BEACHMED-e: Subproject 3.3

REDUCTION OF THE SEDIMENT YIELD AT THE MOUTH OF (BIG) RIVERS DUE TO CONSTRUCTION OF DAMS

AIM

- Computation of R. Nestos sediment yield.
- Exportation of quantitative results about the balance of sediment transport from Nestos River to its coastal region ,before and after the construction of the dams.

Introduction

NESTOS RIVER

	BOULGARIA	GREECE	TOTAL
Length	94 km	140 km	234 km
River basin area	3600 km^2	1960 km^2	5560 km^2
Dams (basin area)	Dospat (565 km^2)	Thissavros (4315.50 km^2), Platanobrysi (405.01 km^2)	

Description of the adopted methodology to calculate the sediment yield .

Four physical processes are involved :

- ***Runoff resulting from rainfall,***
- ***Soil erosion due to rainfall and runoff,***
- ***Inflow of soil erosion products into streams, and***
- ***Sediment transport in streams.***

The quantification of the above chain of physical processes leads to the computation of sediment yield at the basin outlet.

Description of the adopted methodology to calculate the sediment yield .

Applied model in Nestos River Basin:

- **A NEW MODEL , THE RUNERSET MODEL , IS USED (Hrissanthou, 2002;2005)**

- **rainfall-RUNoff-surface ERosion-stream SEdiment Transport model**

RUNERSET MODEL

This model estimates the **monthly** sediment yield and consists of three submodels

Model

Rainfall- Runoff Submodel

Surface Erosion Submodel (Schmidt, 1992)

Stream Sediment Transport Submodel (Yang & Stall, 1976)

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MONTHLY RAINFALL -RUNOFF SUBMODEL:

Required input data:

- **rainfall amount**
- **temperature**
- **sunlight hours per day**
- **latitude**
- **hydrological soil group**
- **Simplified Water Balance Model for the computation of the runoff, h_o(mm)**

$$S_n' = S_{n-1} + N_n - E_{pn}$$

Where

•S_{max} (mm) is the maximum available soil moisture

•S_n (mm) the available soil moisture for the time increment.

A simplified water balance model is used for the computation of the MONTHLY runoff, h_o (mm):

•part of the rainfall water can be stored in the root zone of the soil.

The difference ($S_{max} - S_n$) represents the soil moisture deficit for the time increment considered.

The available soil moisture, S(mm) increases through the rainfall N (mm).

The available soil moisture, S(mm) decreases through:

- **the potential evapotranspiration,**
- **E_p (mm), evapotranspiration,**
- **the deep percolation IN (mm)**
- **the runoff, h_o (mm).**

The water balance equation is written as:

MONTHLY RAINFALL -RUNOFF SUBMODEL:

- If $S_n' < 0$ then $S_n = 0$, $h_{on} = 0$
- If $0 \leq S_n' \leq S_{max}$ then $S_n = S_n'$,

  and $h_{on} = 0$
- If $S_n' > S_{max}$ then $S_n = S_{max}$,

  runoff : $h_{on} = k(S_n' - S_{max})$

MONTHLY RAINFALL -RUNOFF SUBMODEL:

(SCS, 1972):

$$S_{\max} = 25.4\left[\left(1000/CN\right) - 10\right]$$

where *CN* = the curve number(0 < *CN* < 100).

The potential evapotranspiration, *Ep* (mm), is estimated using the Thornthwaite model (1957)

***N* (mm) : rainfall**

***Ep* (mm) : potential evapotranspiration**

***S* (mm) : available soil moisture**

n : time increment

***Sn* (mm) : available soil moisture**

***IN* (mm) : deep percolation**

***S*max (mm) : maximum available soil moisture**

$\varphi_r = Cr\rho A u_r \sin a$

Surface Erosion Submodel(Schmidt, 1992) :

- The erosive impact of droplets and overland flow is proportional to the momentum flux contained in the droplets and the runoff flow.

The momentum flux exerted by the falling droplets, φr (kg m s-2), is given by:

$$\varphi_r = Cr\rho A u_r \sin a$$

$$u_r = 4.5 r^{0.12}$$

$$\varphi_f = q\rho b u$$

φ_r ***(kg m s^{-2})*** *:* momentum flux
C : soil cover factor
r **(m s^{-1})** : rainfall intensity
ρ **(kg m^{-3})** : water density
A **(m^2)** : considered area
u_r **(m s^{-1})** : mean fall velocity of the droplets
α **(°)** : slope gradient
q **(m^3 s^{-1} m^{-1})***:* runoff rate per unit width
b **(m)** *:* width of the considered area
u **(m s^{-1})** : mean flow velocity (by Mannning formula)

Surface Erosion Submodel(Schmidt, 1992) :

The available sediment discharge, q_{rf} (kg m^{-1} s^{-1}), due to rainfall and runoff, in the soil area considered, is given by:

$$q_{rf} = (1.7E - 1.7)10^{-4}$$

where

$$E = (\varphi_r + \varphi_f)/\varphi_{cr} \quad \boldsymbol{E > 1}$$

The critical momentum flux, φ_{cr} (kg m s^{-2}), which designates the soil erodibility, can be calculated from:

$$\varphi_{cr} = q_{cr}\rho b u$$

The critical momentum flux, φ_{cr} (kg m s^{-2}), which designates the soil erodibility, can be calculated from:

$$q_t = c_{\max}\rho_s q$$

The concentration, c_{max}, is calculated by:

$$c_{\max} = \frac{1}{x}\frac{\varphi_r + \varphi_f}{\rho_s A w^2}$$

q_{cr} (m^3 s^{-1} m^{-1}) : runoff rate per unit width at initial erosion

c_{max} (m^3 m^{-3}) : concentration of suspended particles at transport capacity

ρ_s (kg m^{-3}) : sediment density

x : factor depending on the soil slope gradient

w (m s^{-1}) : terminal fall velocity of sediment particles

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Sediment transport in streams:

Required input data for the main stream of each sub-basin:

- baseflow,
- bottom slope,
- bottom width,
- bed roughness,
- diameter of suspended particles,
- grain diameter of bed material,
- kinematic viscosity of water.

The sediment yield at the outlet of a stream can be computed by the concept of sediment transport capacity by streamflow (Yang & Stall, 1976)

$$\log c_t = 5.435 - 0.286 \log \frac{wD_{50}}{\nu} - 0.457 \log \frac{u_*}{w} + \left(1.799 - 0.409 \log \frac{wD_{50}}{\nu} - 0.314 \log \frac{u_*}{w}\right) \log\left(\frac{ui}{w} - \frac{u_{cr} i}{w}\right)$$

$$\frac{u_{cr}}{w} = \frac{2.5}{\log(u_* D_{50} / \nu) - 0.06} + 0.66$$

if 1.2 <u*$D$50/ν < 70

$$\frac{u_{cr}}{w} = 2.05$$

if u*$D$50/ν ≥ 70

c_t **(ppm)** : total sediment concentration by weight
D_{50} **(m)** : median particle diameter i: energy slope
u **(m s^{-1})** : mean flow velocity
u_{cr} **(m s^{-1})** : critical mean flow velocity
u^* **(m s^{-1})** : shear velocity
w **(m s^{-1})** : terminal fall velocity of sediment particles
ν **(m^2 s^{-1})** : kinematic viscosity of the water

NESTOS RIVER BASIN

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Department of Civil Engineering
Hydraulic Structures Sector - Hydraulics & Hydraulic Strucrures Laboratory

Preliminary estimation of mean annual sediment yield at the outlet of Nestos River basin, before and after the construction of the dams

Nestos River

total length : 234 km → **94 km in the Bulgarian territory**; **140 km in the Greek territory**

total area of river basin : 5761 km^2 → **3481 km^2 in Bulgaria**; **2280 km^2 in Greece**

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constructed in 1967
reservoir storage
capacity : 443
million m³

constructed in 1995
reservoir storage
capacity : 565
million m³

constructed in 1995
reservoir storage
capacity : 63 million
m³

Toxotes Exit
(Nestos River Delta)
(Greece)

