

## Article

# Investigation of Flood Management and Mitigation Measures in Ungauged NATURA Protected Watersheds

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**Abstract:** The aim of this study is to investigate the flood management and mitigation measures in ungauged NATURA protected watersheds. The examined watersheds are located in one the most European significant NATURA areas (Prespa Natural Park North Greece). SCS-CN model was applied to perform the hydrological modeling for extreme rainfalls of 50, 100 and 1000 return periods. Extensive field research was conducted to record all the hydrotechnical works of the study area, to evaluate their current condition and measure the respective hydraulic characteristics. The results of the hydrological modeling showed that the flood danger in the study area is generally low. However, almost the half of the hydrotechnical works could not discharge the high and medium probability (50 and 100 years) peak flows. The main causes are the extremely dense riparian vegetation that has been developed on the banks and the thalweg of the riverbeds and in some cases the inappropriate dimensioning of the technical works. The intense development of the riparian vegetation, has increased the roughness coefficient and reduced the dimensions and discharge capability of the technical works, while NATURA restrictions and regulations may be limiting any logging and trimming activities within the streams, especially in priority habitat types. Special Ecological Evaluation studies and educating the public about the necessity of the flood control measures and impact, could provide a framework for a thorough discussion about the flood management in NATURA areas.

**Keywords:** flood generation; hydrotechnical works; hydrological modeling; riparian vegetation; SCS-CN model



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## 1. Introduction

Floods are natural phenomena that constitute an integral part of the hydrological cycle. Most floods are triggered by interactions between extreme unexpected weather events and the watershed geo-hydrological characteristics (relief, land uses, geomorphology, human interference) [1–4]. Floods in Mediterranean region could be considered to be the most often, destructive and hazardous natural phenomena, which usually occur in ephemeral streams and small-scale watersheds [5–8]. The last decades, floods have caused significant human fatalities [9–16] and noteworthy financial losses [10,17–20]. In Greece, as in the rest of Mediterranean area, a main factor that increases the potential of flood events is the human interventions such as urban sprawl [3,10,21–24], a fact that strongly influences the hydraulic characteristics of streams and floodplains [10,25,26].

The investigation of extreme flood events in ungauged watersheds, using hydrological and hydraulic models, presents high uncertainties, because of the short lag time, the unexpected nature of flood phenomena and the lack of rainfall and discharge data [10,25,27,28]. For those reasons, the flood management is very complicated and difficult to be applied in ungauged watersheds. These difficulties are even more intense in NATURA protected

watersheds, because of the special regulations and restrictions, concerning the management of the protected vegetation species and the strict rules of the construction/maintenance of hydrotechnical and flood control works [29,30].

Natural lakes and reservoirs create special conditions for the breeding of wild life, but human interventions and land use changes could be a threat [31,32], downgrading the quality of the habitats. On the other hand, they are particularly important for the human activities such as water for irrigation, drinkable water, fishing, human recreation, etc. [33,34].

The development of dense riparian forest in all the streams of the study area (Greek part of Prespa Natural Park basin) creates a special ecosystem of high ecological and aesthetic value. It also protects the slopes of the riverbeds from potential erosion [35]. The dense riparian forest consists mainly of large trees and shrubs, decisively influencing the roughness coefficient and favoring the sediment deposition. This fact results in a sharp decrease of water velocity and cross sections dimensions, reducing the discharge capability of the hydrotechnical works. The decision making, concerning the logging and trimming of the large trees and shrubs, the removal of sediment deposits from the banks and streams' thalweg, the construction of new flood control works and the maintenance of the old works, generates social conflicts among ecological groups, individual ecologists, local residents and local authorities, who suggest different flood management strategies to be applied.

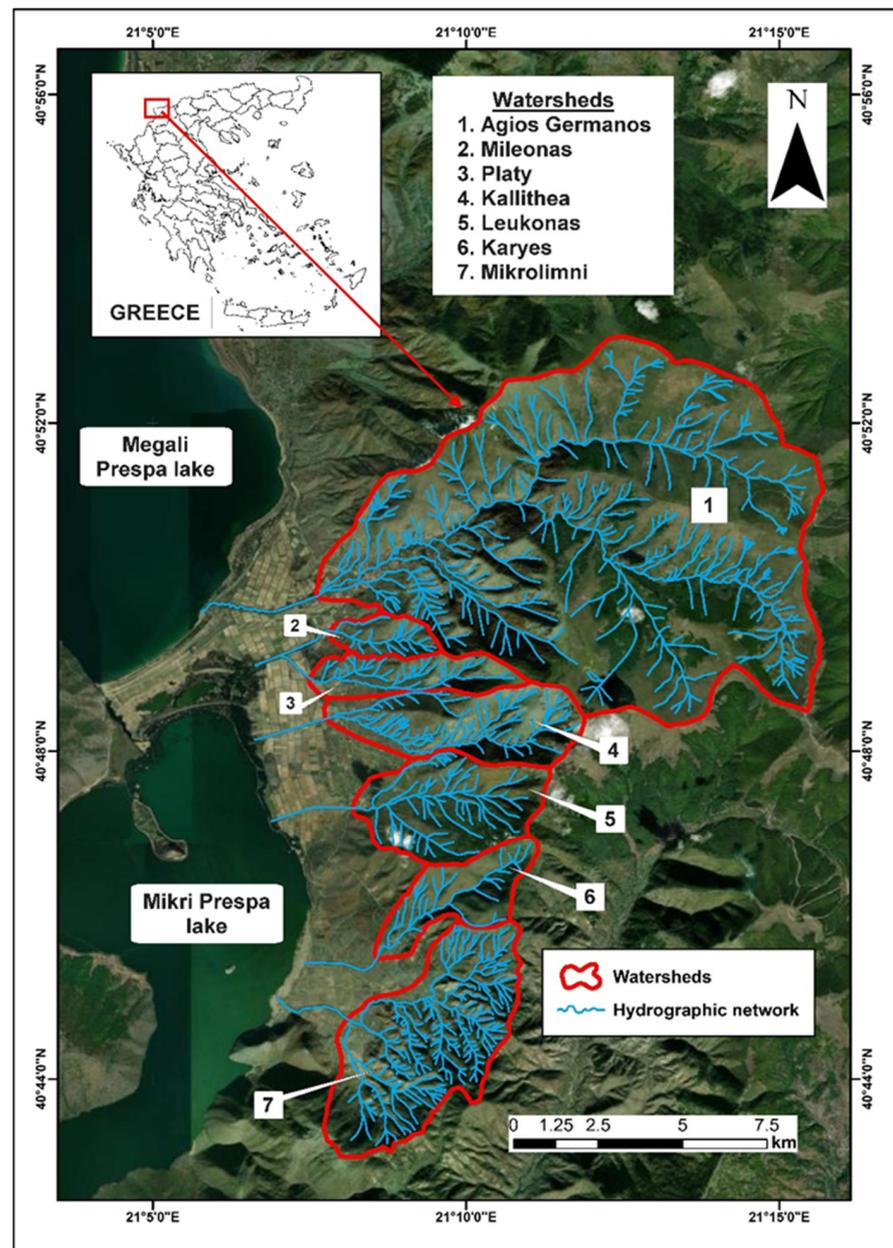
The conflict between the scopes of the European Commission (EC) Water Framework Directive and the EC Habitats Directives (NATURA 2000) is known and generates conflict of interests among different people groups [36]. To the best of our knowledge there are few studies that deal with the flood risk management in NATURA protected areas [37,38], and there are very few that deal with ungauged NATURA protected small catchments [39], in which the zero-intervention strategy is applied within the floodplain area.

