The Rational method: Estimation of Peak Discharge for the Pouri River

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1. Introduction

The rational method to calculate an estimation of the peak discharge for the Pouri river in three different return periods. We will use GIS (Geographical Information System), and mathematical calculations.

With algorithms, geoprocessing tools and spatial analysis, ArcGIS Pro (The GIS software used in this study) will give us the values to calculate the peak discharge for the Pouri river in three different return periods.

2. Basics

Application of the rational method is based on a formula to calculate the maximum runoff flow of a watershed during rainfall, depending on the rainfall, of the area and the ground waterproofing.

The formula is:

$$Q = 0.278\ C\ i\ A$$

Where:

Q = peak discharge (m^3/s)

C = runoff coefficient

I = rainfall intensity (mm/h)

A = catchment area (km^2)

3. Time of Concentration Formula

A calculation who is important for the method, estimates the time required for water to travel from the hydraulically most distant point of a watershed to its outlet, which is a crucial parameter for determining peak runoff discharge.

$$t_c = \frac{4\sqrt{A} + 1.5L}{0.8\sqrt{H_{mref} - H_{ref}}}$$

Where:

Tc = Time of concentration(h)

A = Basin area (km^2)

L = Flow length (km)

Hmref = Mean elevation (m)

Href = Bottom elevation (m)

4. Rainfall Intensity-Duration-Frequency Curve Equation

A calculation to estimate the average point rainfall intensity (x) for a specific time (k), and a return period (T).

$$x = \lambda . \frac{(T/\beta .)^{\xi} - 1}{(1 + k/\alpha)^{\eta .}}$$

Where:

x = Rainfall Intensity (mm/h)

k = Reference time duration (h) (It's 'Tc')

T = Return period frequency (years)

ξ, a = Regional parameters (h for a)

λ, β, n = Geographical parameters

5. Surface Reduction Coefficient

The point rainfall intensities obtained are converted into surface rainfall intensities by multiplying them by the surface reduction coefficient Φ

$$\varphi = \max\left\{1 - \frac{0.048A^{0.36-0.01\ln A}}{k^{0.35}}, 0.25\right\}$$

Where:

Φ = Surface Reduction Coefficient

A = Basin area (km^2)

k = Reference time duration (h, Its ‘Tc’)

6. Final Calculation

To finish our ‘i’ calculation, we have to multiply Φ with x.

$$i = \Phi * x$$

7. Calculation

Our data:

For the Time of Concentration Formula:

$$A = 89km^2$$

$$L = 20km$$

$$Hmref = 320m$$

$$Href = 0.3m$$

For the Rainfall Intensity-Duration-Frequency Curve Equation:

$$k = 4.72906\ h$$

$$T = 50, 100, 1000 \text{ years}$$

$$\xi, a = 0.18$$

$$\lambda = 76.17$$

$$\beta = 0.0034$$

$$n = 0.658$$

After the calculation, we can find frequency for each time return period:

Q =

For 50 years = 352.14 m3/s

For 100 years = 433.49 m3/s

For 1000 years = 725.47 m3/s

Result:

Our estimation of the peak discharge for the Pouri river for a return period of 50 years is 352.14 m3/s, for a return period of 100 years is 433.49 m3/s, and for a return period of 1000 years is 725.47 m3/s.

8. Data Recuperation with GIS

For our method, we used different values. Some of them were found by GIS (A, L, Hmref, Href, β and λ). The end of this work is about how to find these values.