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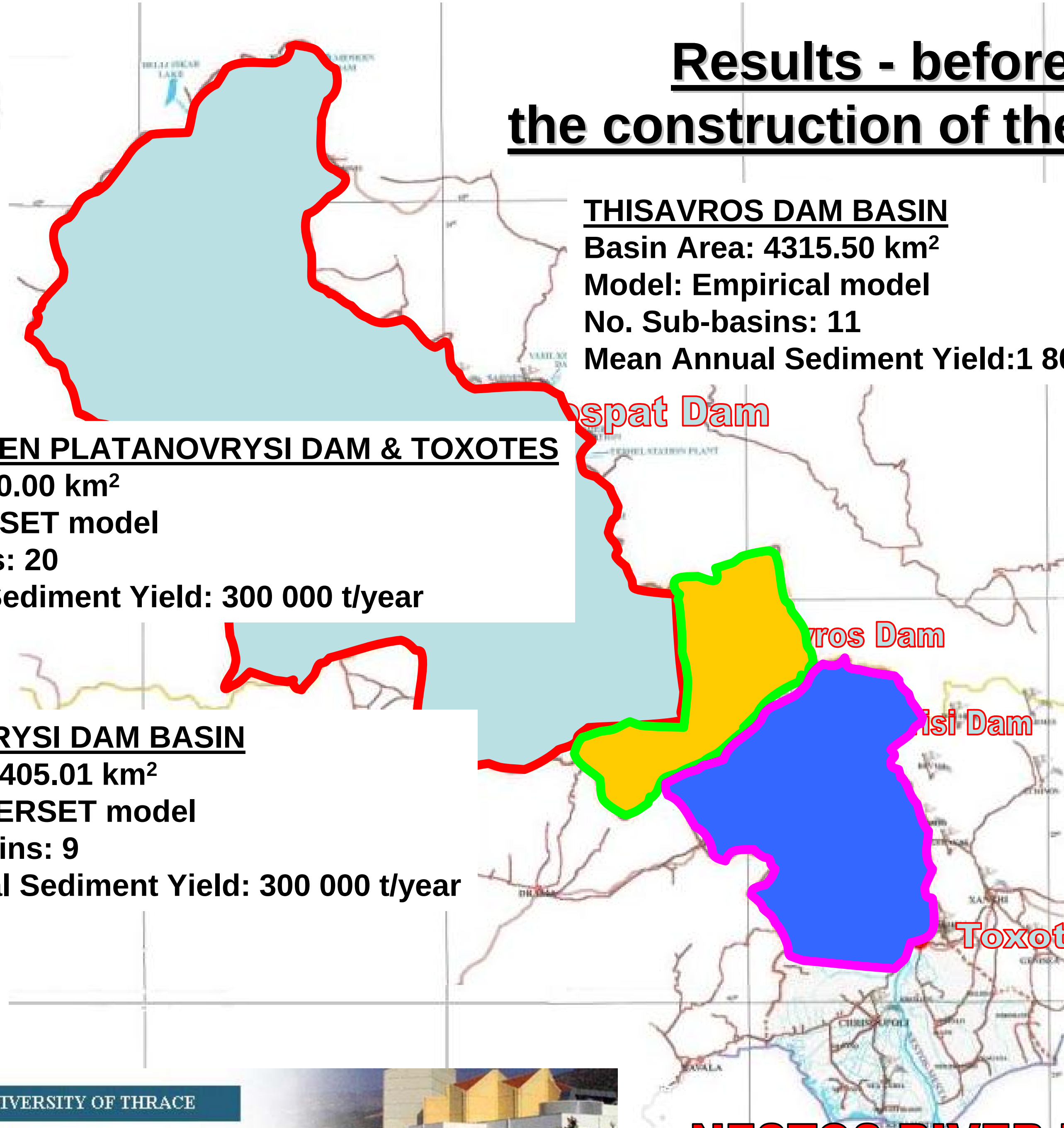
Results - before the construction of the dams



THISAVROS DAM BASIN

Basin Area: 4315.50 km^2

Model: Empirical model

No. Sub-basins: 11

Mean Annual Sediment Yield:1 800 000 t/year

BASIN BETWEEN PLATANOVRYSI DAM & TOXOTES

Basin Area: 840.00 km^2

Model: RUNERSET model

No. Sub-basins: 20

Mean Annual Sediment Yield: 300 000 t/year

PLATANOVRYSI DAM BASIN

Basin Area: 405.01 km^2

Model: RUNERSET model

No. Sub-basins: 9

Mean Annual Sediment Yield: 300 000 t/year

NESTOS RIVER BASIN

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Results - after the construction of the dams

The sediment yield originating from Thisavros dam basin is accumulated in Thisavros Reservoir, while the sediment yield originating from Platanovrysi dam basin is accumulated in Platanovrysi Reservoir.

<u>BASIN BETWEEN PLATANOVRYSI DAM & TOXOTES</u>

Basin Area: 840.00 km^2

Model: RUNERSET model

No. Sub-basins: 20

Mean Annual Sediment Yield: 300 000 t/year

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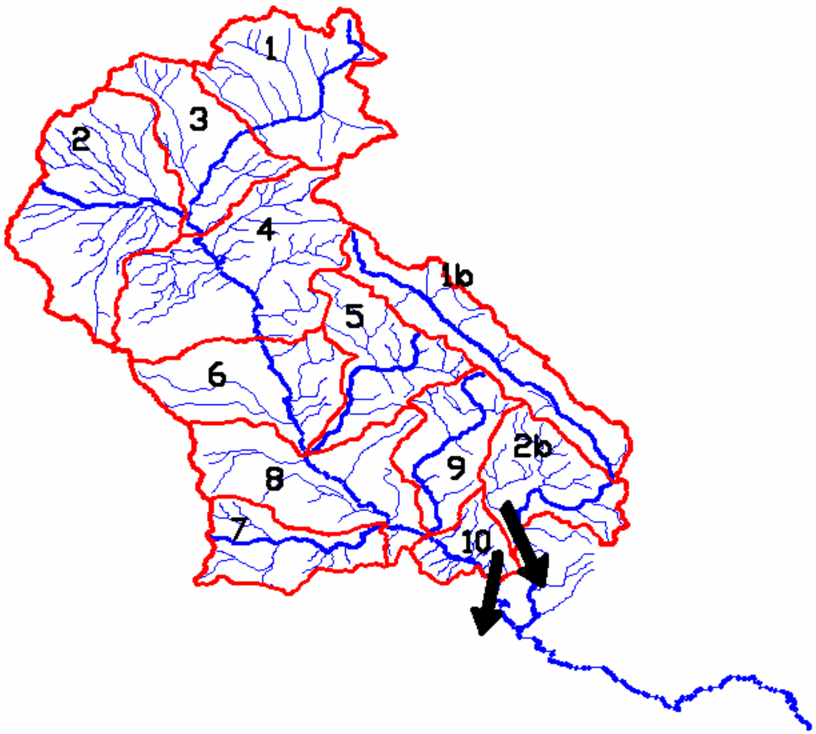
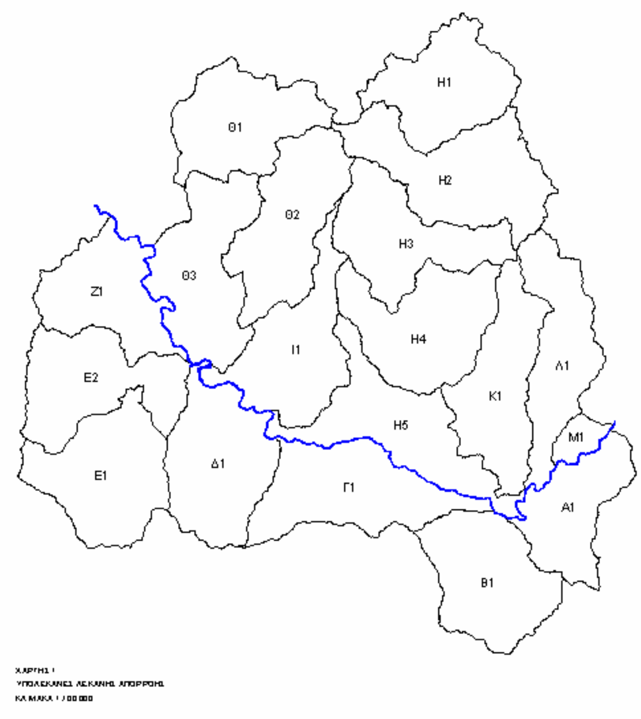


THE BULGARIAN PART OF THE HYDROLOGICAL BASIN OF THISAVROS DAM IS DIVIDED INTO:

12 SUB BASINS

THE GREEK PART OF THE HYDROLOGICAL BASIN OF THISAVROS DAM IS DIVIDED INTO:

19 SUB BASINS



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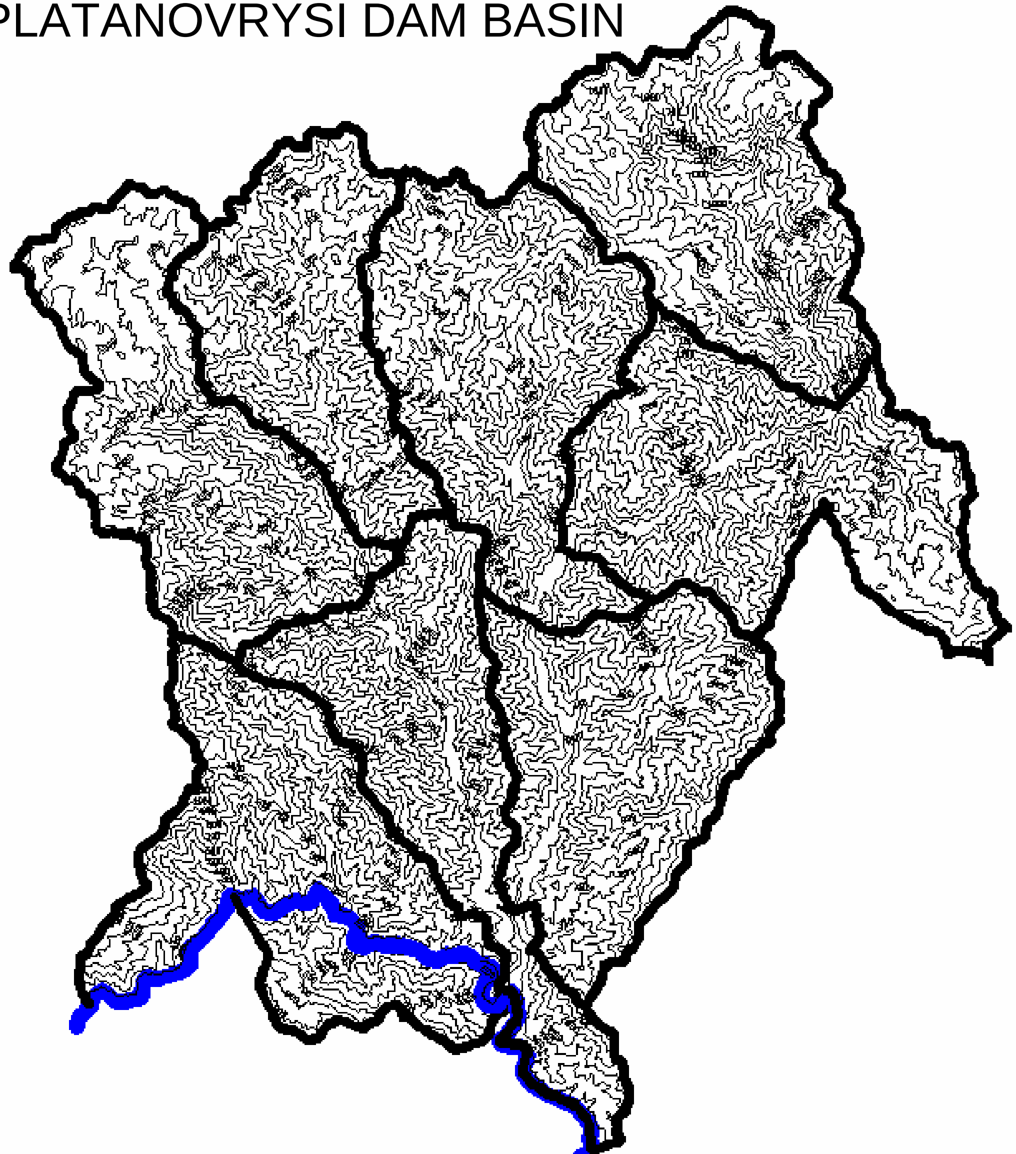
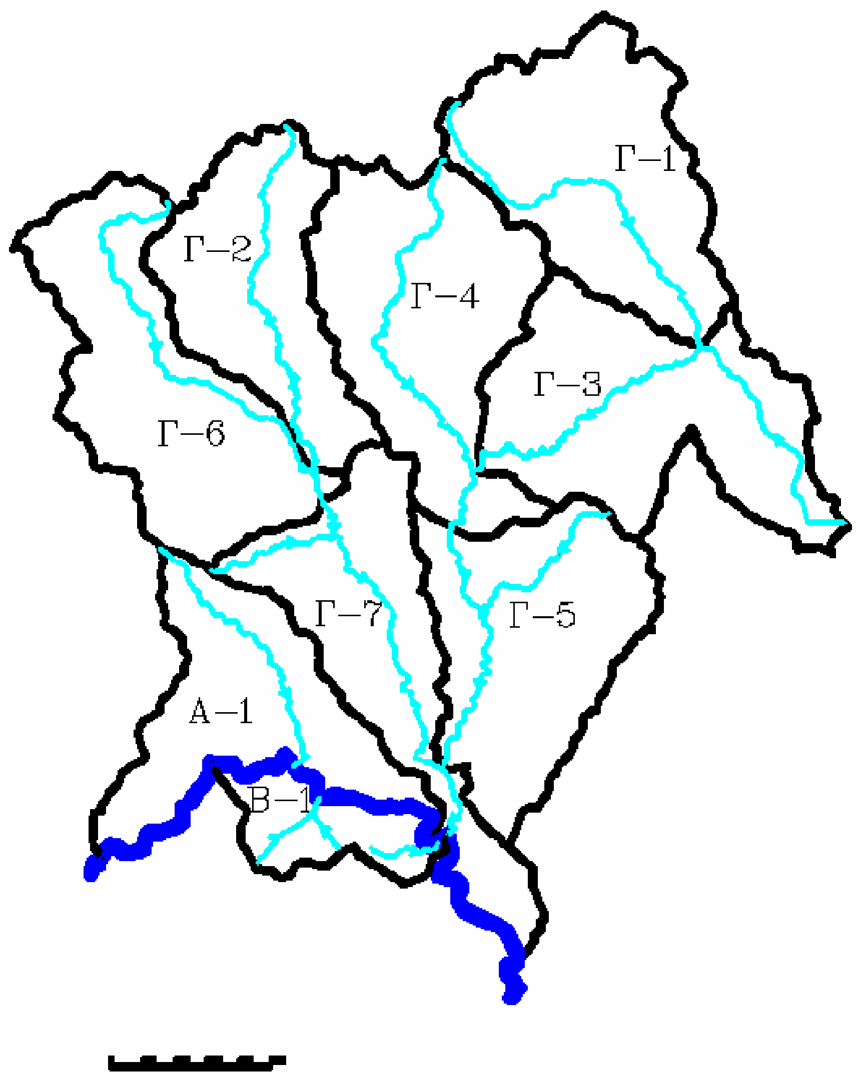
PLATANOVRYSI DAM BASIN

