International Conference Sediment Transport Modeling in Hydrological Watersheds and Rivers

Istanbul, Turkey, 14-16 November 2012

Sediment Yield Assessment In Greece

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Brief Outline of the Presentation

- Calculation of the mean annual sediment discharge in 12 river cross sections in North-Western Greece using a "physically – based" sediment rating curve. In other 3 catchments sediment discharge is estimated from reservoir deposits' measurements (hydrographic survey).
- Computation of a number of hydrologic and geomorphologic parameters using an advanced surface mapping software.
- Non-linear, multiple regression analyses between sediment yield/discharge with certain, statistically & theoretically independent, geomorphologic variables.

Research Project

Assessment of catchments' sediment yield with the combine use of hydrologic and geomorphologic parameters, Funded by the National Technical University of Athens, Greece, under the research framework "PROTAGORAS"

Sediment discharge rating curves

- A sediment discharge rating curve is a power function between simultaneous measurements of sediment discharge (Q_s) and river discharge (Q) according to the equation:

$$Q_{S\,i} = aQ_i^{\,b} n_i$$

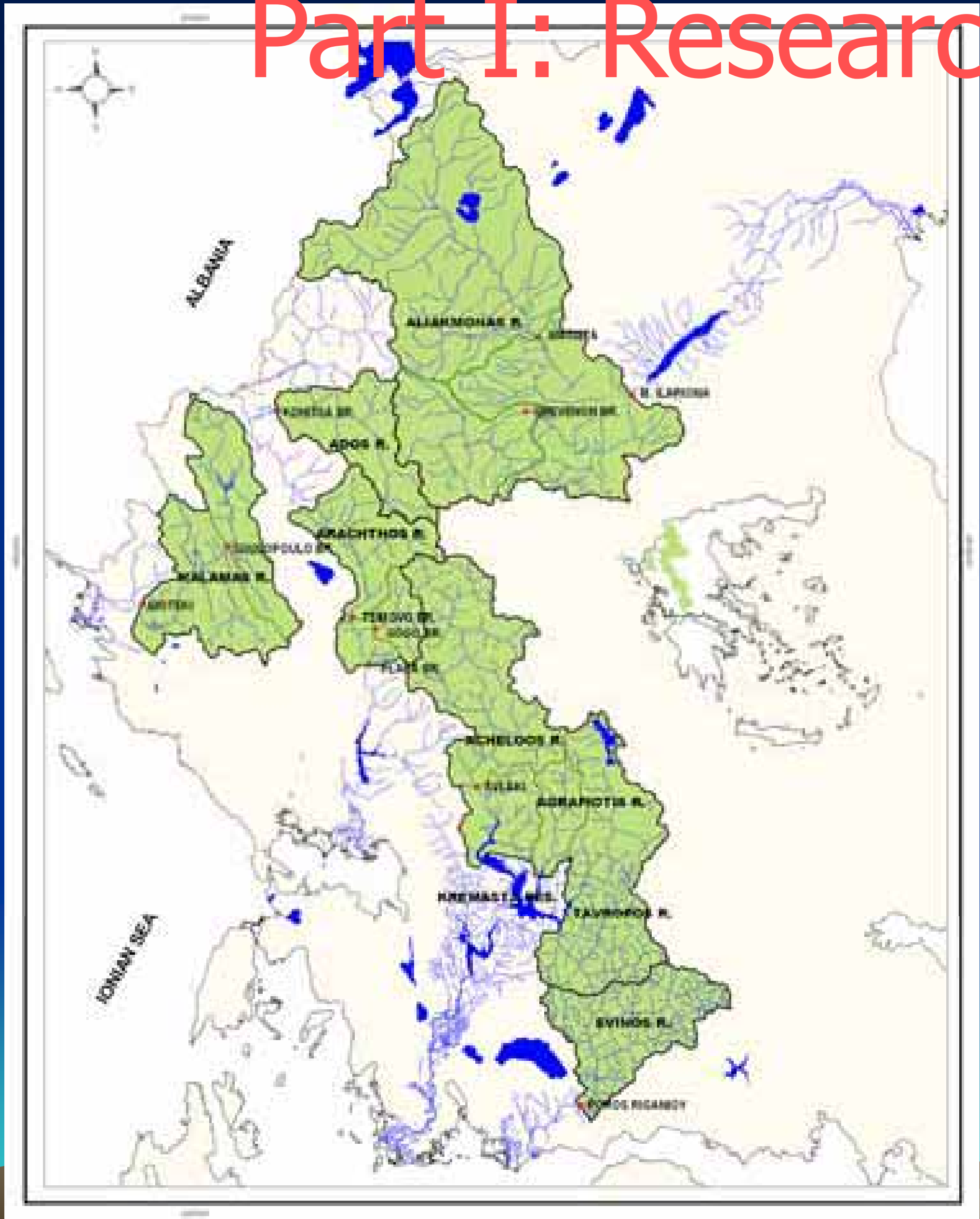
- The parameters *a* and *b* usually are computed from the linear regression of their logarithms, such as:

$$\log Q_{Si} = \log a + b \log Q_i + \varepsilon_i$$

- Ferguson (1986) proposed a correction factor that is proportional to the deviation of the logarithms from the linear rating curve.

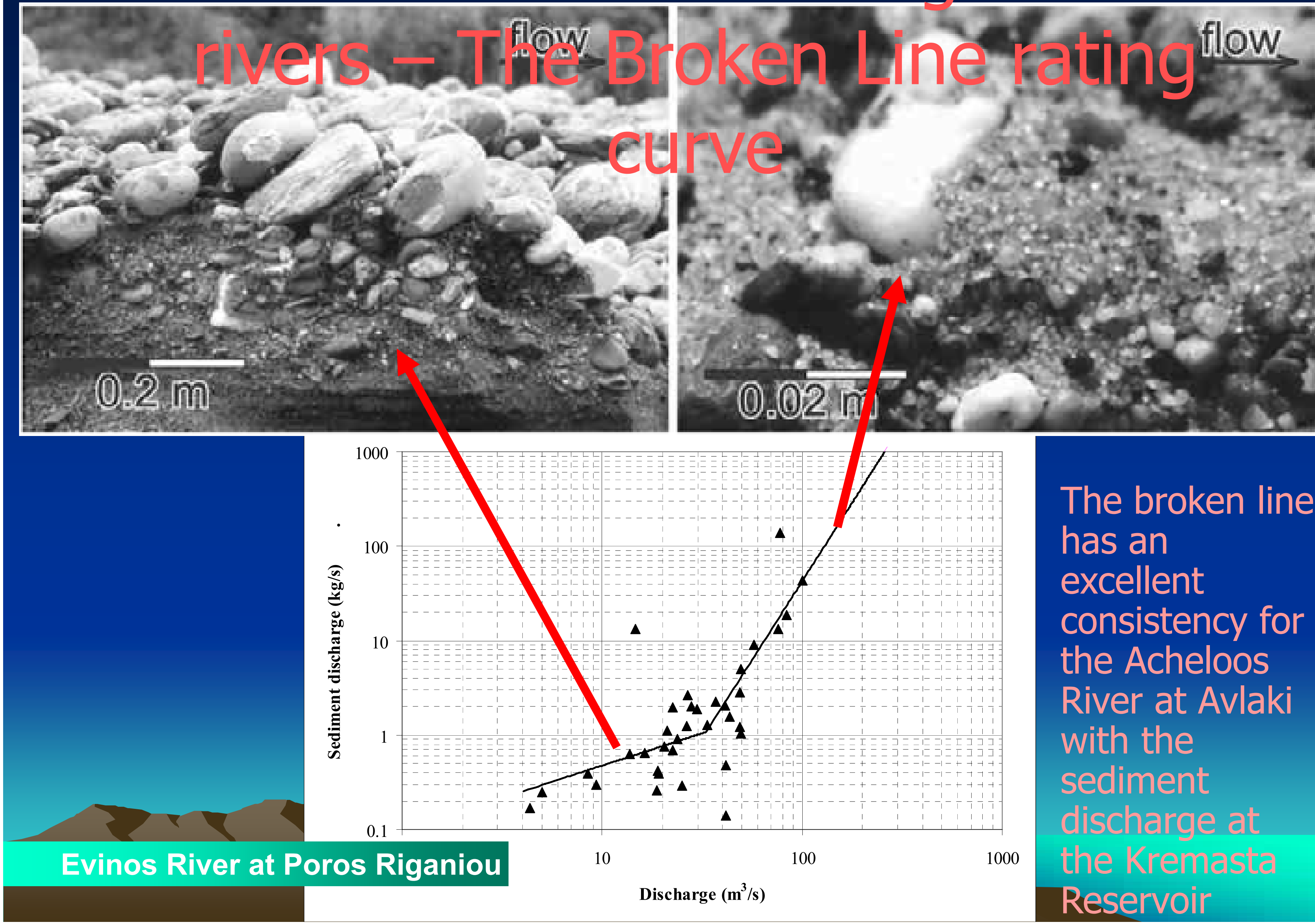
- The residuals ε_i should be uncorrelated and homoscedastic; however this requirement is rarely met in practice.

