvial fan deposits. The hydrogeological behaviour of the post alpine formations varies in the vertical as well as the horizontal sense due to lateral transitions and frequent alternations. The formation with hydrogeological interest, because to its surface expanse, is the lower formation of marls and sandstones. It exhibits small to very small permeability, thus facilitating surface runoff.

6 Land use

Except the town of Corinth, no other urban areas occur in the remainder of the basin. However, what is interesting is that a large part of the basin has suffered extensive conflagration in the recent past and today it is sparse vegetated. Also, deforestation has taken place for agricultural reasons, either for creating cultivation land or pasture. The latter hinders infiltration and increases the velocity of surface flow.

7 Human interventions

A series of human interventions can be observed in the larger part of catchment which either reduce the stream cross-section, or impede water flow, while plenty of material, ready to be swept away, has been dumped into the river bed. Those interventions can be classified in the following categories: (a) cultivations, (b) debris disposal, (c) constructions within the river bed, (d) bridges and various constructions for the modification of stream flow and (e) artificial incision of stream. The description that follows is presented along flow direction from south to north.

In the area of Athikia and on the road that links the village with Hiliomodi, a small and low concrete bridge was built to facilitate the flow of rain waters, with a small, oblong-shaped opening (Fig. 1, damaged site 4). Apart from the inefficiencies that exhibited, it was also blocked by a boulder which caused the destruction of the road and a small downstream offset of the bridge itself. Athikia is built on a similar streams which discharge Mt. Trapezona. The result of the heavy rainfalls was the flooding of many houses (Fig. 1, damaged stite 5).

From Hiliomodi to the area of Sousana occurs the second bigger branch of Xerias, the Klisoura stream. Along this appear small constructions, mainly bridges, with pipes of small cross-section that were finally blocked by washed off material, such as stones and logs (Fig. 1, damaged sites 1 & 2). Sand and silt of considerable thickness were deposited upstream of the constructions. Near Soussana, the bed of Klisoura is about 50-80m deep, while part of it has been cultivated; also a house was observed in it.

In the plain of Soussana the river bed is quite broad, with ill-defined levees. There are vineyards dive orchards in the whole river bed is