ALTITUDE MAP



PLATANOVRYSI DAM BASIN

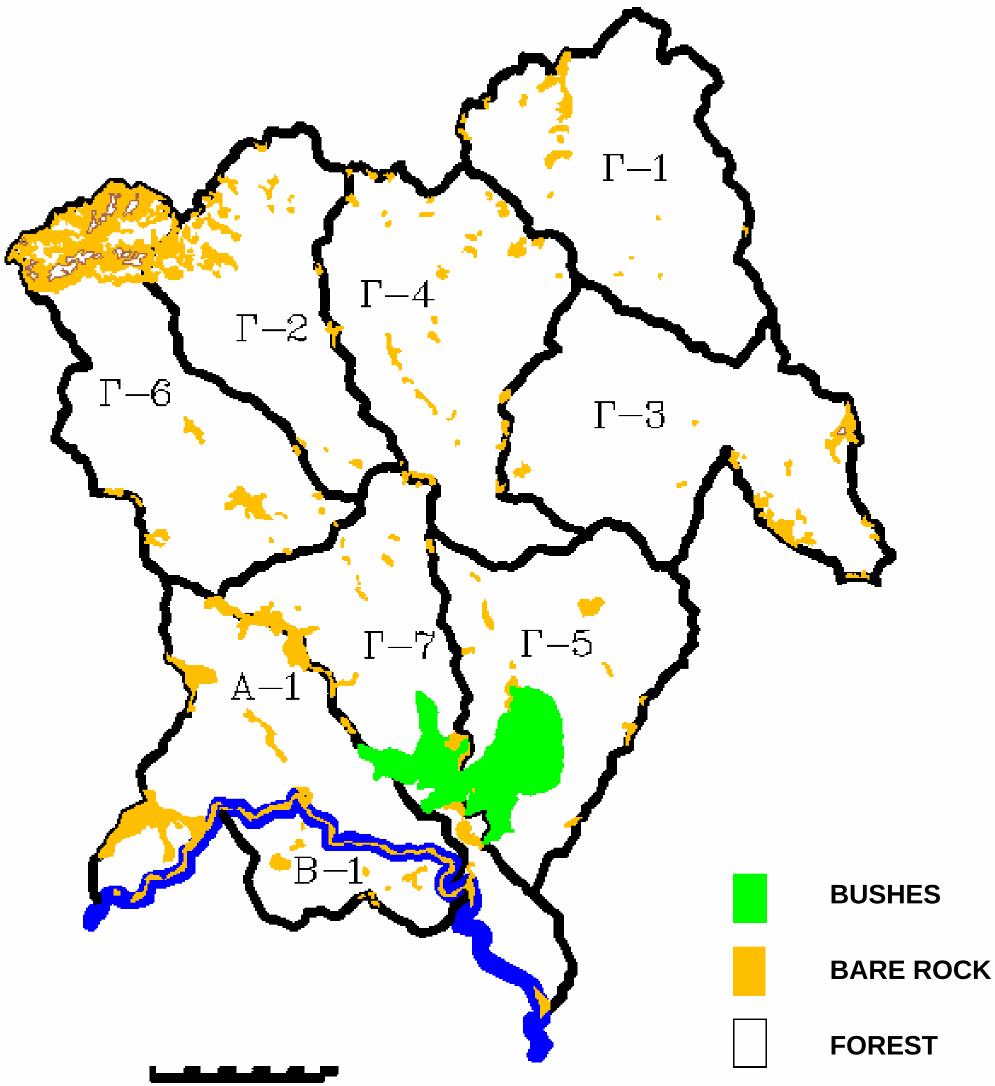
MAIN STREAMS MAP



PHASE B'

PLATANOVRYSI DAM BASIN

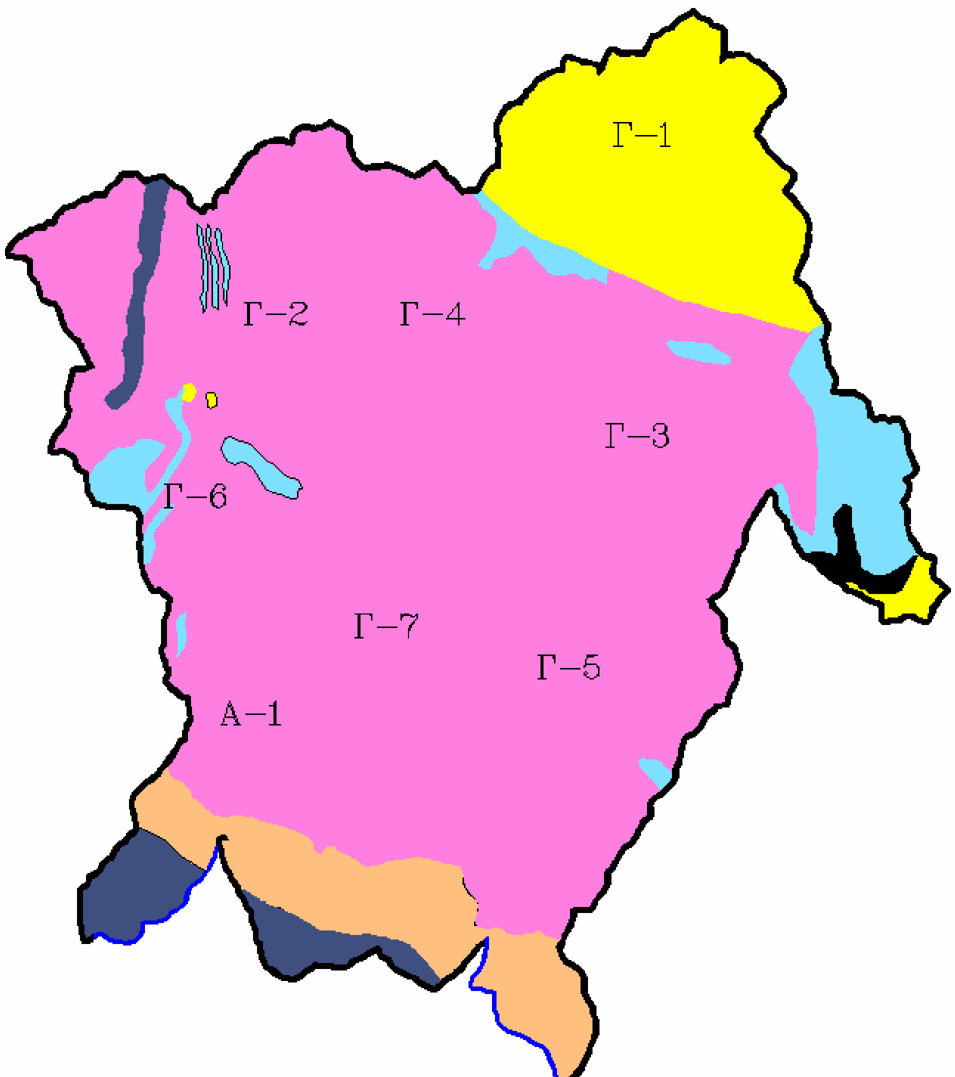
LAND USE MAP



PHASE B’

