# FLOOD MODELING IN KARLOVASSI BASIN AREA – SAMOS ISLAND (GREECE)

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## ABSTRACT

Karlovassi basin area has been studied for long period by the team from University of Athens. This area suffers from frequent floods which frequency even raised after large area of forests in Kerketeas Mountain area was burned down in year 2000. In recent period the area has been studied from the point of view of flood risk. High volume of data was collected and processed as an input to the flood risk model. The model was built using Arc Hydro toolset in ArcGIS environment (Maidment, 2002). Based on this model a GIS based flood risk map was created.

In order to get more detail description of rainfall-runoff process a decision has been made to apply hydrologic model which works with more detail description of runoff process. For these purposes fully HEC-1 model (Hydrologic Engineering Center, 1998) was chosen. HEC-1 describes runoff process with semi-distributed approach. Results for modeling of precipitation event from November 2001 are presented here.

**Keywords:** flood risk, hydrologic modeling, Karlovassi, Samos

## 1. INTRODUCTION

The main target of this study is to estimate the flood risk in Karlovassi area categorizing areas in different levels of susceptibility. In order to determine the parts of the drainage network, especially the parts which favor probable flood events, multiple processing steps were required, as described to the following chapters. In particular, the flood risk estimations were based on the geometrical characteristics and the morphology of the study area.

The methodology applied, involved primarily the estimation of the streams' power and the flood risk related to these streams. Although the estimated stream power refers to the total basin area, it was calculated at the outlet of the catchment, where the dynamic energy of the total runoff has been transformed to kinetic energy (Boglis, 2009; Boglis, et al., 2009; Fountoulis, et al., 2007; Karagiozi, 2008).

Further analysis of the area of interest has been made, in order to get better overview of the hydrologic process by estimating the discharges in Karlovassi town area for the big flood event which occurred on 28$^{th}$ and 29$^{th}$ November 2001. For this purpose HEC-1 (Hydrologic Engineering Center, 1998) has been chosen.

## 2. STUDY AREA

Basic information about the area of interest is introduced in following chapters. This information includes mainly basin area description and information about relief, permeability of the geological formations and land use.

## 2.1. Geographical setting

The study area is located in the North West part of Samos Island in a town called 'Karlovassi'. The annual probability of a flood event is relatively high; flood events cause damages mainly to Karlovassi and its surroundings. The flood risk was dramatically increased as a result of the devastating forest fires of July 2000, which burned almost 90.000 hectares in Kerketeas Mountain, east of Karlovassi and destroyed the vegetation cover in a big part of the island (Gournelos, et al., 2001). The flood of October 2003, which caused extensive damages to the urban road network and the surrounding settlements, represents a typical example. In November 2001, another flood event, accompanied by debris flow caused severe damages near the streams' outlets in Karlovassi town.

The drainage basins of two streams were jointly studied (Fig. 1): a) Megalo Rema, which crosses Karlovassi and discharges in the sea and b) Fourniotiko Rema which discharges east of the town and is well known for its substantial flood discharges during flash storms.

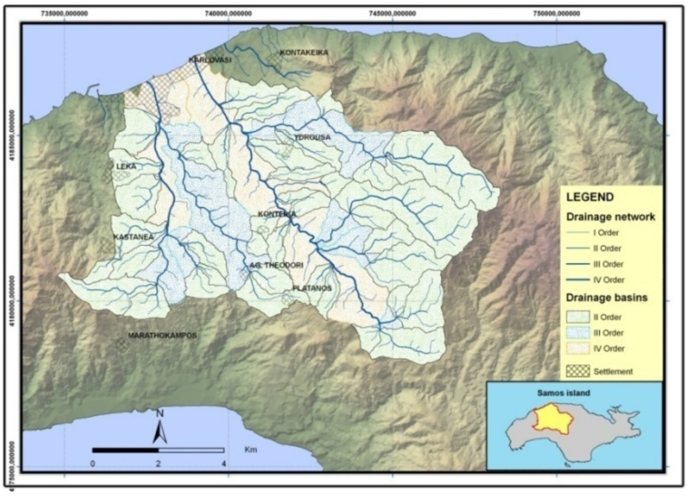


**Figure 1**: Division of the area of interest into basins used for flood risk estimation.

## 2.2. Morphology

The area of interest includes, from morphological point of view, both flat areas as well as very steep parts. Flat regions are situated in lower part along sea shore, while the steepest areas are concentrated along the crest line of the study area in upstream parts. Average slopes for sub-catchments which are shown on Figure 10 vary up to more than 40 %. Average slope in Fourniotiko Rema basin is 33 % while in Megalo Rema it is 26 %. The shapes of both drainage basins are similar, they are wide in upper areas and as moving to the outlets are narrowing.