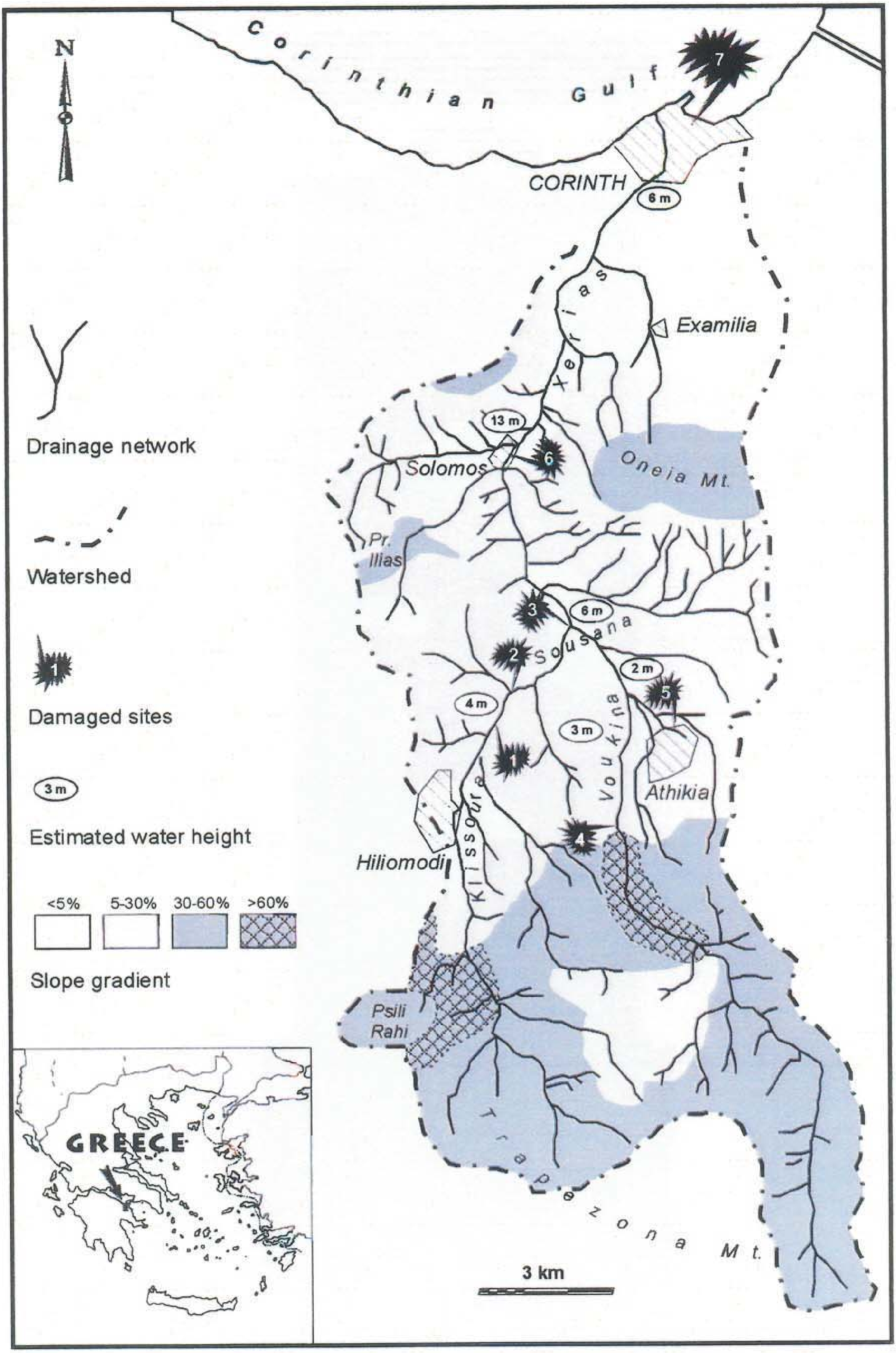

Figure 1: The area that was affected by the intense rainfalls of January 1997.

cultivated with vines and olive trees, while the road axes which link the villages in the area are located within this plain. During the floods, the level of the water reached at least 2 meters above the old national motorway of Corinth-Argos, as evidenced by remnants of debris.

At the confluence of two main streams a new motorway bridge has been built, quite close to the older one. Both of them are made of concrete and have large, round openings that unfortunately proved inadequate to cope with such high precipitation (Fig. 1, damaged site 3). The old bridge was blocked by debris and the new one by a bus that was carried away by the torrential stream (Fig. 2). Vast expanse of vineyards was flooded and the new motorway was destroyed.

Even the high arch bridge at Solomos did not cope successfully with the torrential flow (Fig. 1, damaged site 6). Despite the fact that the river bed there is incised and deep enough and the arch is about 6m high, 20m wide, large uprooted trees blocked it (Fig. 3) and the water level rose and flooded the nearby houses 2 m above the road surface.

From Solomos up to Corinth the stream bed is naturally incised. However human intervention along its course has weakened its flow capacity. Debris and waste by the river had provided abundant material that was washed away by the torrent.

Corinth is built on the delta fan of Xerias. Within the town, the stream bed is artificially incided along the two thirds of its course, in a rectangular cross-section concrete canal, on the upstream end of which exist three concrete bridges, the parapets of which were destroyed and trucks, that were swept off by the torrent, were wedged in between (Fig. 4). The stream, on entering the town, turns 60^o eastwards. On this bent an iron low railway bridge was built, and did not withstand the torential flow. At the turn of the canal the low preventing wall could not hold away the water, which flooded hundreds of houses and swept away tens of cars.

The construction of the new Athens-Patra motorway aggravated the situation, as all neighbouring streams were redirected to Xerias. In all, an extra $1.5{\times}10^6 m^3$ are estimated to have been channelled in this way during the storm.