Part I: Research Application



- Sediment discharge measurements in 12 sites by the PPC between 1965 and 1980
- Three sites from reservoir sedimentation studies (Kremasta Reservoir in 1998-1999)
- Mean daily discharges for all the 12 river sites were available from the PPC
- Absolutely no sediment discharge measurement programs are in operation in Greece from 1980

Mechanics of erosion in gravel bed rivers – The Broken Line rating curve

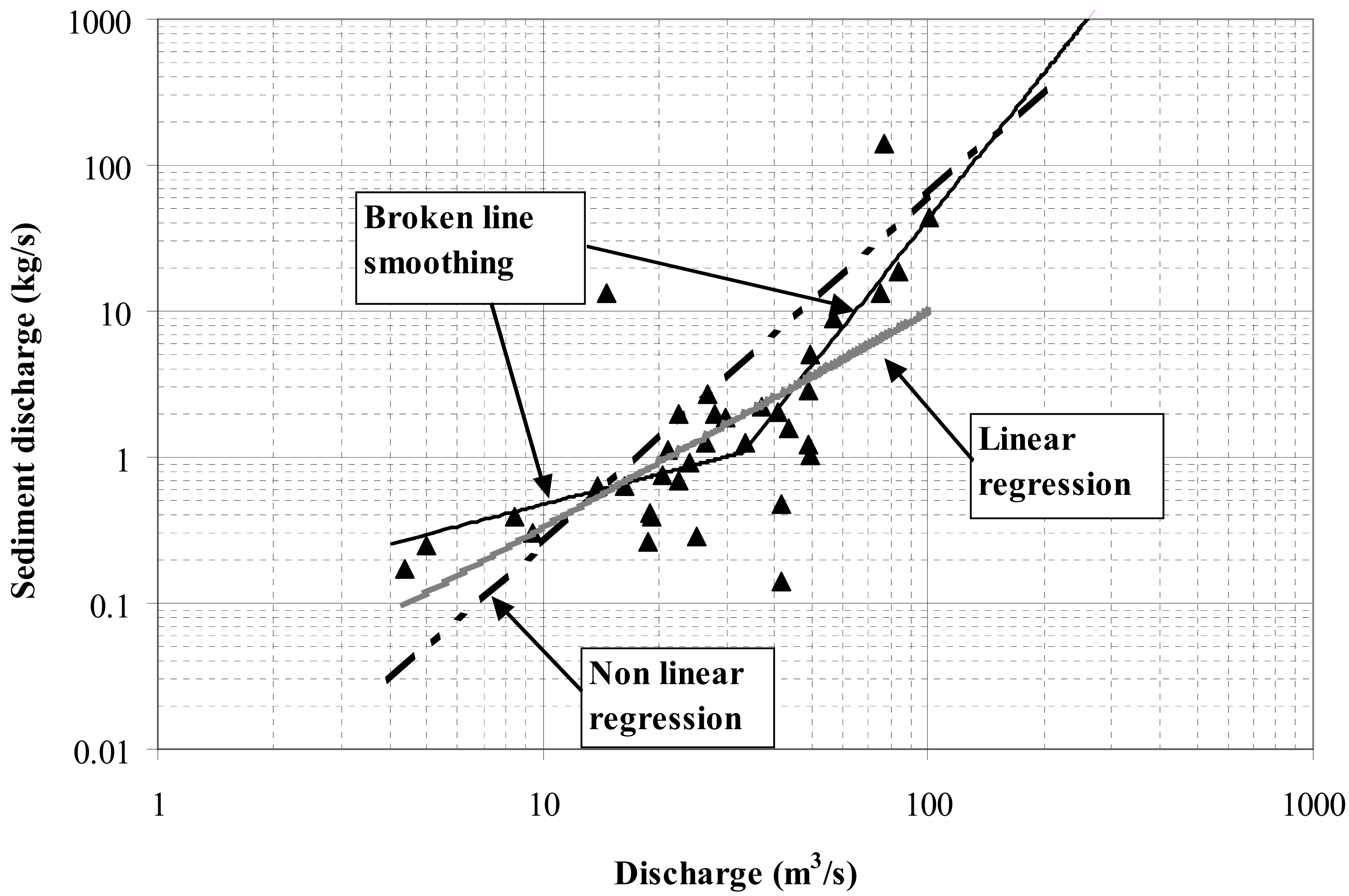


Evinos River at Poros Riganiou

The broken line has an excellent consistency for the Acheloos River at Avlaki with the sediment discharge at the Kremasta Reservoir

Gravel – bed arrangement and the armour layer in Aracthos R. at Plaka Br.

Sediment discharge rating curves



MEAN ANNUAL SEDIMENT DISCHARGE (kg/s) IN ACHELOOS RIVER AT AVLAKI	
Measured from reservoir deposits in Kremasta Res.	**66.0**
Simple power regression	13.5
Ferguson correction	17.6
Wet-Dry periods	21.4
Non-linear regression	19.0
Increasing-Decreasing hydrograph stage	17.9
Broken-Line Interpolation	**73.3**