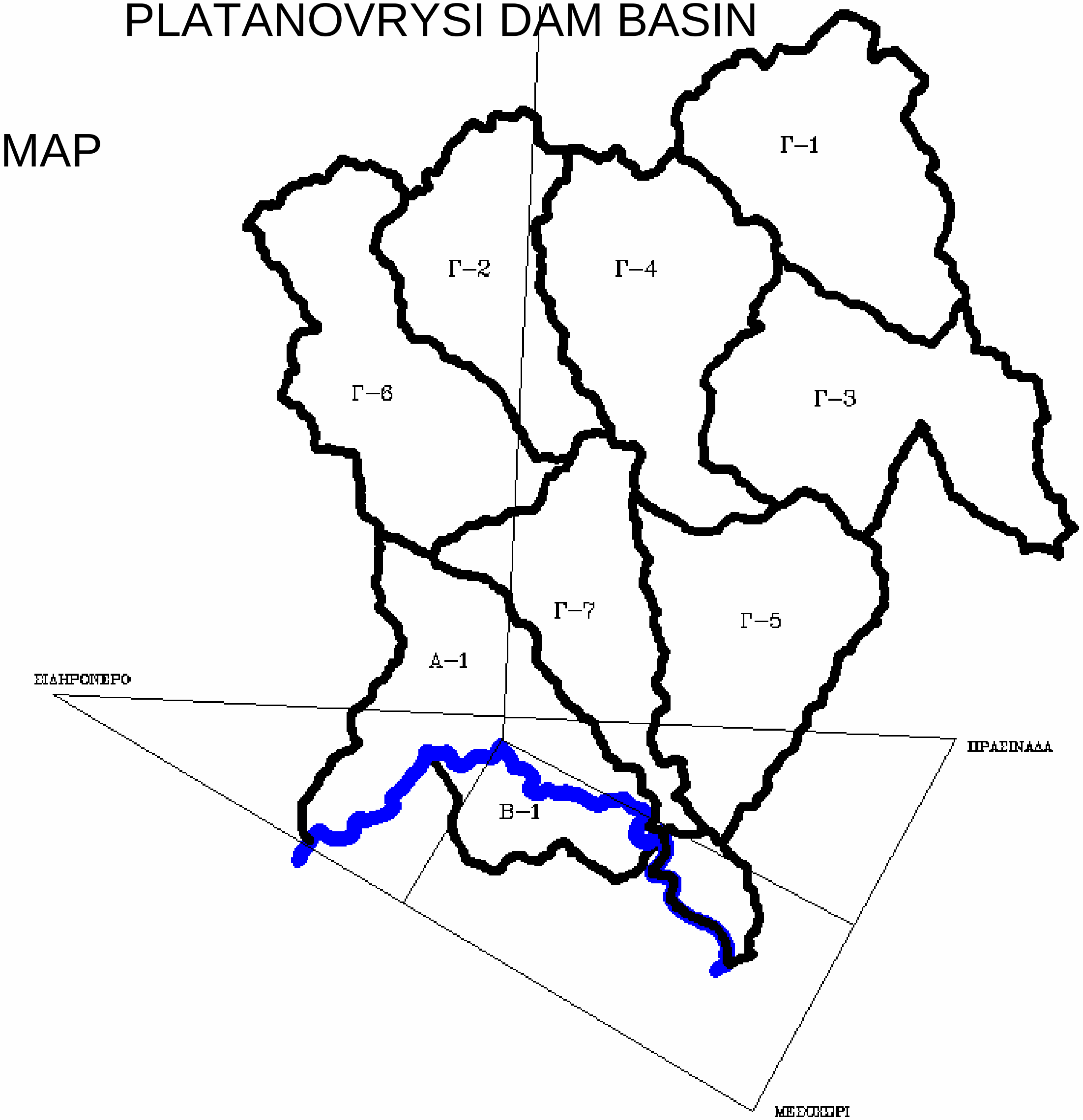
PLATANOVRYSI DAM BASIN

GEOLOGICAL
MAP

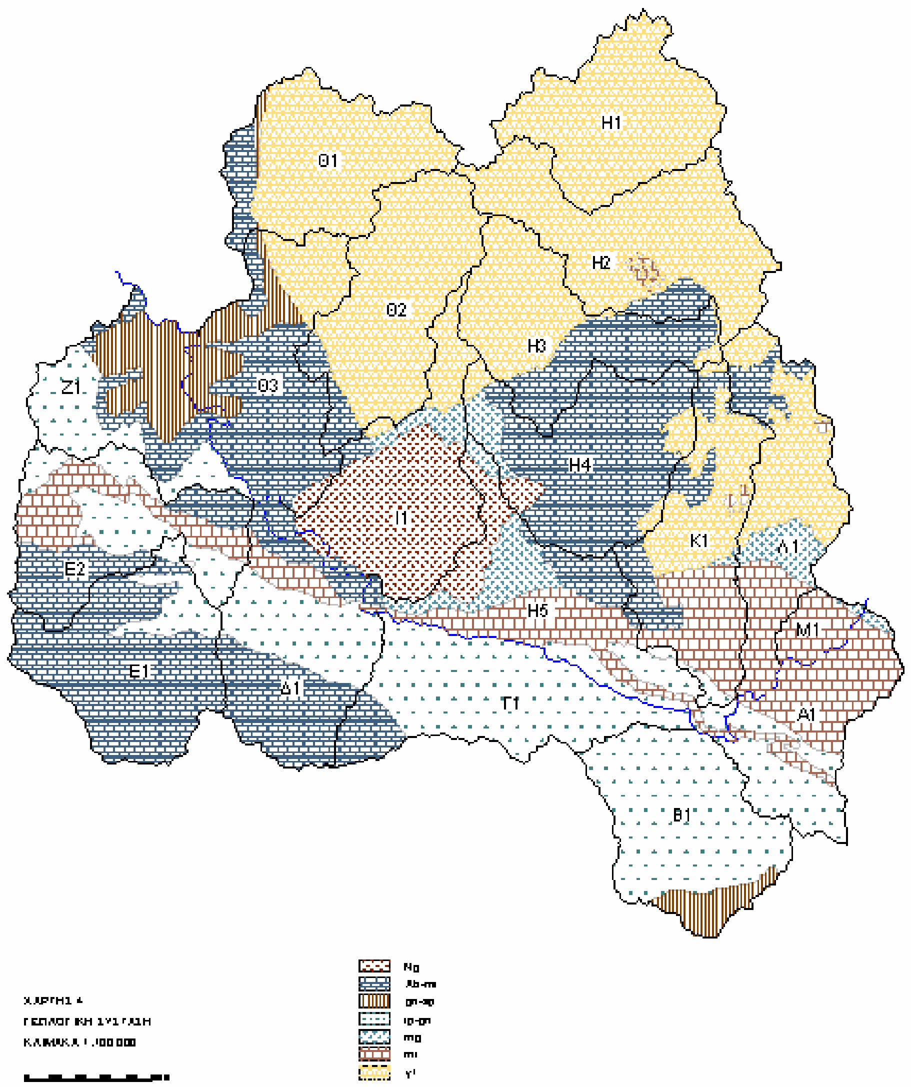


PLATANOVRYSI DAM BASIN

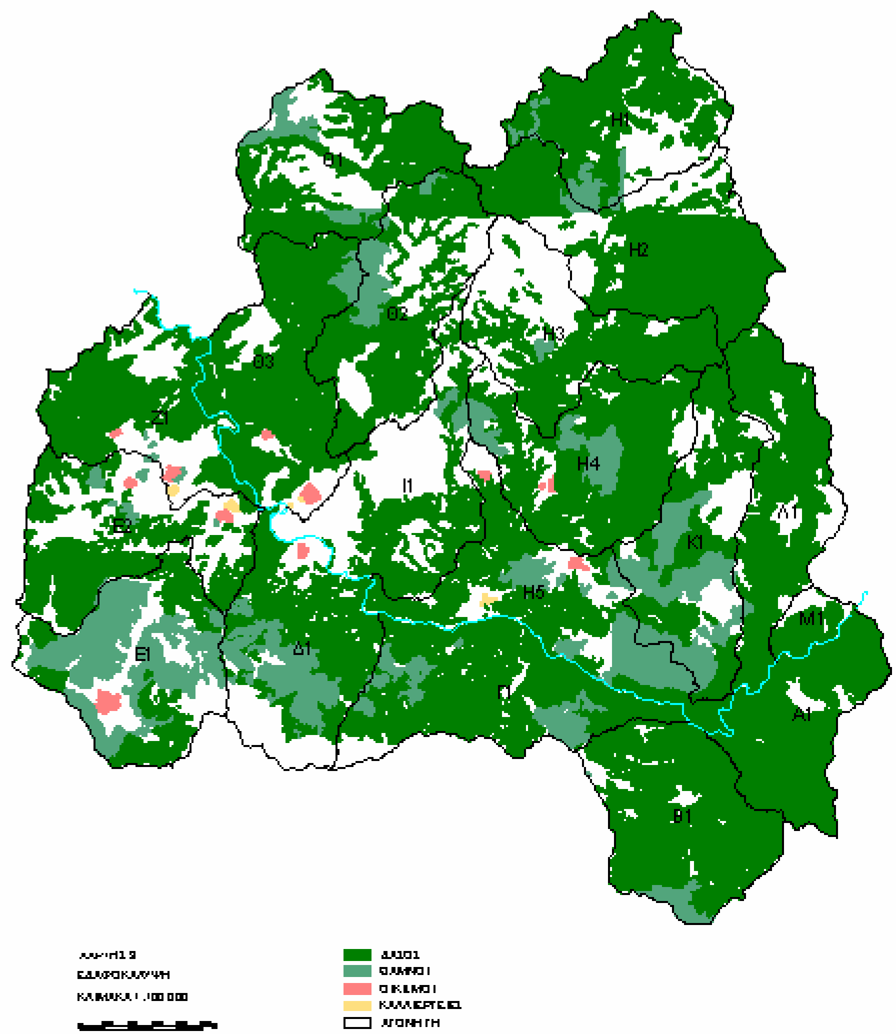
THIESSEN POLYGONS MAP



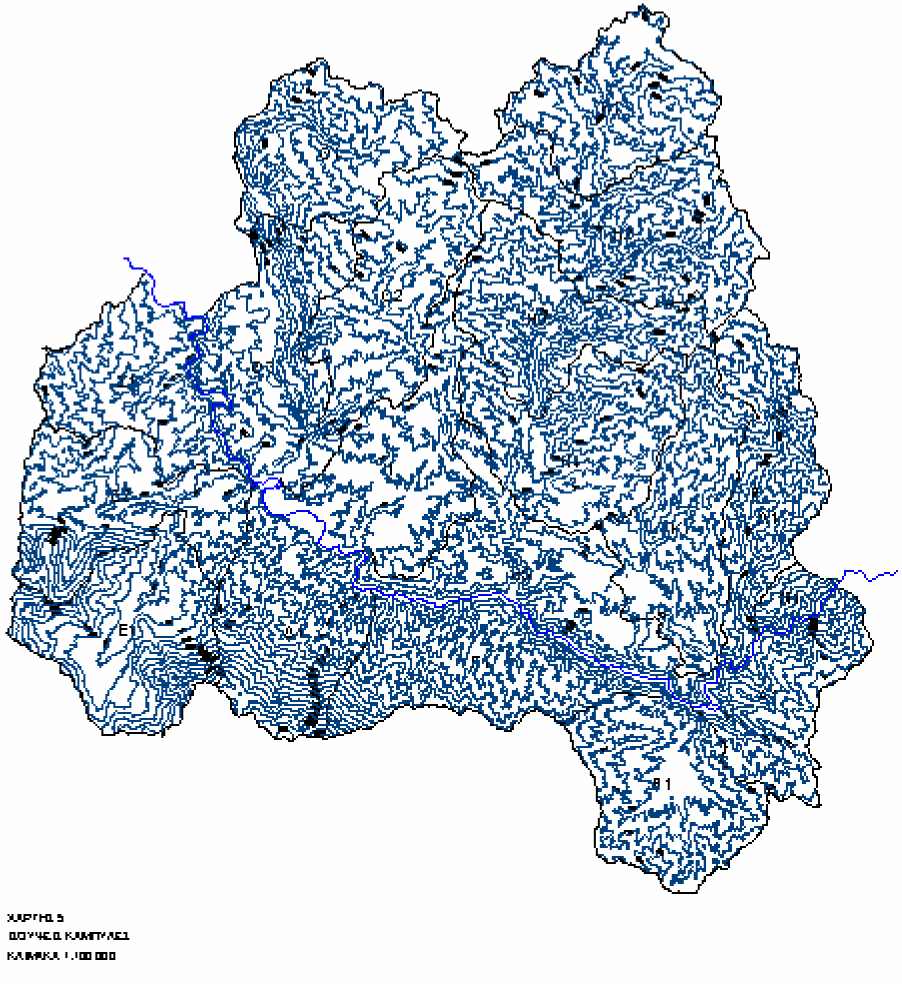
GEOLOGICAL MAP



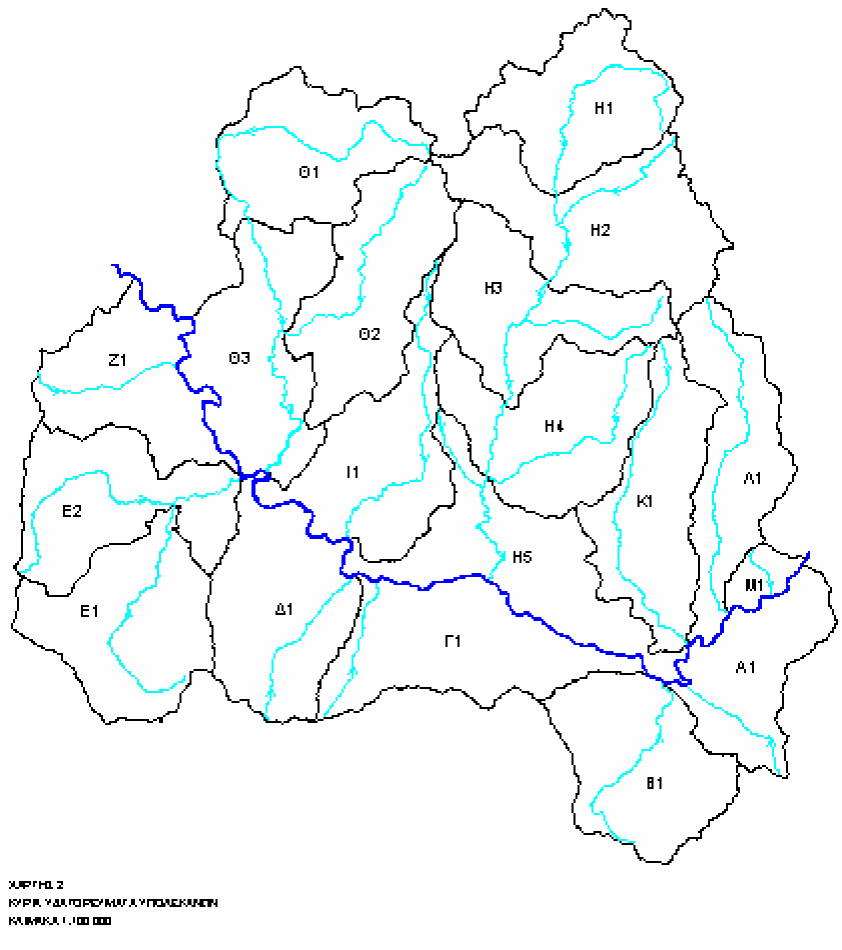
LAND COVER -VEGETATION



TOPOGRAPHIC MAP -SLOPE