The aim of the study is to investigate the flood management in ungauged watersheds, which are under the protection of the NATURA regulations and restrictions, in the Greek Part of Prespa basin (GR 1340001). More specifically, (a) all the hydrotechnical works that influence the surface water flow were recorded, (b) the most flood vulnerable hydrotechnical works were located during the field work, (c) the stream maximum discharges were calculated for 50, 100 and 1000 return periods according to EU Directive (2007/60/EK), (d) the water discharge capability of each hydrotechnical work was calculated and evaluated in comparison to the stream maximum discharges, (e) the influence of NATURA regulations and restrictions that concern the construction and maintenance of the hydrotechnical works was discussed based on the study results.

## 2. Materials and Methods

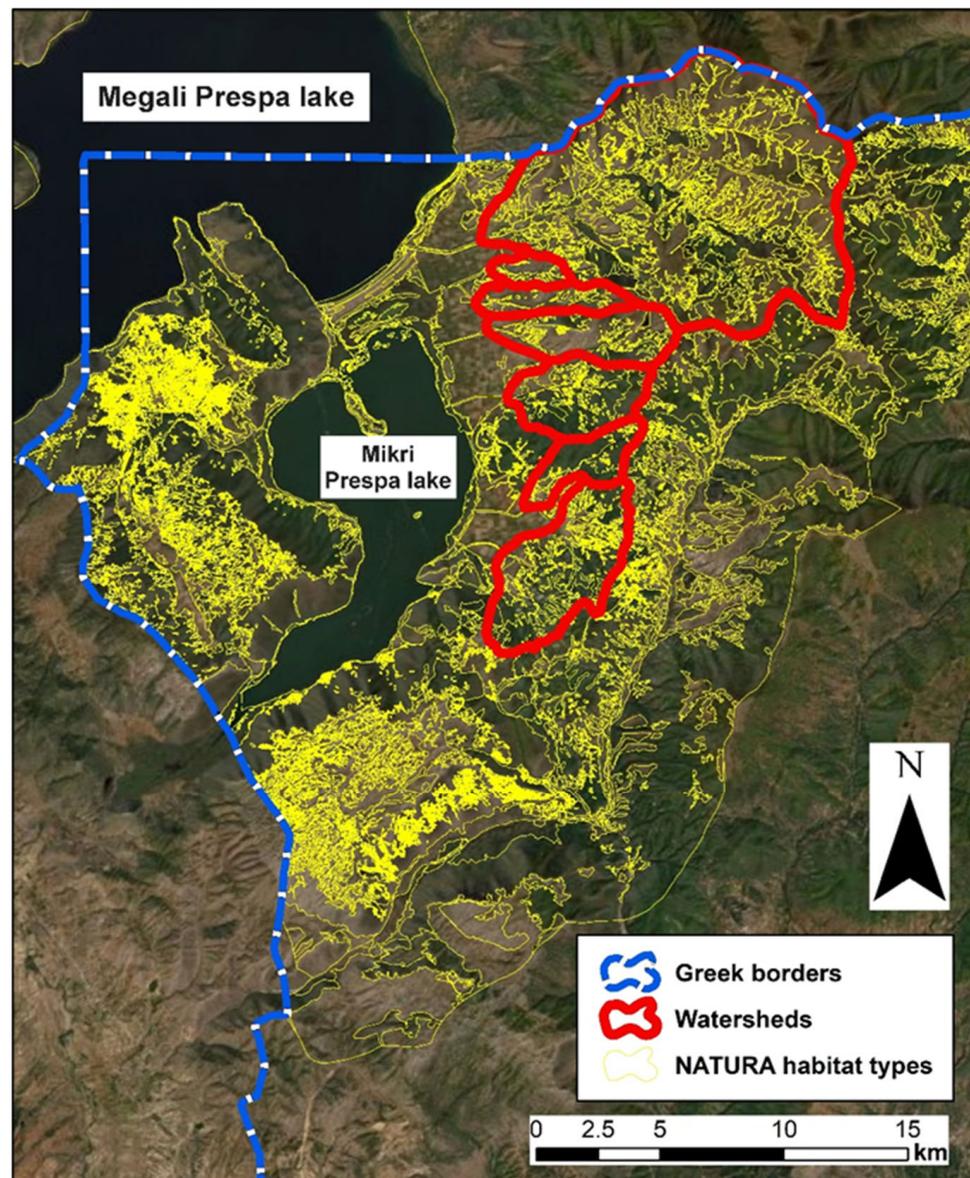
### 2.1. Study Area—Watersheds Description

The importance of the Prespa natural park (Figure 1) for the conservation of nature is really high. At its ecosystems one could find lots of rare species with some of them being endemic and appearing only at the Prespa lakes. More than 1800 plant species on 70 vegetation types, 270 bird species (of which 143 breed here) and lots of important fish, reptiles, amphibians and mammals can be found at the area. The district hosts a lot of endangered and threatened species on 49 different ecotypes in a restricted range where the diversity of altitude, land uses, climatic conditions and geological backgrounds is great [35,40]. Due to the wealth of the region, 4 different sites of the NATURA 2000 network have been designated. Prespa is also included at the Ramsar convention as a wetland of international importance.



**Figure 1.** The watersheds that examined in the Greek part of Prespa Natural Park.

The dense forest vegetation that is growing on the stream banks and thalwegs of the study area, influences the flow of the flood water discharge, by increasing the roughness coefficient and decreasing the water velocity. Additionally, the dense forest vegetation traps significant amounts of sediments of various dimensions, which drastically decrease the stream cross sections dimensions, also decreasing the water discharge capability. The vegetation management within the stream banks and thalweg and the construction and maintenance of the technical works is very complicated, because the vegetation of the study area is part of the NATURA habitat types (Figure 2, 92A0-*Salix alba* and *Populus alba* galleries, 91E0-Alluvial forests with *Alnus glutinosa* and *Fraxinus excelsior*) [40,41]. As a result, any human intervention (flood management plans, flood control measures, construction and maintenance of the technical works) within the study area should be followed by a Special Ecological Evaluation study.