## 2.3. Permeability of the geological formations

The soils in the estuaries of torrents are alluvial and colluvial on the hill slopes, with good permeability. The soils on the slopes are formed in terraces with dry walls, fertile and without excessive salt. The hydrolithology of the wide area has the below specific characteristics (Provatas, et al, 2004) (Fig. 2):

- The low regions' alluvial depositions are consisted of clayey silts, sands and gravel formations. They form in general shallow aquifers with variable permeability depending on the granulometry of the various layers. Lateral (mainly limestone) taluses are generally consisted of non-cohesive coarse materials (sand, gravels, shingles and locally blocks of stone) of small thickness and quite satisfactory permeability.
- The depositions from the torrential terraces are consisted of sand, gravel, and breccias, as well as of finely granular conjunctive components (clay, silt). They generally present a water table that depends on the depth of the underlying impermeable formation.
- Calciferous formations (limestones, marbles, dolomites) are characterised by intense karstic phenomena, mainly in fault-controlled areas. They present favourable conditions for the development of underground waters, which discharge to karstic springs, or transfuse underground in the alluvial depositions and lateral taluses. On the contrary, marls practically constitute impermeable formations, due to the fine texture of the clay and tuff material they consist.

### 2.4. Land use

Land use data layer was derived at University of Athens from interpretation of aerial photos taken in 1960. This means that the data does not include information about land use after the big forest fires of 2000. According to used method only basic land use classes as forests, bushes or built up areas could be gained. However, for purposes of semi-distributed or lumped modeling it is sufficient. Used data for calculations presented in chapter 4 are shown on Figure 3.

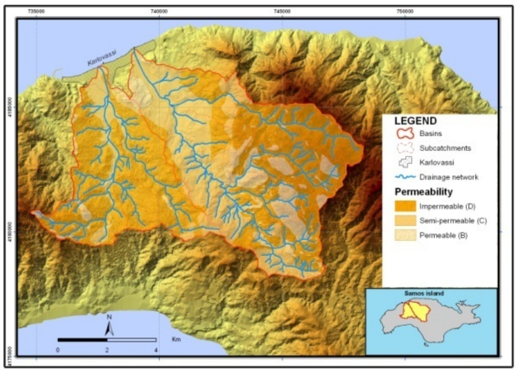


**Figure 2**: Permeabilities in Karlovassi basin area.

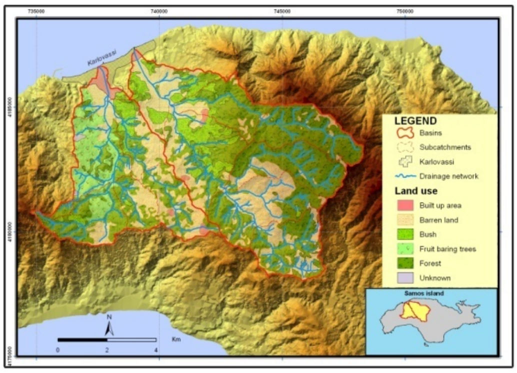


**Figure 3**: Land use in Karlovassi basin area.

## 3. METHODOLOGY OF FLOOD RISK ESTIMATION

The main stages of data processing include a) the generation of the digital elevation model, b) the generation of the drainage network, c) the generation of the basins, and d) calculation of the parameters concerning the drainage basins (Figs. 5-7).

The generation of the digital elevation model was carried out through the use of primary data, as obtained by the digitization of the contours (20 m step) and the trigonometric points from the topographic maps of the Geographical Military Service (scale 1:50.000). The production of a digital terrain model in a rectangular block of cells (GRID), was necessary for the following steps. The GRID includes altitude points in the vertexes of its cells arranged in rows and columns, which form a raster-data structure (Schut, 1976).

The produced Digital Terrain Model (DTM) was used as primary data for the vectorization of the drainage network and the watersheds of the study area. After its completion, the DTM was checked for sinks and was modified, where necessary. The hydrological depiction of the drainage basins is a significant parameter for the calculation of the hydrological parameters and the further study of the drainage systems in the area of interest. For this purpose, the depiction of drainage basins of 2$^{nd}$ or higher order (polygon features), the basins' outlet (point features), as well as the drainage network (linear features) and its classification according to the Strahler stream order classification, were carried out automatically via the Arc Hydro toolset (Fig. 4) (Maidment, 2002).