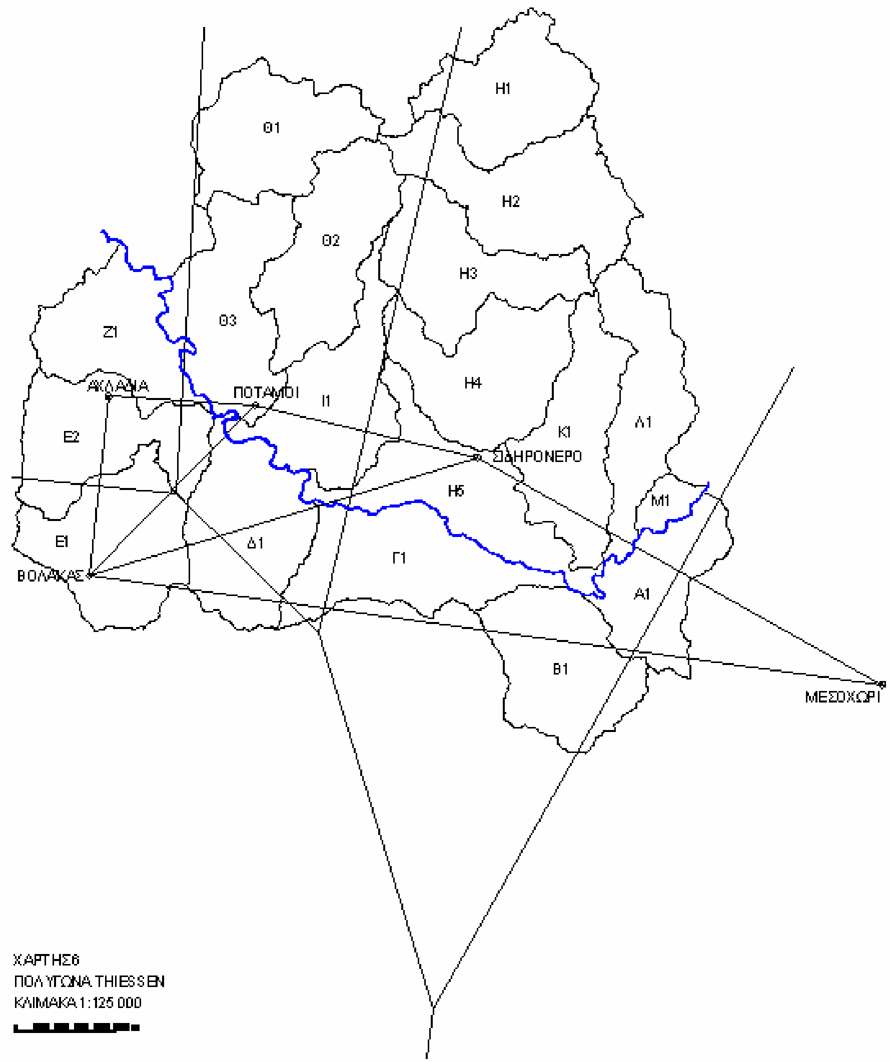
MAIN STREAMS OF THE SUB BASINS



ON-GOING WORK

GREEK PART OF THISSAVROS DAM BASIN

THIESSEN
POLYGONS MAP



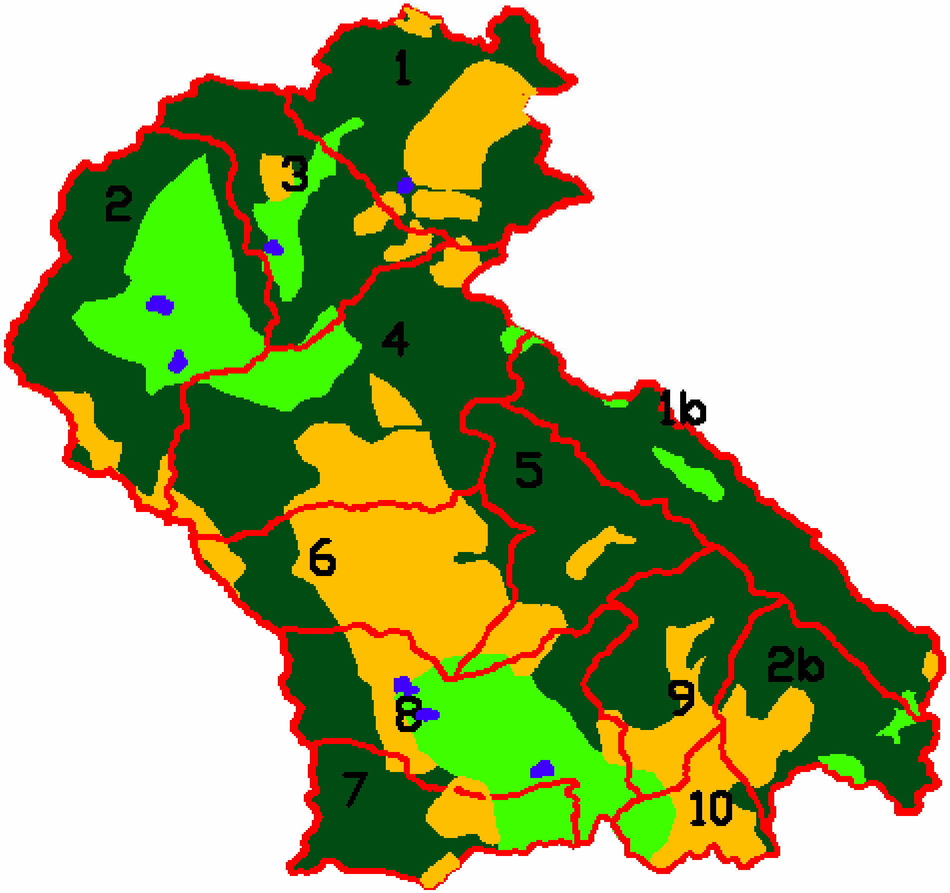
- **RUNERSET model will be calibrated using data from the Mesta –M.Koula sub-basins of the Bulgarian part of Nestos River basin, for which water discharge and sediment yield data are available.**