A) Territory Delimitation:

Our study is about the sub basin of the Pouri river. We must delimitate the sub basin:

First, add to the ArcGIS Project these files:

1- The Thessaly DEM

2- The different sub basins of the region

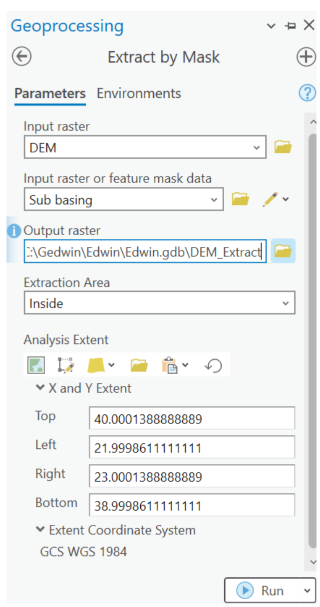
3- All Greece rivers

There are global files, extract only our sub basin.

For that, use these ArcGIS Pro tools:

- The selection: selection of the sub basin and the river of the Pouri river, and create a layer with the tool: *Selection -> Make Layer from Selected Features*

- Extract by Mask: To extract the DEM inside "sub_basin":

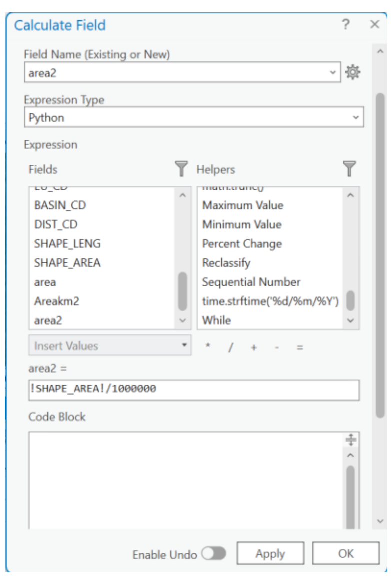


Important step to fill the DEM: Use the geoprocessing tool (Fill) with the DEM

The view of the first part:

To collect A:

Sub_Basing -> Attribute Table -> Calculate:

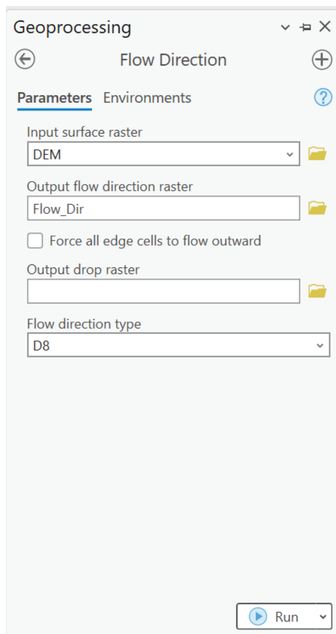


To collect Hmref and Href:

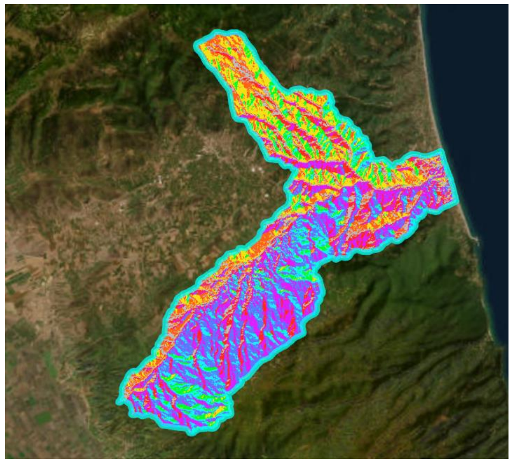
Fill_DEM_B -> Properties -> Source -> Statistics (Hmref = Mean; Mref= Minimum)

B) Extract the hydrographic network with the DEM

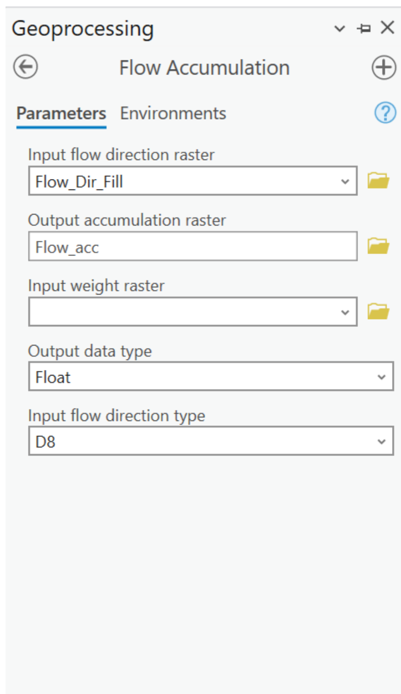
First calculate the flow direction, with the tool “Flow Direction” who will use the DEM:



It will create this multicolor layer:



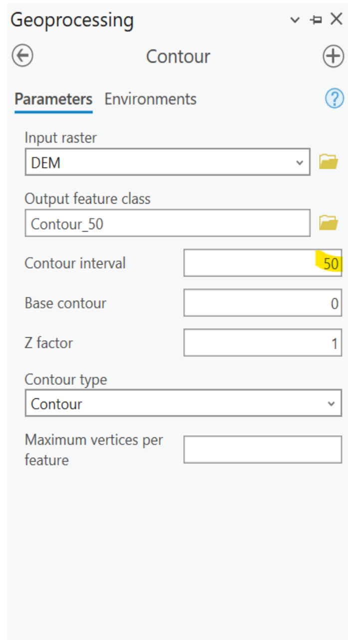
This layer will be used to create the sub basin hydrographic network, with the tool “Flow Accumulation”, who will used the layer “Flow_Direction”:



Result:

We can change the values of this layer to make the hydrographic network more or less accurate:

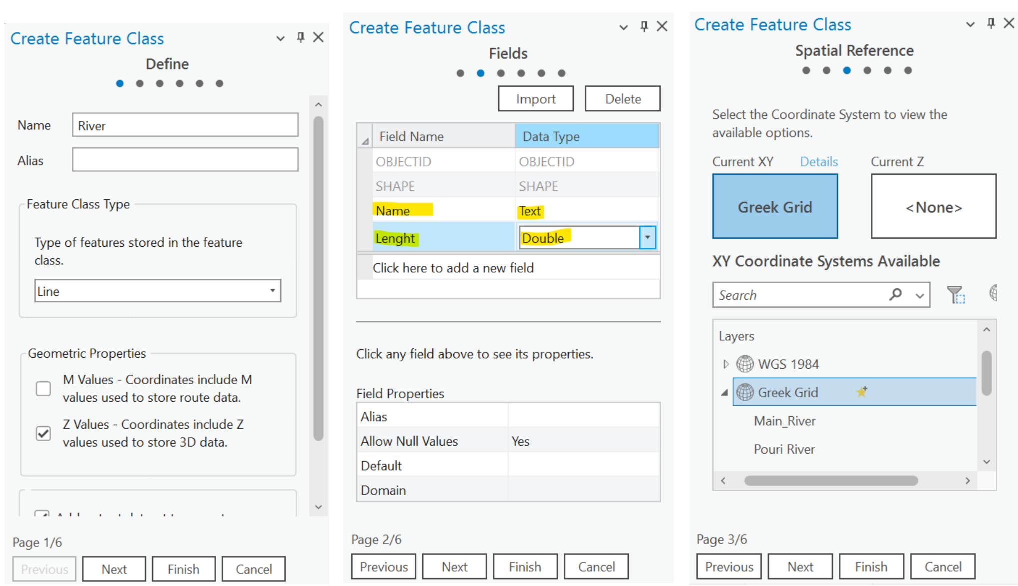
Create the isolines layer, an intermediate stage to have a complete map. With the tool "Contour" who will use the DEM, and an interval of 50 meters:



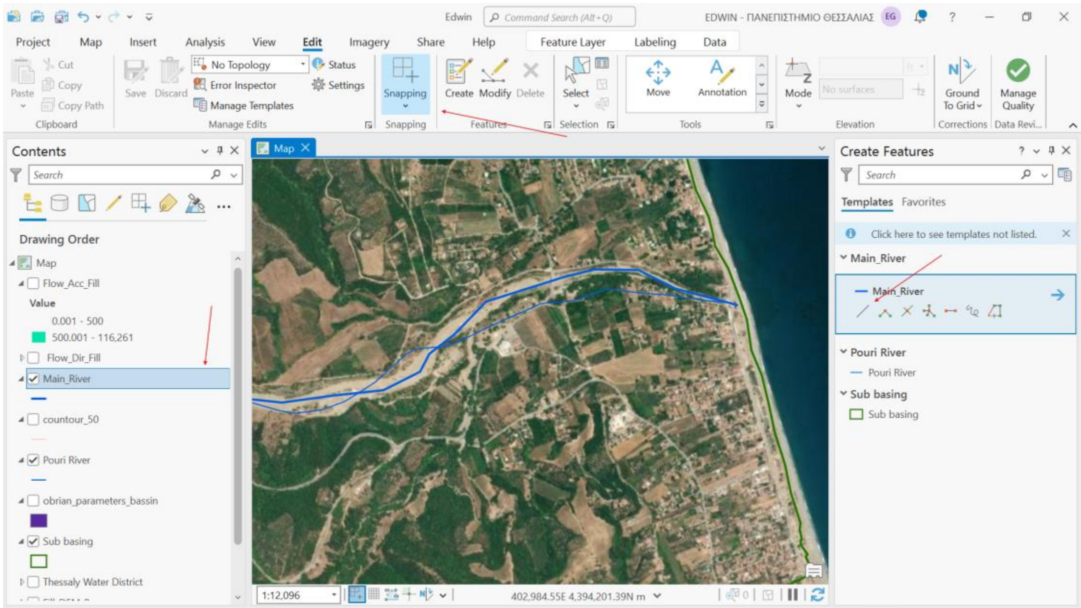
C) Pouri River extraction (L)

To create the final Pouri river layer, use the digitalization tool, with the help of a background map (satellite)

First, create the poly line layer "Pouri_River":

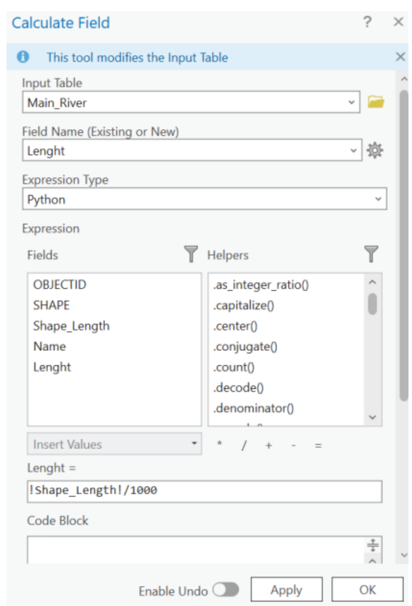


And turn on the editing mode to trace the river:



To collect L:

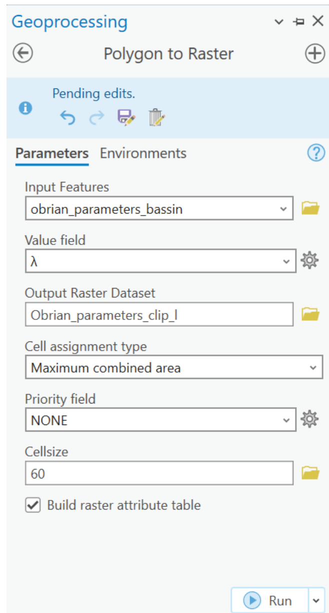
Pouri_river -> Attribute table -> Calculate



D) Recuperation of β and λ:

- Add "Obrian_parameters", a layer gave by the region with the β and λ data and extract the sub basin zone.

- Use "Polygon to Raster" geoprocessing tool to get β and λ:



References:

F. Evangelia. (2025). “River Regulation with Geographic Information System”. University of Thessaly