**Figure 2.** NATURA habitats types in the wider research area.

The hydrological modeling was applied in seven (7) typical Mediterranean watersheds, namely Agios Germanos, Mileonas, Platy, Kallithea, Leukonas, Karyes and Mikrolimni (Figure 1). These seven watersheds assigned with the respective settlement names, form the Greek part of the basin of the Prespa Natural Park. The total study area is 104.83 km<sup>2</sup> and the headwaters of the main streams are located to Varnoudas (2334 m a.s.l.) and Moutsaras (2113 m a.s.l.) mountain ranges, the main streams flow generally with a west direction, pass through the above-mentioned settlements and finally flow into Prespa lakes. The relief of the watersheds could be characterized as mountainous and very steep, with an average slope over 42%, but with significant differentiation between the floodplain and the areas above 1000 m a.s.l. In Table 1 the main watershed morphometric characteristics are presented.

**Table 1.** Morphometric characteristics of the watersheds in the study area.

	Area (km <sup>2</sup> )	Perimeter (km)	Min Altitude (m)	Max Altitude (m)	Mean Altitude (m)	Mean Watershed Slope (%)
<b>Agios Germanos</b>	65.02	34.86	861	2334	1630	44.65
<b>Mileonas</b>	1.85	6.01	873	1406	1049	39.96
<b>Platy</b>	3.75	10.99	867	1970	1186	37.03
<b>Kallithea</b>	7.88	13.54	878	2109	1358	47.34
<b>Leukonas</b>	8.01	11.63	901	1835	1231	41.38
<b>Karyes</b>	4.52	10.76	892	1675	1231	37.33
<b>Mikrolimni</b>	13.80	16.86	863	1496	1068	40.78

The 47.2% of the watersheds area is covered by grass land and pastures, 38.3% is covered by broad leaved and coniferous forests, 5.5% and 4.9% is covered by cropland and bare rocks, respectively, but with differentiation among the watersheds. The dominant rocks of the area are gneiss and granite, which behave as an impermeable formation to the water infiltration, and their participation exceeds the 90%. Most of gneiss lithological types are easily weathered and covered by loose weathering mantle of ranging thickness, resulting in the manifestation of springs of usually low yield, in its contact with the intact rock [42]. The formation of the drainage network is mainly dendritic, the average density of drainage network is calculated to be 4.63 km/km<sup>2</sup> and the average main stream slope is 11.08% (Table 2). The density of the drainage network in the study area is relatively low, a fact that is attributed to the forest coverage and the extended presence of erosion resistant rocks (gneiss and granite).

**Table 2.** Hydrographic characteristics of the watersheds in the study area.

	Drainage Network Formation	Drainage Network Density (km/km <sup>2</sup> )	Main Stream Length (km)	Main Stream Average Slope (%)
<b>Agios Germanos</b>	Dendritic	3.30	18.82	6.08
<b>Mileonas</b>	Dendritic	5.30	4.47	10.89
<b>Platy</b>	Parallel	4.52	6.27	15.21
<b>Kallithea</b>	Parallel	5.07	8.27	14.69
<b>Leukonas</b>	Dendritic	4.38	6.12	11.32
<b>Karyes</b>	Parallel	4.14	6.44	11.80
<b>Mikrolimni</b>	Dendritic	5.71	7.15	7.63

## 2.2. Estimation of the 24-h Maximum Rainfalls for 50, 100 and 1000 Years Return Periods

The European Directive 2007/60/EC for the flood risk assessment, clarified that the flood risk should be calculated concerning the return periods of 50, 100 and 1000 years, estimating the respective Intensity–Duration–Frequency (IDF) rainfall curves. The calculation of IDF rainfall curves is a complex process, which requires the use of long rainfall time series, strict time step, reliable data and short recording time step (less than 6 h). Unfortunately, there are no adequate and detailed rainfall data in the study area. To overcome this limitation, the time series of the daily maximum 24-h rainfall obtained from Koula Meteorological Station (MS) were used. Koula MS in operating continually for the last 64 years, and thus provides a significant time series length. However, Koula MS has only operated as an automated rain gauge with 30 min time step for the last seven years. Statistical analysis was implemented using the Hydrognomon software [43]. Initially, a quality control of the data was performed to identify potential extreme values that do not make sense, but also the dates on which missing values have been recorded. The missing values were substituted by applying the method of simple linear regression [44],

using all the available time series of the broader study area. The error of the predicted values was calculated using well known statistic indexes, the Root Mean Square Error (RMSE), the Nash-Sutcliffe efficiency (NSE) and the Mean Bias Error (MBE). The Standard Deviation (SD) was calculated to be 5.97 and the RMSE was 3.17, almost the half of SD, which indicates an acceptable error range [45,46]. The NSE was 0.66, which falls into the model acceptable range (0–1) [45,46]. The MBE was –0.98, indicating an underestimation of the predicted values, which is totally normal, as the Koula rain gauge is located at a lower altitude and presents lower values of precipitation.

Statistical analysis was performed on time series data in order to calculate the 24 h max rainfall. The statistical distributions were subjected to  $\chi^2$  test and Kolmogorov–Smirnov test to evaluate how well they were fitted to the time series, taking into account the concern about the influence of the time series length on distribution performance. The distribution that was best fitted to the time series was the GEV-max (Generalized Extreme Value-max; Figure 3 and Tables 3 and 4). According to the analysis, the maximum 24 h rainfalls for 50, 100 and 100 years return periods were 77.4 mm, 84.9 mm και 108.9 mm, respectively.