- **RUNERSET model will be applied to the entire Bulgarian part of Nestos River basin and to Greek part of the basin up to the Thisavros dam for more accurate estimations .**

ON-GOING WORK

BULGARIAN PART OF THISSAVROS DAM BASIN

LAND USE MAP



ON-GOING WORK

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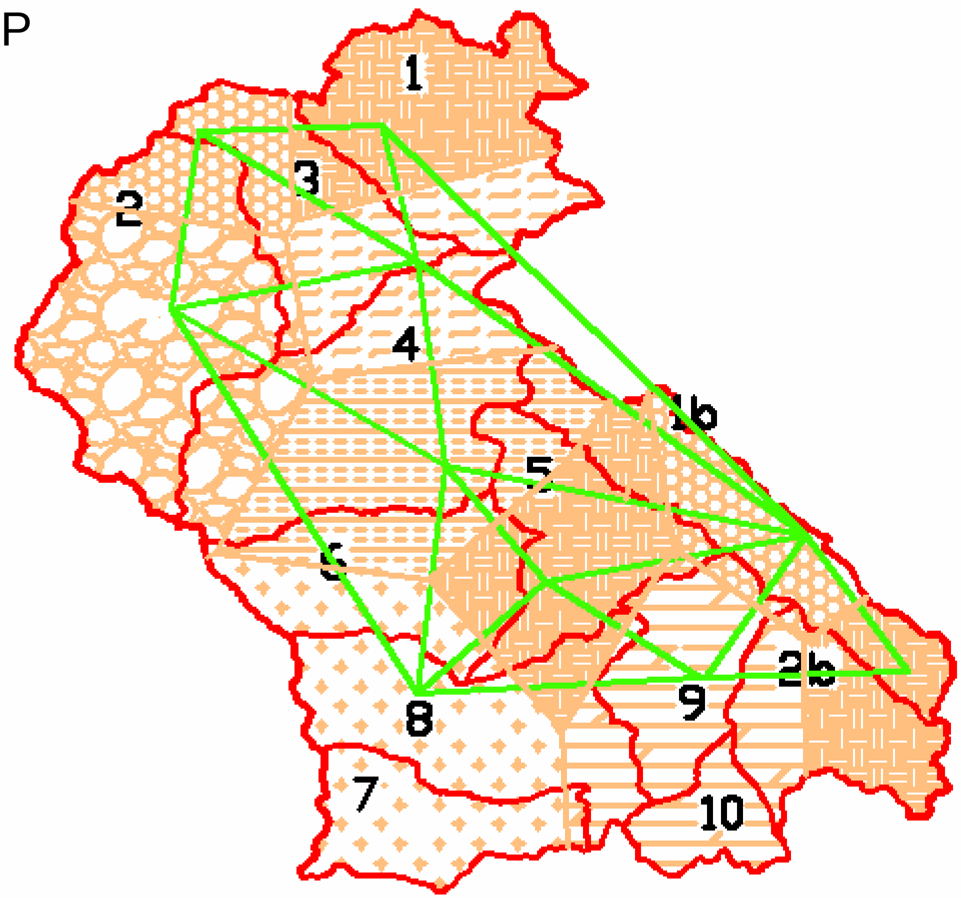
BULGARIAN PART OF THISSAVROS DAM BASIN