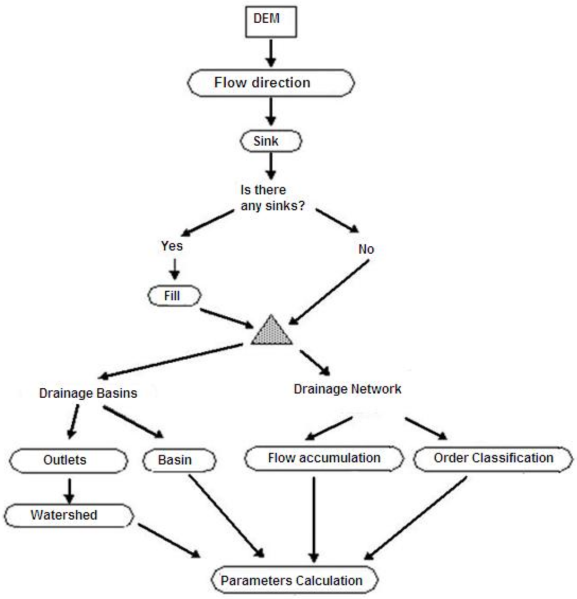


**Figure 4:** Flow chart of the followed steps using Arc Hydro (according to Loesch, 2000).

For the calculation of the stream power the parameters used were the mean slope, the maximum and minimum elevation (relief index), the extent and the mean elevation of each drainage basin. Having completed these calculations and the overall study of the hydrological system, it was possible to proceed with the estimation of the flood prone areas, through the production of the final Flood Hazard map of the basins.

The outlet of each catchment (of order II or higher) was considered as the site where the dynamic energy of the discharge has been transformed to the kinetic one (Fountoulis, et al., 2007; Karagiozi, 2008).

In order to maximize the differentiation among the basins' outlets, the above mentioned parameters were used as input in a mathematical product, each one functioning as an "amplifier" to the total. The mathematical product does not comprise a measure of the rate relief of the stream power, but a very well defined quantitative measure for the comparison of the outlets (Fig. 8).

Under the assumption that the expansion of the stream power is placed downstream, two more steps were taken for the better representation of the stream power: the calculation of each catchment mouth's elevation and the mapping of the low elevation region in the study area.