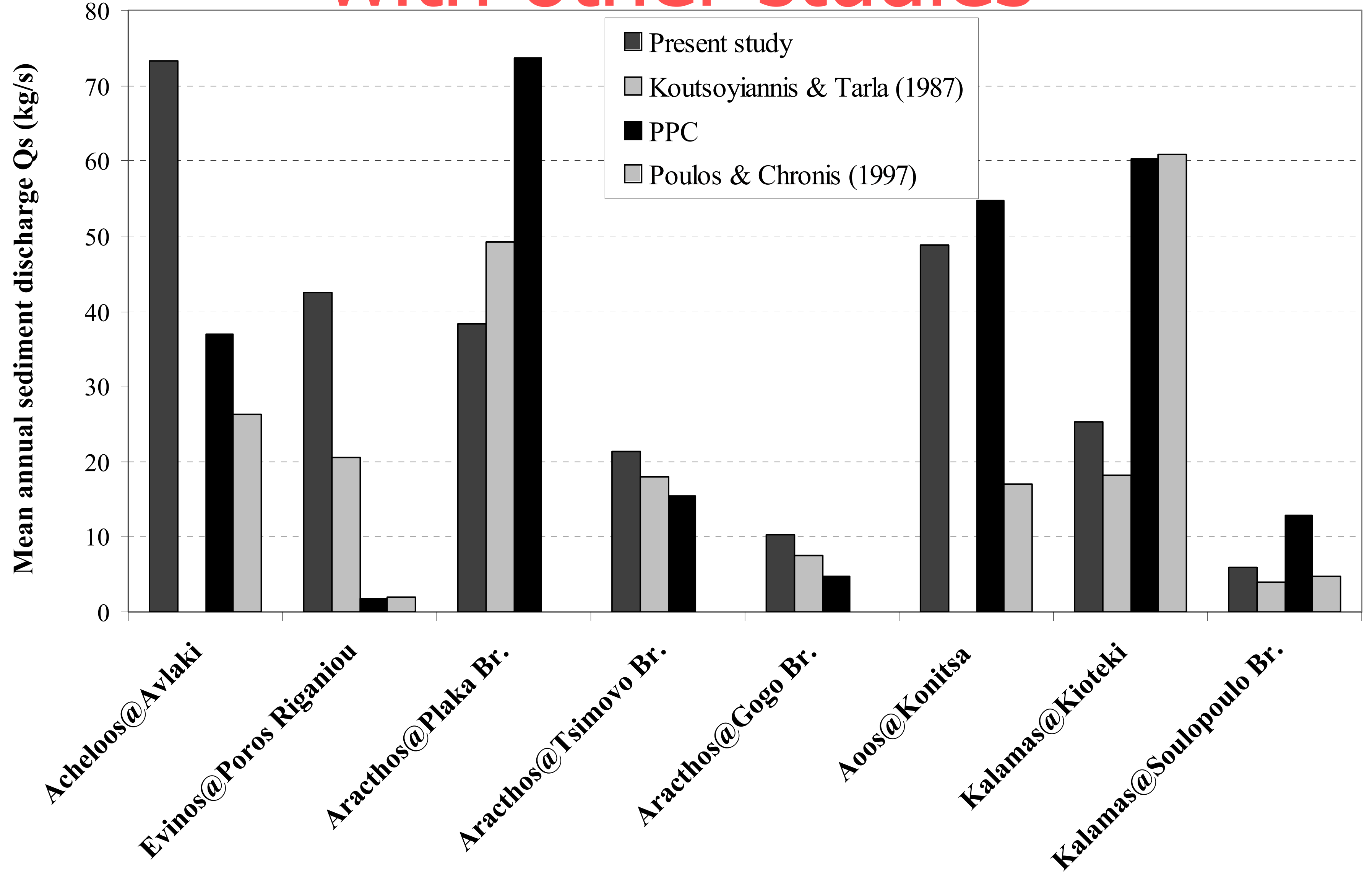
Unpublished Ph.D. Thesis

Zarris, D., “Appraisal of sediment deposits in hydropower reservoirs”, National Technical University of Athens