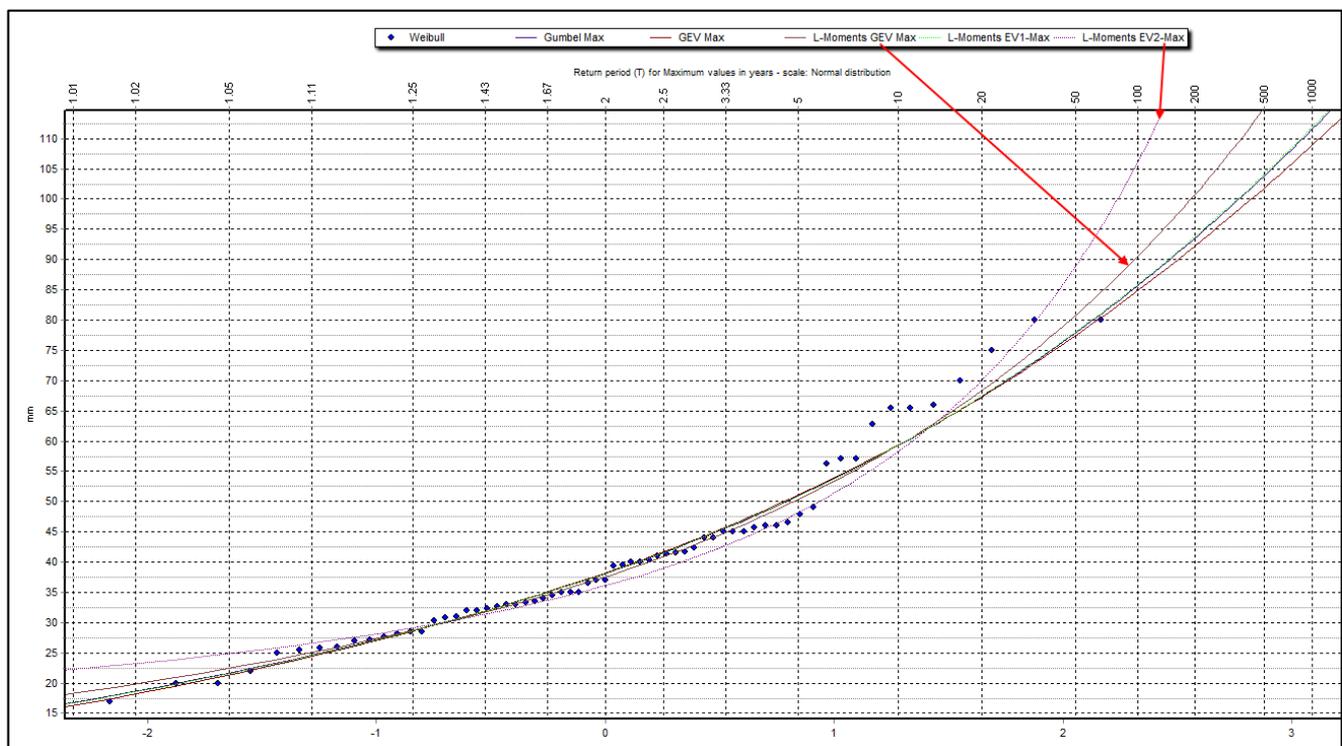


Figure 3. The 24-h maximum annual rainfalls depicted in a normal scatter plot with the tested distributions.

Table 3. Distributions’ performance subjected to  $\chi^2$  test.

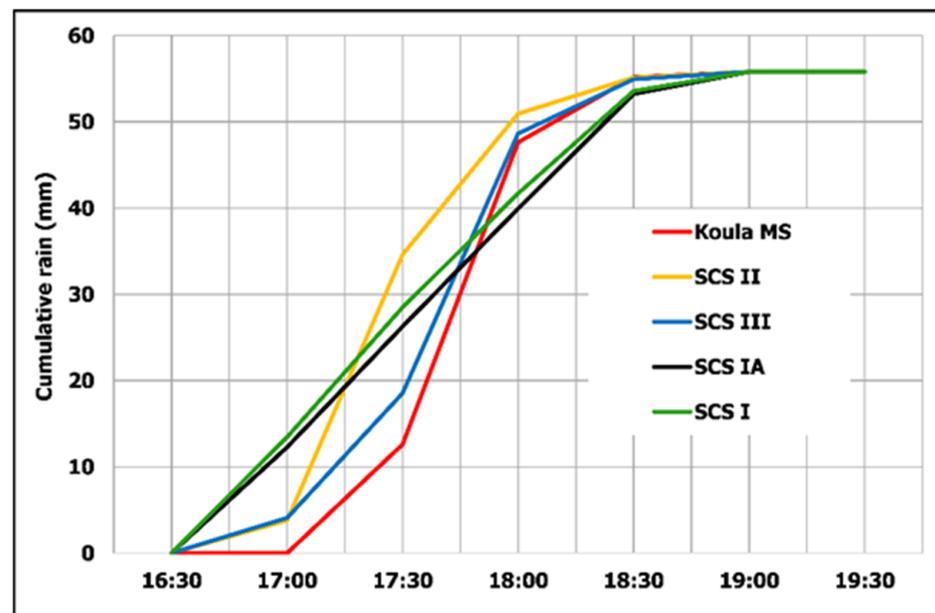
x-Square Test	a = 1%	a = 5%	a = 10%	Attained a	Pearson Param.
EV1-Max (Gumbel max)	ACCEPT	ACCEPT	ACCEPT	17.13%	7.73846
GEV-Max	ACCEPT	ACCEPT	ACCEPT	22.12%	5.67692
GEV-Max (L-Moments)	ACCEPT	ACCEPT	ACCEPT	21.71%	5.76923
EV1-Max (Gumbel, L-Moments)	ACCEPT	ACCEPT	ACCEPT	13.18%	8.47692
EV2-Max (L-Moments)	ACCEPT	ACCEPT	ACCEPT	13.18%	8.47692

**Table 4.** Distributions' performance subjected to Kolmogorov–Smirnov test.

Kolmogorov–Smirnov Test	a = 1%	a = 5%	a = 10%	Attained a	DMax
EV1-Max (Gumbel max)	ACCEPT	ACCEPT	ACCEPT	92.35%	0.06814
GEV-Max	ACCEPT	ACCEPT	ACCEPT	93.71%	0.05122
GEV-Max (L-Moments)	ACCEPT	ACCEPT	ACCEPT	92.97%	0.05484
EV1-Max (Gumbel, L-Moments)	ACCEPT	ACCEPT	ACCEPT	91.93%	0.06865
EV2-Max (L-Moments)	ACCEPT	ACCEPT	ACCEPT	57.55%	0.09686

### 2.3. Disaggregation of the 24-h Maximum Rainfalls for 50, 100 and 1000 Years Return Periods

To perform the hydrological simulation in the study area, it was necessary to disaggregate the calculated values of the 24-h maximum rainfalls (50, 100 and 1000 years return periods). The disaggregation was achieved applying the SCS storm types (I, IA, II, III), compiled by the Soil Conservation Service [47]. To decide which of the four storm types was best fitted on the available storm data from Koula MS, a comparison with known extreme events was applied. During the field research, residents and local authorities were asked if they had witnessed flood events in the past. Based on this information, an extreme flood event was recorded on August 3, 2015 between 17:00 and 19:00, which could be confirmed by the available meteorological data. The total recorded rainfall was 55.8 mm with duration of 2 h. The total rainfall (55.8 mm) was disaggregated using the SCS storm types for 2 h duration [48] and compared with the observed rainfall data (Figure 4).



**Figure 4.** Disaggregated cumulative rainfall event (3 August 2015, 55.8 mm) using SCS storm types (I, IA, II, III) compared with the observed data (Koula MS).

### 2.4. Hydrological Modeling

The hydrological modeling was applied for the seven watersheds of the study area, using the rainfall-runoff model of Soil Conservation Service–Curve Number (SCS-CN) [47]. SCS-CN hydrological model is well-known and widely used in many countries [49–53] and also in Greece [54–60]. The Curve Number (CN) is a dimensionless empirical parameter used for the estimation of runoff and infiltration from rainfall excess, and ranges from 30 to 100, with the highest values indicating higher runoff potential.