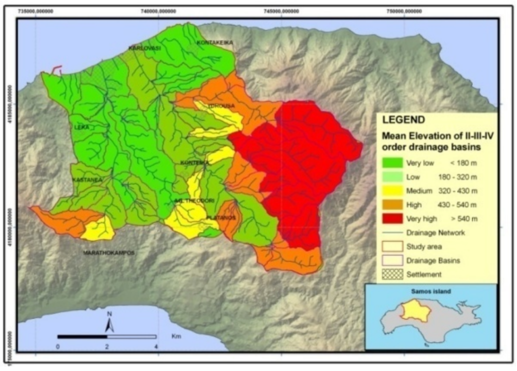


**Figure 5**: Mean elevation of the drainage basins.

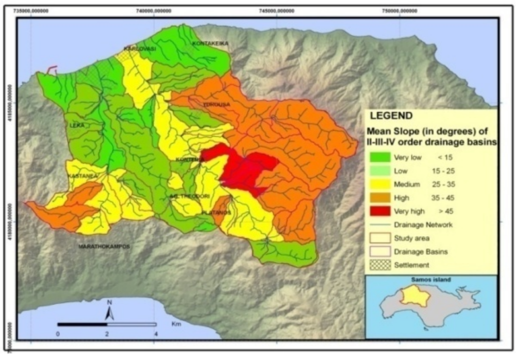


**Figure 6**: Mean slope of the drainage basins.

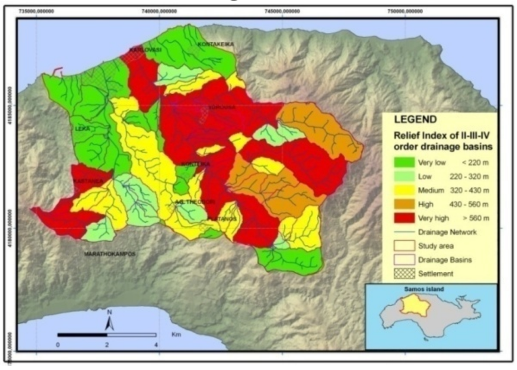


**Figure 7**: Relief index of the drainage basins.

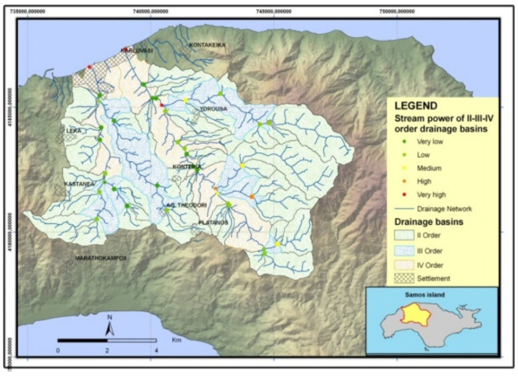


**Figure 8**: Stream power of the drainage basins.

Finally, for the better definition of the high flood prone sites (according to the morphological characteristics), the map of the stream power was reinforced by two more limitations, that of the morphological slopes and that of the site elevation which has to be equal or lower than the elevation of the energy – relief point. For this reason, an extra calculation was necessary, so that the previous map be redefined taking into account the elevation and the morphological slopes.

The flood hazard map (Fig. 9) shows that the areas with medium up to very high flood risk are associated with areas of Holocene formations. Moreover, the susceptibility results deriving from this map are consistent with the in situ observation and the recent flood events that occurred in the area.

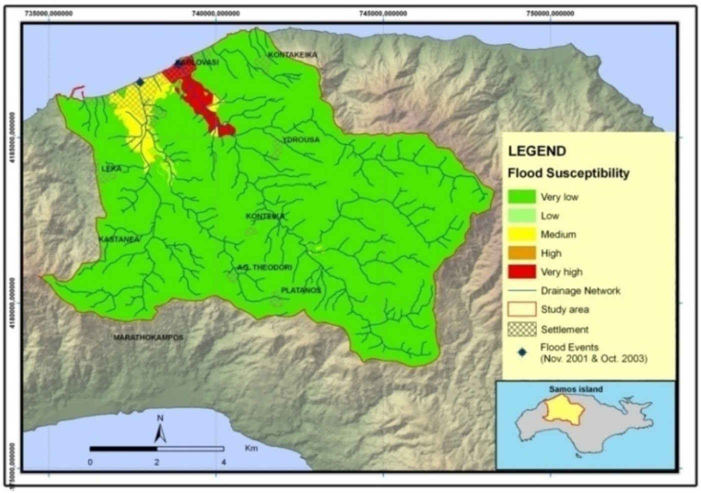


**Figure 9**: Flood risk in the Karlovassi drainage basin.

## 4. HYDROLOGIC MODELING

In order to get better overview of hydrologic process and mainly on surface runoff in the area of interest it has been decided to apply hydrologic model. For this purpose HEC-1 (Hydrologic Engineering Center, 1998) which is available within WMS (Watershed Modeling System) environment has been chosen. Using mentioned model precipitation event which occurred on 28$^{th}$ and 29$^{th}$ November 2001 has been modeled to get an overview of discharges in Karlovassi town area at that time.

### 4.1. Applied model and methods

The model HEC-1 itself is independent on WMS environment. However, this software offers many tools for data preparations and hydrologic parameters calculations. The model uses as units sub-catchments in the area of interest for which parameters are calculated with lumped approach.

There are many methods for calculation of model parameters from which following methods were chosen.

- SCS-CN method for precipitation loss calculation (Mishra and Singh, 2003).
- Clark’s method for calculation of synthetic unit hydrograph parameters. For this purpose lag time was calculated using SCS method (Hydrologic Engineering Center, 1998).

HEC-1 model is designed for calculations of surface runoff hydrographs. This means that it can be used for small basins where subsurface processes cannot take an important place.

### 4.2. Input data

As an input data for the calculation of model parameters using mentioned methods spatial data which include the information about land use and soils are necessary. Also elevation data is necessary information for calculations carried out within presented study.

For purposes of presented study the data presented on maps in chapter 2 were used. As CN values are given for different combinations of land use and hydrological soil groups which are based on infiltration rates it was necessary to transform permeability information into these groups. Hydrological soil groups used for CN values assignment are four (A to D) while group A represents soils with highest infiltration rates and group D represents soils with lowest infiltration rates. As group A includes mainly pure sands and gravels it was decided to assign to three known permeability classes groups B, C and D.

DTM is another necessary input for the model. For this study DTM presented in chapter 3 has been used. By processing the DTM the hydrologic model tree was built for both Furniotiko Rema and Megalo Rema basins (Fig. 10).