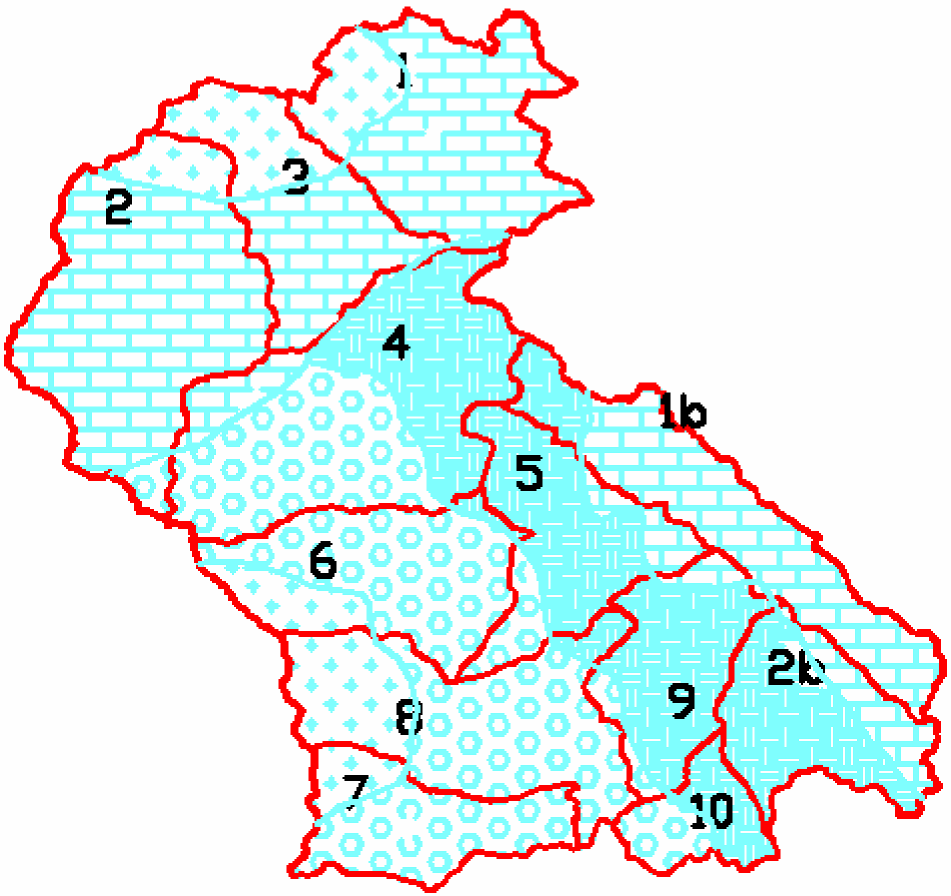
THIESSEN
POLYGONS MAP



ON-GOING WORK

BULGARIAN PART OF THISSAVROS DAM BASIN

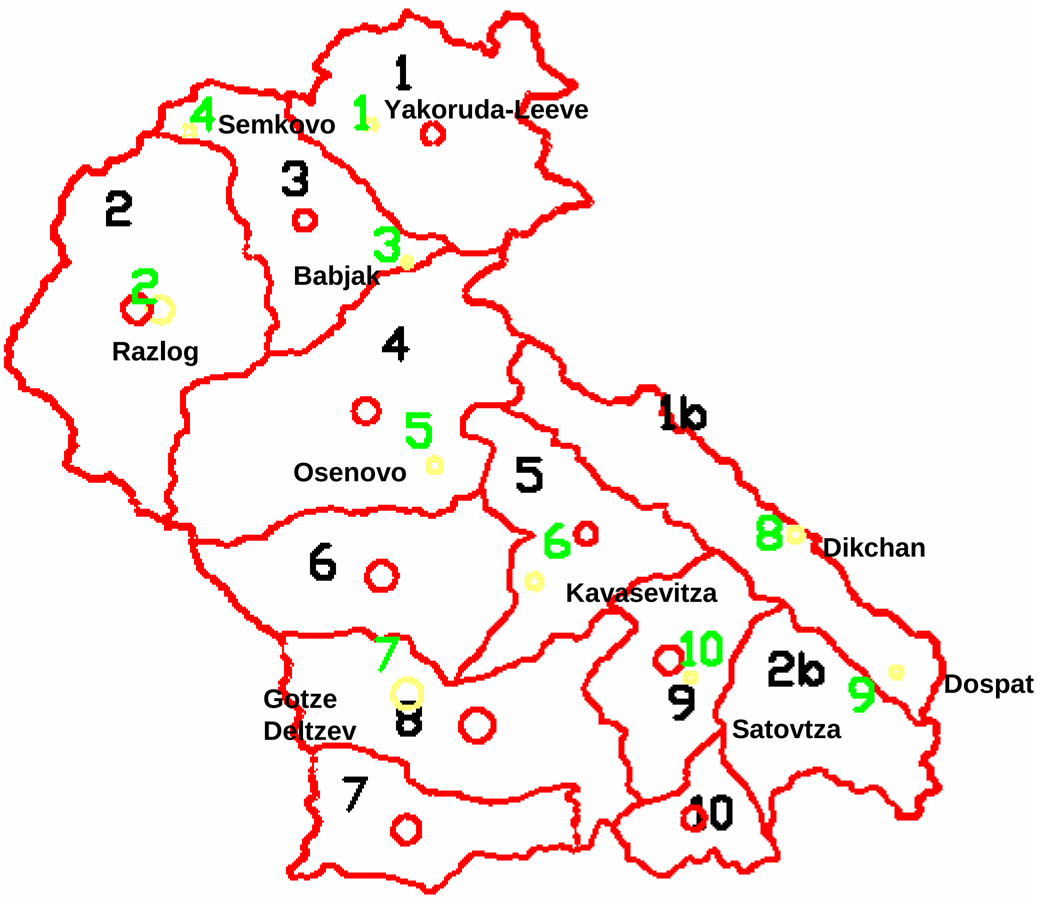
GEOLOGICAL
MAP



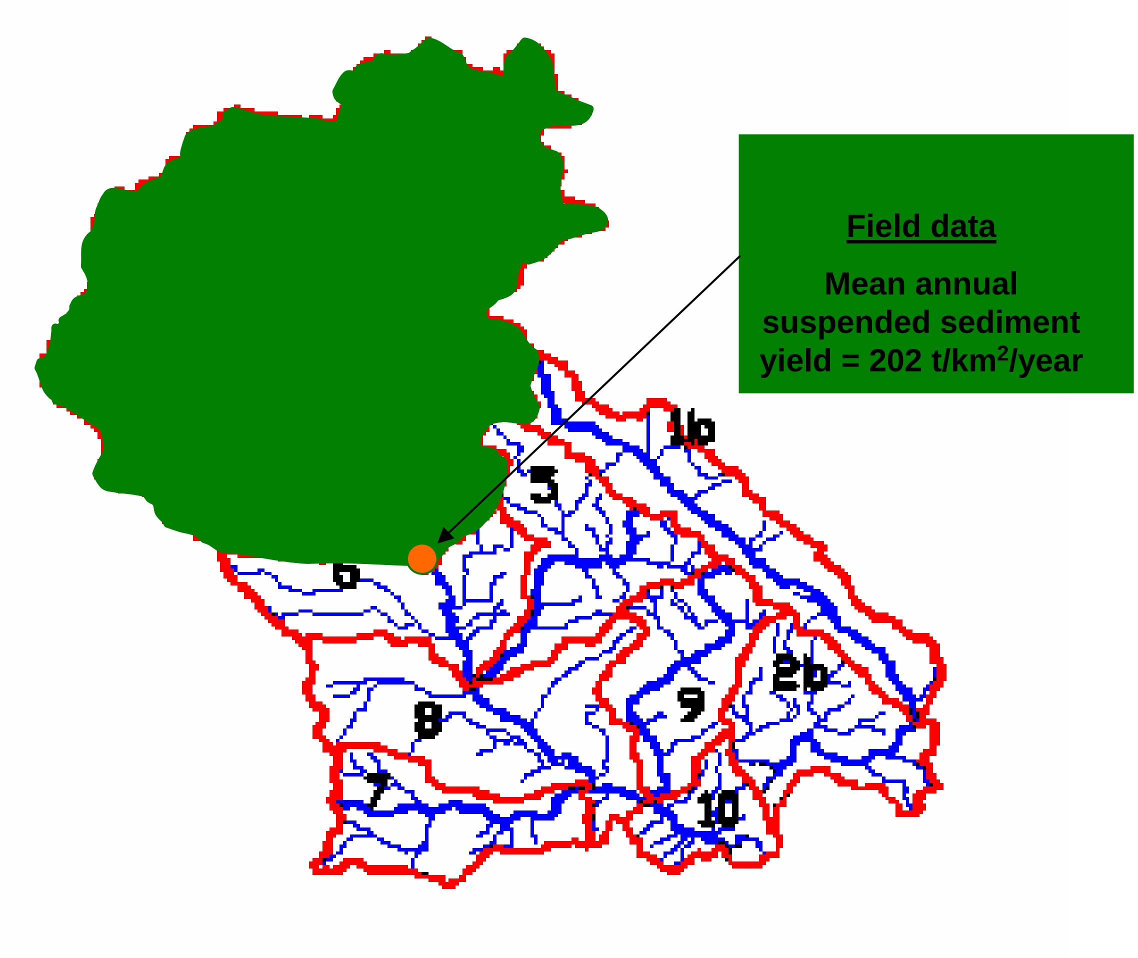
ON-GOING WORK

BULGARIAN PART OF THISSAVROS DAM BASIN

GRAVITY CENTERS AND STASIONS MAP



ON-GOING WORK



ON-GOING WORK

The calculation of the mean annual sediment yield that reaches to the Thissavros Dam from the greek part of the basin has been done already, using the RUNERSET model.

SUM OF RESULTS			
YEAR	**yd [tn]**	**ya [tn]**	**dr = ya / yd**
1980	192500	184000	0,96
1981	130800	127800	0,98
1982	322000	312500	0,97
1983	116000	114000	0,98
1984	376500	360500	0,96
1985	95000	94500	0,99
1986	632000	613000	0,97
1987	900500	875500	0,97
1988	372600	357600	0,96
1989	127500	121000	0,95
1990	569400	552400	0,97

MEAN ANNUAL SEDIMENT YIELD =337527tn (=420 tn/km^2/year)

ON-GOING WORK

The calculation of the sediment yield that reaches the greek part of the basin and originates, from the bulgarian part, **is under process**. The calculation is performed both for Nestos and Dospat Rivers, taking into consideration the same time period.

At the end, the results will be compared with available field data in the bulgarian part (Mesta –M.Koula) for validation purposes. Moreover, suggestions will be made for appropriate methods of sediment management.

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REMARKS & CONCLUSIONS

- We calculated using a simplified empirical model that the mean annual sediment yield that reaches the outlet of the Nestos River basin has been decreased by about 2.100.000 t/year, after the construction of the dams.
- We are now working (during phase C) to refine our modeling to give the monthly variations of the sediment yoeld using a more precise model of the sediment erosion anf transport.
- The balance of sediment transport from Nestos River to its coastal region has been disturbed considerably.

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