The Hydrologic Engineering Center's Hydrologic Modeling System (HEC-HMS) software [61] was implemented to calculate the flood hydrographs for 50, 100 and 1000 years return periods. The basic components of HEC-HMS software (CN, impervious area, transform method, base flow method, initial abstraction, lag time, loss method, etc.) were set as follows: CN (loss method), no baseflow method (ephemeral streams) and SCS unit hydrograph (transform method) were applied. The initial abstraction and the respective CN were modified according to Antecedent Moisture Conditions (AMC) and the flood hydrographs for each watershed and return period were calculated two times, one for AMCI and one for AMCII, in order to cover the worst flood scenarios. SCS considers that there are three categories of Antecedent Moisture Conditions (AMC), which are Type I (dry), Type II (medium) and Type III (wet). These are defined based on cumulative rainfall thresholds of the previous five days, as shown in Table 5.

**Table 5.** Categorization of rainfall of the previous 5 days for the calculation of the initial rainfall losses of the SCS-CN method [62].

AMC Group	Total 5-Day Antecedent Rainfall (mm)	
	Dormant Season	Growing Season
I	Less than 13	Less than 35
II	13–28	35–53
III	Over 28	Over 53

The SCS-CN model was previously calibrated and validated in other relevant studies in Greece, which presented similar geomorphologic and land-use conditions [26,55].

The dimensionless empirical parameter CNII,20 (for AMC II average humidity conditions and an initial loss rate 20%) was estimated using GIS techniques and the empirical equation provided by the "Deucalion Project", which has been validated in Mediterranean watersheds [63]:

$$\text{CNII,20} = 10 + 9 \times \text{iPERM} + 6 \times \text{iVEG} + 3 \times \text{iSLOPE} \quad (1)$$

where iPERM (water permeability), iVEG (land uses-vegetation density) and iSLOPE (drainage capability) are variables that receive values ranging between 1 and 5, according to the related tables [63,64] and field research. The iPERM was based on the dominant type of building constructions, soil and geological characteristics of the watersheds, which were estimated using the geological maps (1:50,000) provided by the Institute of Geology and Mineral Exploration of Greece [42] (map sheets: Florina and Korytsa), as well as field surveys. The vegetation variable (iVEG) was estimated using the detail data that are available from the Greek Ministry of Environment and Energy [41]. A Digital Elevation Model (DEM, 5 × 5 m resolution) provided by the Hellenic Cadastre was used, in order for the iSLOPE variable to be estimated.

Humidity conditions II and the corresponding CNII values are considered to be representative of 50% of the flood episodes. However, during the winter season when the soil is almost permanently saturated, the CNII value does not correspond to the real conditions. For this reason, the value corresponding to average humidity conditions (type II) should be converted to the initial soil moisture conditions type III according to the empirical relation [62]:

$$\text{CNII,20} = (23 \text{ CNII,20}) / (10 + 0.13 \text{ CNII,20}) \quad (2)$$

Concerning the time of concentration ( $t_c$ ), previously published studies refer that Giandotti equation is more reliable in the Greek and Mediterranean watershed conditions [64,65]. For that reasons, Giandotti equation [66] was selected to be used in order to calculate the time of concentration ( $t_c$ ):

$$t_c = \frac{4\sqrt{F} + 1.5 L}{0.8\sqrt{H - h}} \quad (3)$$

where,  $t_c$ : the time of concentration (hours),  $F$ : watershed area ( $\text{km}^2$ ),  $L$ : the main stream length (km),  $H$ : average altitude (m).

The lag time ( $t_L$ ) was calculated in relation to the time of concentration ( $t_c$ ) using the following equation [67]:

$$t_L = 0.6 \times t_c \quad (4)$$

where,  $t_L$ : the lag time (hours) and  $t_c$ : the time of concentration (hours)

### 2.5. Field Work—Maximum Water Discharge Capability of the Technical Works

The main purpose of the field survey was the detailed recording of the technical works that were associated with the surface water runoff in the watersheds and the influence on the maximum water discharge. Additionally, using information provided by the residents and the local authorities, the flood vulnerable locations and technical works were recorded. The current conditions, dimensions, Manning's roughness coefficient and stream slope of the selected technical works (bridges, culverts, water pipes) that discharge the water peak flow were measured and the maximum discharge capability was calculated. These hydrotechnical works presented limited dimensions, poor maintenance and their locations (near settlements, infrastructures, livestock, road network) are characterized by high flood risk, and in case of flood event significant human life and socioeconomic losses could be emerged. The hydraulic characteristics of the selected cross sections are presented in Table 6.

Using the measured hydraulic characteristics of the selected cross sections of the technical works, the maximum water discharge capability was calculated applying the Manning equation [68]:

$$u = 1/n \times R^{2/3} \times J^{1/2} \quad (5)$$

$$Q = F \times u \quad (6)$$

where,  $u$ : water velocity (m/s),  $R$ : hydraulic radius ( $R = F/U$ ),  $F$ : cross section area ( $\text{m}^2$ ),  $U$ : cross section wetted perimeter (m),  $J$ : energy grade line slope (m/m),  $n$ : Manning's roughness coefficient [69] and  $Q$ : water discharge ( $\text{m}^3/\text{s}$ )

During the field survey, the vegetation that was growing near the technical works, on the banks and the thalwegs of the streams was recorded, with the aim to evaluate the influence of vegetation on the maximum water discharge. According to the field survey and the habitat types (Council Directive 2006/105/EC), all the vegetation types in the study area are under the protection of the NATURA regulations and restrictions.

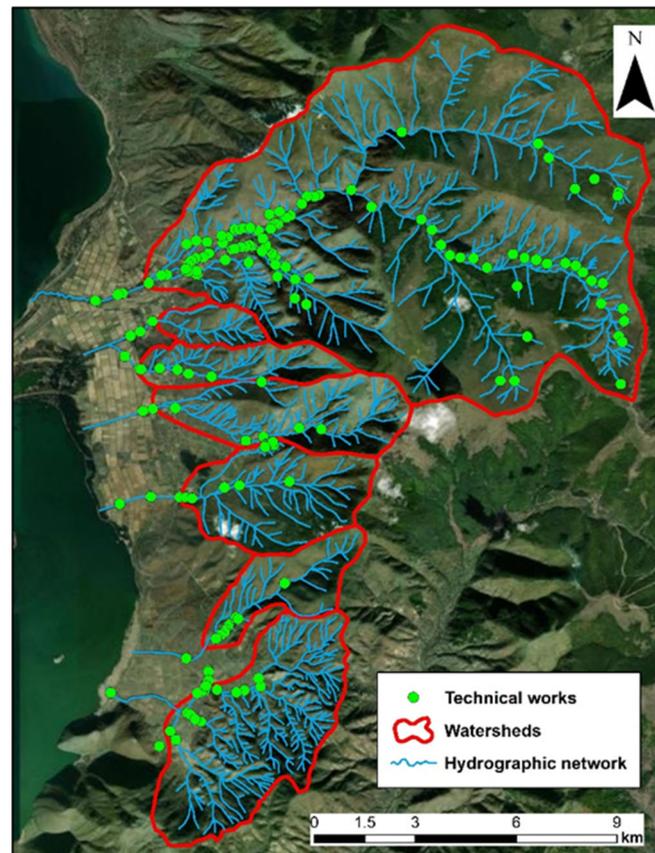
**Table 6.** Hydraulic characteristics and the water velocity of the examined cross sections.