8 Discussion-conclusions

What should be stressed at first is that this type of rainfall is a one-in-the-century event, as evidenced by the available data. The total rainfall in 24 hours was 320 mm, giving a water volume of $51.2{\times}10^6 m^3$ for the whole catchment, plus $1.5{\times}10^6 m^3$ supplied from the drain system of the new

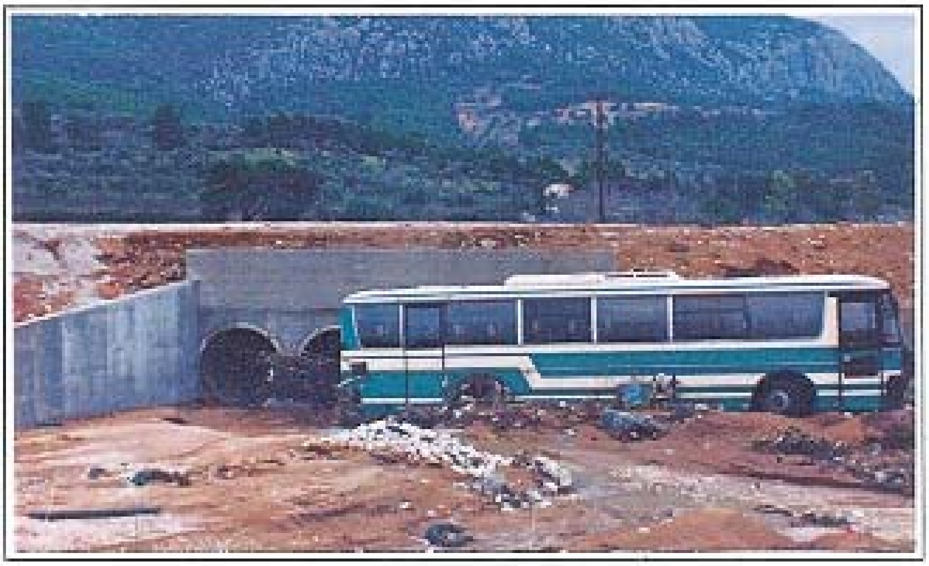

Figure 2: Motorway bridge pipes blocked by a bus that was carried away by the torrent.

Figure 3: Large uprooted trees blocked the high arch bridge at Solomos village.

Figure 4: The parapets of the bridge were destroyed and trucks, that were swept off by the torrent, were wedged in between.

national motorway. The largest part of this volume had to be drained into the Corinth Gulf through the drainage network of Xerias, if we also take into account the factors that have reduced infiltration, as deforestation and occurrence of impermeable deposits.

Environmental conditions might have been adverse but nature can channel even extreme volumes of water, if human intervention has not altered certain natural procedures. This is the second and most important factor which aggravated the results of the flooding phenomena. What is also noteworthy is that even in cases of constructions where prior investigation is essential, such as artificial incision of streams in the town of Corinth (together with other flood-prevention measures), the construction of the railway bridge or the new bridge in the old national motorway Corinth-Argos, proved insufficient. The crusial mistake in all these cases has been that a design period of 30 years was taken into account, which was not representative.

Note that Corinth has been re-located, due to the destruction of the old town in the earthquake of 1858. This relocation proved to be quite unfortunate, as the town has been founded mostly on the flood deposits of Xerias. During the flood, the river followed its natural course. Even so, all these could have been avoided since it is not the first time the town has been flooded.

Another point which must receive special emphasis is the areas where the floods occurred. Besides the town itself, which is built on the delta of the torrent confluence the Sousana plain, the two main streams of Xerias was also flooded. This is a planar area which has been formed by the alluvial deposits of two more streams, transported from the mountain range of Trapezona and Psili Rahi. In this area it is reminded that during the interval between the two hourly maximum of rainfall, there was deposition of alluvial deposits, mainly sand, silt and coarse clay, which were then washed away by the second phase of heavy rainfall. This observation indicates that the areas which were hit by the floods are not accidental but have to do with the field of influence of the floods around the stream, the extent of which is also evidenced by the older flood deposits.

The morphology of the catchment area and the form of the drainage network are under the tectonic control. The broader area of the Corinth gulf generally is characterised by large active fault zones striking E-W, some of which occur in the drainage basin of Xerias. These faults bound a number of fault blocks (tilted blocks) with areas of high morphological relief in the upthrown ones and low relief in downthrown ones. The former are deeply incised, while the latter are filled with alluvial deposits.

In conclusion, it can be said that although the flooding vulnerability of Corinth is extremely high, a new relocation sounds unrealistic. What should be done is a comprehensive study on flooding hazard protection and mitigation. The design period should include a time-span long enough to include phenomena with return period of at least 100 years. Such study (or studies) should also include investigation of the hydrogeological behaviour of formations, the geomorphological features and redesign of human interventions.

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