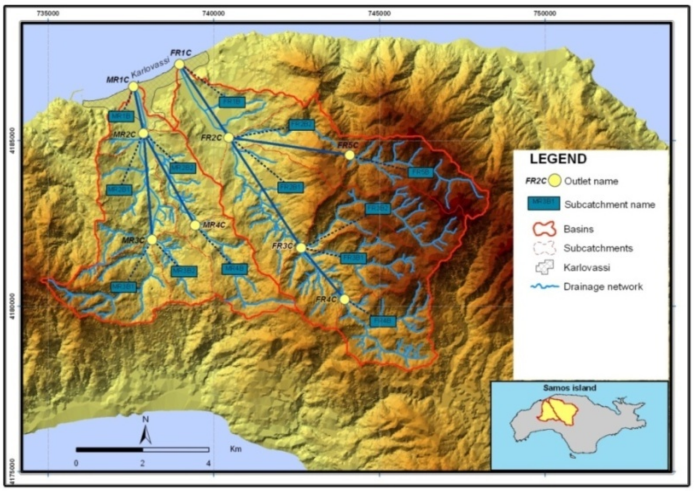


**Figure 10**: Hydrologic model used for calculations with HEC-1 model.

To be able to involve stream routing also channel parameters have to be put in. Because of lack of measured data estimated values of channel dimensions as well as Manning roughness parameter have been used. Estimations are based on field survey carried out in July 2009.

As an input of the model precipitation hyetograph. As mentioned above the real event from 28$^{th}$ and 29$^{th}$ November 2001 has been modeled for this study. The data from two gauging stations were available for the area of interest. These were stations Vourliotes which is situated in the Megalo Rema basin area and Pandroso which is situated in the Folurniotiko Rema basin area. Since hyetographs for both stations are very similar it has been decided to use an average hyetograph for whole study area.

### 4.3. Results

The modeling results are discharge hydrographs at outlets of both basins as well as hydrographs for outlets of single sub-catchments. The results can be affected by the fact that the land use information is based on aerial photographs from 1960 and that forest fires occurred in summer 2000 which changed the land use pattern towards higher presence of barren land in Fourniotiko basin area. Therefore it can be assumed that the final hydrograph would be higher.

Calculated peak discharge for Fourniotiko basin is 1.136 $m^3.s^{-1}$, while peak discharge value for Megalo Rema basin is 647 $m^3.s^{-1}$ (for more information see Fig. 11). These values are very high and correspond to the damages which were observed in Karlovassi. Calculated discharge values cannot be verified, as there are no measured ones. Therefore, the output from present study must be considered with respect to uncertainties of the model and used methods.

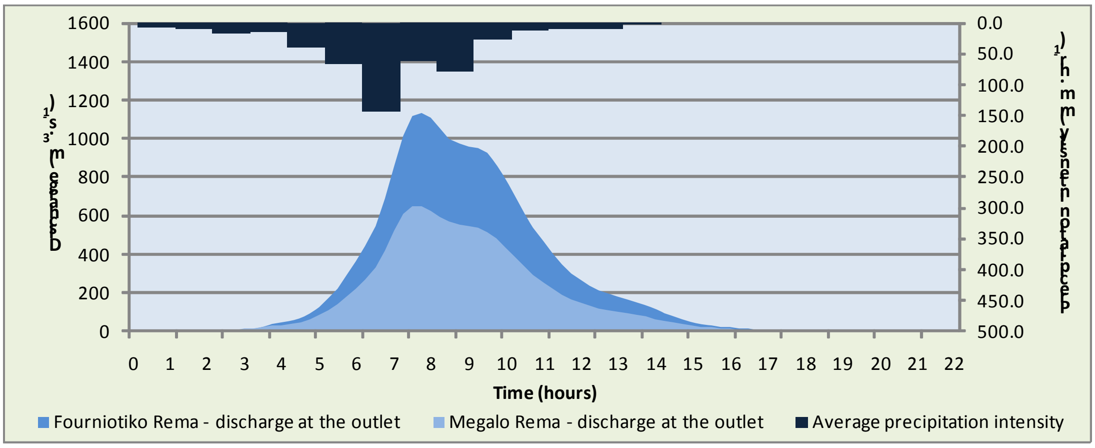


**Figure 11**: Calculated surface runoff hydrographs for Fourniotiko and Megalo Rema basins (event from 28th and 29th November 2001).

## 5. CONCLUSIONS

This paper presents two essential steps of the whole procedure of flood problems solution in areas where rainfall-runoff data are missing. First step is an assessment of flood risk in the study area which is presented in chapter 3. Second step is the calculation of possible discharges in important profile. For these reasons hydrologic models can be applied. Of course, dealing with floods must include also further steps, like assessment of channel capacities and design of single measures to decrease flood risk in important areas. The results of the present study can help to better understand of the hydrologic processes in the Karlovassi basin area.

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