		Cross Section Width (m)	Cross Section Height (m)	Slope J (m/m)	Wetted Perimeter U (m)	Manning's Roughness Coefficient ( <i>n</i> )	Cross Section Area (m <sup>2</sup> )	Hydraulic Radius R (m)	Water Velocity u (m/s)
1	Agios Germanos (AG18-bridge)	7.70	2.30	0.0440	12.0.033	0.028	17.71	1.44	9.36
2	Agios Germanos (LE6-culvert)	2.80	2.00	0.0340	6.80	0.04	5.60	0.82	4.05
3	Agios Germanos (LE3-culvert)	3.50	1.70	0.0530	6.90	0.04	5.95	0.86	5.21
4	Agios Germanos (YP12-culvert)	1.60	1.00	0.0790	3.60	0.04	1.60	0.44	4.09
5	Agios Germanos (YP9-culvert)	4.00	2.70	0.0807	9.40	0.028	10.80	1.15	10.91
6	Agios Germanos (YP7-bridge)	6.60	2.10	0.0760	10.80	0.04	13.86	1.28	8.14
7	Mileonas (MH2-concrete pipe)	2 concrete pipes with 1 m diameter		0.0110	3.14	0.033	0.78	0.25	1.25
8	Platy (PL4-culvert)	5.30	2.80	0.0400	10.90	0.05	14.84	1.36	4.90
9	Kallithea (KA8-culvert)	5.50	1.20	0.0850	7.90	0.04	6.60	0.84	6.47
10	Leukonas (L4-bridge)	10.00	2.40	0.0480	14.80	0.04	24.00	1.62	7.54
11	Karyes (K2-culvert)	4.00	2.00	0.0740	8.00	0.04	8.00	1.00	6.80
12	Karyes (K6-culvert)	2.00	1.00	0.0720	4.00	0.033	2.00	0.50	5.09
13	Karyes (K7 και K8-culverts)	2.50	1.00	0.0720	4.50	0.033	2.50	0.56	5.46
14	Mikrolimni (M20-culvert)	2.90	1.00	0.0229	4.90	0.033	2.90	0.59	3.21
15	Mikrolimni (M8-culvert)	2.10	1.70	0.01	5.50	0.033	3.57	0.65	2.67

### 3. Results and Discussion

#### 3.1. Technical Works Recording—Maximum Discharge Capability Estimation

In Figure 5 the recorded technical works of the study area are presented. It is obvious and also expected, that most of the hydrotechnical works were constructed at the junctions between the road and hydrographic network.



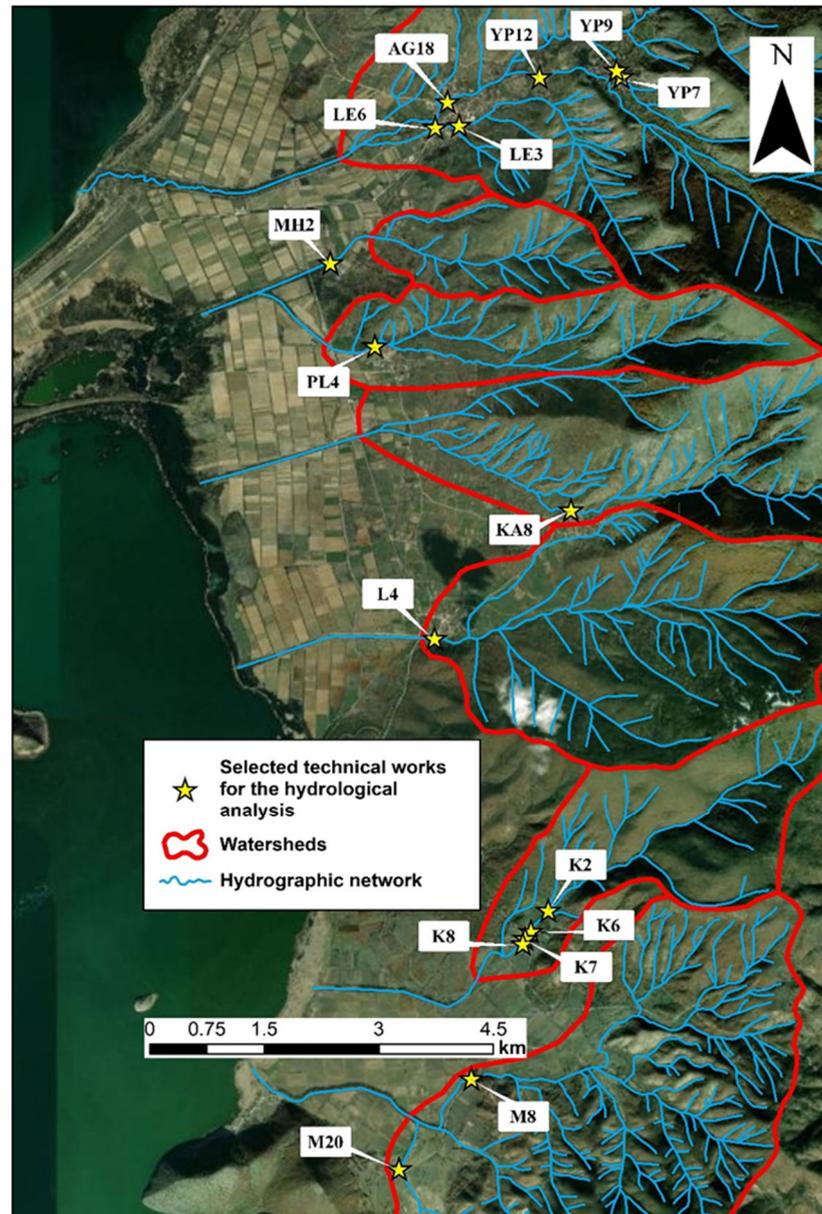
**Figure 5.** The location of the recorded hydrotechnical works within the study area.

Additionally, in Table 7 the categories and the number of technical works for each watershed are presented. Table 7 revealed that the majority of the technical works (bridges and culverts, 66%) have a direct relation with the discharge of the flood peak flows.

**Table 7.** Total recordings of all the existing hydrotechnical works in the research area.

	Records for Each Watershed	Bridge	Pedestrian Bridge	Water Pumping	Check Dams	Concrete Culverts	Plastic Culverts	Concrete Stream Sections	Other Technical Works
Agios Germanos	98	15	6	8	10	40	8	5	6
Mileonas	3	1	0	0	0	1	1	0	0
Platy	8	3	0	0	3	0	0	0	2
Kallithea	18	4	0	1	11	0	1	0	1
Leukonas	7	4	0	0	0	0	2	0	1
Karyes	12	3	0	1	1	5	0	0	2
Mikrolimni	19	1	2	0	2	12	0	1	1
Sum	165	31	8	10	27	58	12	6	13

During the field survey, the condition of the technical works was evaluated, while the most flood prone locations/works were recorded. This evaluation was based on the following criteria: (a) the proximity with settlements, houses and important infrastructures, (b) the existence of dense vegetation and trapped sediments and (c) the hydraulic characteristics of the cross sections. In Figure 6 the most flood prone locations/works are depicted and in Table 6 there are the respective hydraulic characteristics of each location/work.



**Figure 6.** Location and coding of the selected technical works that were used for the hydrological analysis.

### 3.2. Curve Number (CN) and Time of Concentration ( $t_c$ ) Estimation—Hydrological Modeling

Figure 7 shows the spatial distribution of the CNII,20 parameter, while Table 8 shows the mean values of the CNII,20 and CNIII parameters for all the watersheds in the research area. CNIII values were resulted applying the Equation (2). Figure 7 depicts increased values of the CNII,20 parameter, which are attributed to the increased average slope of the study area, low water permeability of the geological formations of the area (gneiss, granite) and the relatively low cover by forest vegetation.

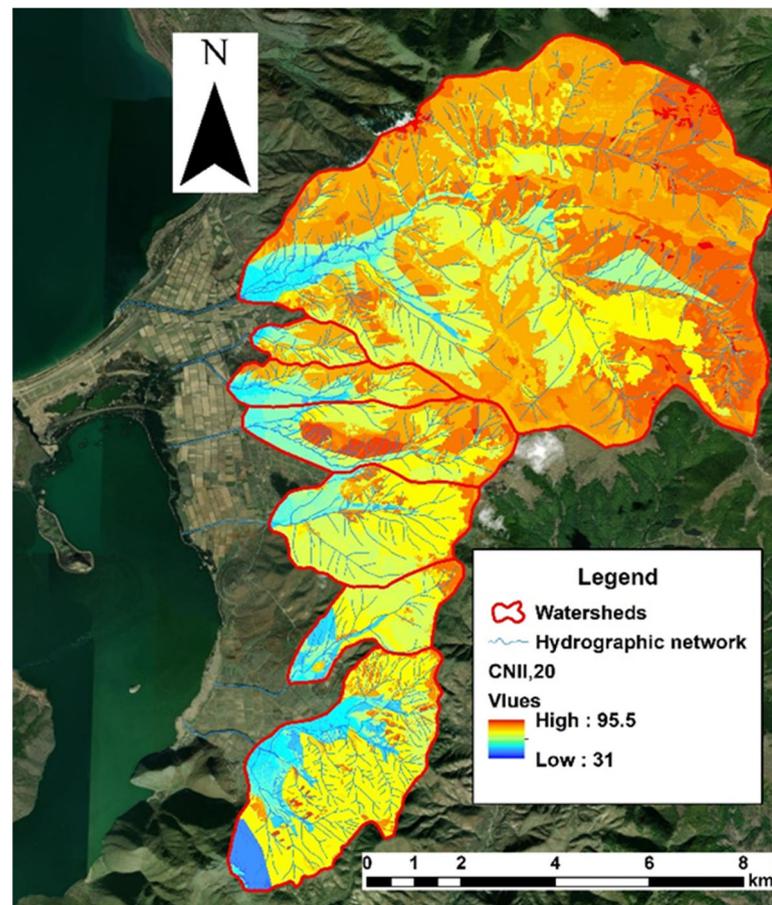


Figure 7. Spatial distribution of the CNII,20 for AMCII in the watersheds of the study area.

Table 8. CNII,20 and CNIII mean value for all the watersheds.

Watersheds	CNII,20	CNIII
Agios Germanos	80.34	90.12
Mileonas	73.94	86.71
Platy	70.91	84.86
Kallithea	75.51	87.64
Leukonas	71.05	84.95
Karyes	68.31	83.22
Mikrolimni	67.99	83.01

The values CNII,20 and CNIII are relatively high and particularly those of CNIII (over 80), which means that in wet conditions (mainly in winter and autumn) the risk of flooding is increased, due to the reduced capability of soil and vegetation to retain large amounts of precipitation. It is known that forests present finite capabilities to retain large amounts of precipitation, especially during extreme rainfall events [70], even if the forest cover percentage is significantly high [22,55]. It is evident, that the AMC plays a crucial role in the flood generation and in the study area the flood risk potential is very high especially in wet conditions (AMCIII).

In Table 9, the results of the calculated values of Giandotti time of concentration and lag time are presented. The watersheds presented similar values of time of concentration mainly because of the similar values of hydrographic and morphometric characteris-

tics, with an exception in Agios Germanos and Mikrolimni watersheds, which exhibited higher values.

**Table 9.** Hydrographic and morphometric characteristics required for the calculation of Giandotti time of concentration and lag time.

	Area	Min Altitude	Mean Altitude	Main Stream Length	Time of Concentration Giandotti	Lag Time (USDA)
Units	km <sup>2</sup> F	m Hmin	m Hmed	km L	h t <sub>c</sub>	min t <sub>L</sub>
Agios Germanos	65.02	861	2334	18.82	1.970	70.92
Mileonas	1.85	873	1049	4.47	1.144	41.20
Platy	3.75	867	1186	6.27	1.200	43.21
Kallithea	7.88	878	1358	8.27	1.348	48.54
Leukonas	8.01	901	1231	6.12	1.411	50.78
Karyes	4.52	892	1231	6.44	1.233	44.39
Mikrolimni	13.8	863	1068	7.15	2.234	80.41

In Table 10, the maximum discharge capability of the selected hydrotechnical works and the peak discharges for 50, 100 and 1000 return periods of the respective streams are presented. According to the results, there are many cases of the selected hydrotechnical works that are proven not sufficient to discharge the expected peak flows for the examined return periods. Specifically, in Table 10 the red values (red cells) indicate the circumstances, in which the technical works will fail to discharge the expected peak flows. The marginal cases are marked in orange, while the cases, in which the technical works will discharge the expected peak flows are presented in green color. Accepting the known uncertainties of the hydrological models in ungauged watersheds, the marginal values were based on a reasonable range between  $\pm 20\%$ , which could be characterized as acceptable in hydrological modeling [10,56,71,72].

**Table 10.** Maximum discharge capability of the technical works and the stream peak flow for 50, 100 and 1000 years return periods.

	Maximum Discharge Capability of the Technical Works Q (m <sup>3</sup> /s)	Stream Peak Flow (Q m <sup>3</sup> /s)					
		AMC II			AMC III		
		50 Years	100 Years	1000 Years	50 Years	100 Years	1000 Years
Agios Germanos (AG18-bridge)	165.79	157.00	187.80	295.50	259.00	294.40	412.50
Agios Germanos (LE6-culvert)	22.68	9.90	12.10	19.90	18.20	20.90	29.80
Agios Germanos (LE3-culvert)	31.02	8.27	10.11	16.63	15.21	17.47	24.91
Agios Germanos (YP12-culvert)	6.55	14.80	18.40	31.60	30.00	34.60	50.30
Agios Germanos (YP9-culvert)	117.79	3.20	4.00	6.80	6.70	7.70	11.20
Agios Germanos (YP7-bridge)	112.81	3.20	4.00	6.80	6.70	7.70	11.20
Mileonas (MH2-concrete pipe)	0.98	5.00	6.20	10.50	10.10	11.60	16.80
Platy (PL4-culvert)	72.77	7.90	10.00	18.00	18.30	21.20	31.30
Kallithea (KA8-culvert)	42.72	15.30	18.80	31.10	28.90	33.20	47.60
Leukonas (L4-bridge)	180.86	15.50	19.70	35.30	36.00	41.80	61.70
Karyes (K2-culvert)	54.41	7.50	9.90	18.60	20.10	23.60	35.40
Karyes (K6-culvert)	10.19	7.50	9.90	18.60	20.10	23.60	35.40
Karyes (K7 και K8-culverts)	13.65	7.50	9.90	18.60	20.10	23.60	35.40
Mikrolimni (M20-culvert)	9.31	4.92	6.43	12.19	13.29	15.60	23.58
Mikrolimni (M8-culvert)	9.53	8.53	11.14	21.12	23.01	27.03	40.85

### 3.3. The Influence of the NATURA Restrictions and Regulations on Flood Management Measures

The results revealed that the specific peak flow ranged between 2.5 and 7.8 m<sup>3</sup>/s/km<sup>2</sup>, values which internationally, and in Greece, are considered relatively low for flood danger potential. Usually, values of specific peak flow between 9 and 11 m<sup>3</sup>/s/km<sup>2</sup> are considered dangerous and can cause severe flooding [10,55,73]. Thus, the area can be considered as of low flood risk in terms of flood peak flows.

The Greek legislation considers that the small dimension and low importance technical works should be constructed to be capable to discharge the maximum discharges of 50 and 100 years return period for AMCII. The results showed that almost the half of the technical works of the study area could not discharge the high and medium probability (50 and 100 years) flood peak flows.

The main causes that directly affects and dramatically reduces the maximum discharge capability of the technical works are the extremely dense riparian vegetation that has been developed on the banks and the thalweg of the riverbeds and in some cases the inappropriate dimensioning of the technical works. This vegetation consists mainly of NATURA protected trees and shrubs of large size and in high density. The development of dense riparian forest in all the riverbeds of the region creates a special ecosystem of high ecological and aesthetic value, which is protected by NATURA regulations. It also protects the banks of the streams from potential erosion. However, the strict restrictions on trees/shrubs logging and trimming within the streams, have caused the unlimited development of the riparian vegetation around and sometimes on the technical works and along the streams and also the concentration of large amounts of sediments in various locations. This situation significantly increased the roughness coefficient and reduced the dimensions of the technical works cross sections. In many cases, the dense vegetation and the sediments have blocked to a large extent the openings of the technical works, while it is characteristic that in few cross sections the dimensions of the cross sections were not measured, because access was impossible. In Figure 8 the condition of the technical works is indicatively presented.



Figure 8. Cont.



Figure 8. Cont.



**Figure 8.** Representative pictures of the selected hydrotechnical works for the hydrological analysis. (AG18):bridge; (LE6):culvert; (LE3):culvert; (YP12):culvert; (YP9):culvert; (YP7):bridge; (MH2):concrete pipe; (PL4):culvert; (KA8):culvert; (L4):bridge; (K2):culvert; (K6):culvert; (K7):culvert; (M20):culvert; (M8):culvert.

The creation of flood management plan, the construction of new flood control works, the maintenance and/or reconstruction of the old technical works, the logging and trimming of trees and shrubs, the sediment depletion of streams, require a Special Ecological Evaluation study, complying with NATURA regulations and the Greek legislation requirements. The Special Ecological Evaluation study is subjected to public consultation, where every individual person or group can erase arguments. Prespa National Park Management Body (PNPMB) is the authority responsible for activities such as wetland management, providing information and raising awareness, protecting the area and guarding against illegal activities such as unlicensed sand extraction and hunting which place a stress on the natural environment. Society for the Protection of Prespa (SPP) participate as a member of the Board of Directors, but has also actively supported the work of the PNPMB. The PNPMB, SSP, the forest service, Ministry of Environment and Energy (YPEN) and local authorities (Municipality) are the main stakeholders who should collaborate in order to plan the vegetation management in streams and the flood management and control measures. Various ecological groups and ecologists are active in the research area, which are extremely sensitive to the NATURA habitat protection, and frequently just for the trimming of some shrubs and branches several difficulties and obstacles are encountered. This fragmentation of flood risk management, among many services, combined with the sensitivity of many ecologists to the logging and trimming of trees and shrubs, has led to the deterioration of the maintenance/reconstruction of hydrotechnical works and the lack of flood control management plan, a fact which increase the flood risk in the study area.

#### 4. Conclusions

The results of the maximum 24-h rainfalls for return periods of 50, 100 and 1000 showed that the rainfall intensity in the study area is generally low and as a result the potential of flood generation is also low. The hydrological analysis and the value of the specific peak discharge revealed also that the flood risk in the examined watersheds is low. However, the inadequate maintenance of the hydrotechnical works, the deposition of sediments, the dense vegetation in the streambeds and in some cases the inappropriate dimensions of technical works, have as a result the increase of the flood risk.

The protection of the environment constitutes the first priority when we are talking about NATURA habitats, which are extremely crucial for the maintenance of rare and endangered flora and fauna species. However, in NATURA areas various human activities take place and flooding constitutes a serious problem. Consequently, efforts should concentrate on protecting valuable and endangered habitat types while ensuring that flood risk in the area remains low. Vegetation management within the streams and next to hydrotechnical works is undoubtedly a complicated process, which requires relevant scientific expertise, time, light machinery and capital investment.

Special Ecological Evaluation studies aiming at the flood risk assessment and educating the public about the necessary flood control measures necessity and impact, could provide a framework for a thorough discussion about the flood management in NATURA areas. The Special Ecological Evaluation studies could be the outcome of the combined knowledge and efforts of the stakeholders, local authorities and the ecological groups of the area, as well as considering public consultation arguments.

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