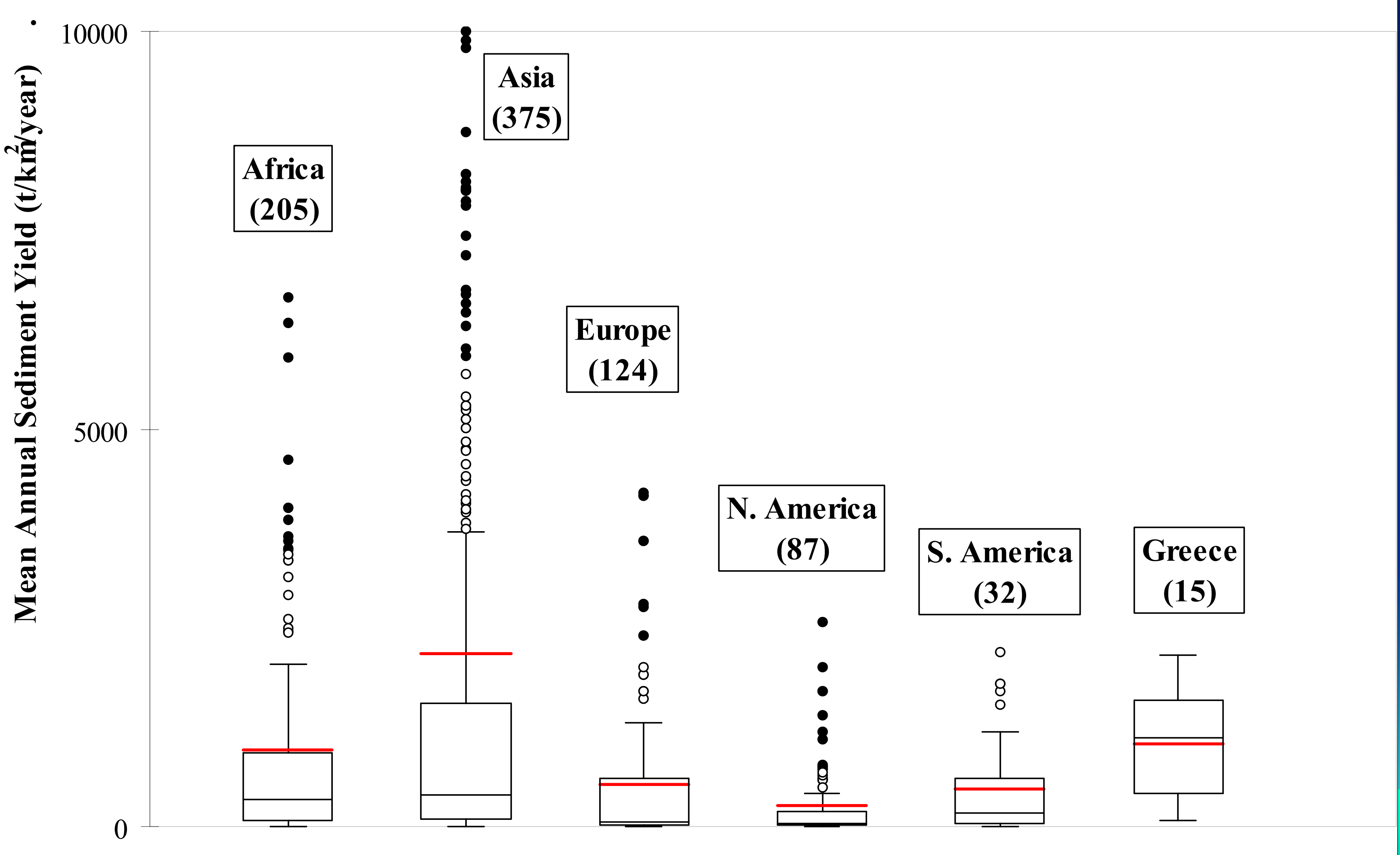
Part II: Results

River	Cross Section	Area (km^2)	Q (m^3/s)	Qs (kg/s)	Sy (t/km^2)
Acheloos	Avlaki	1355	50.2	73.3	1705.5
Acheloos	Kremasta Res.	1733	-	66.0	1201.0
Agrafiotis	Kremasta Res.	320	-	20.9	2059.7
Tavropos	Kremasta Res.	1239	-	19.5	496.3
Evinos	Poros Riganiou	914	25.3	42.5	1466.4
Arachthos	Tsimovo Br.	640	18.7	21.3	1049.5
Arachthos	Gogo Br.	203	11.4	10.3	1600.1
Arachthos	Plaka Br.	970	36.1	38.4	1249.0
Kalamas	Soulopoulo Br.	660	22.7	5.9	281.9
Kalamas	Kioteki	1481	48.9	25.4	540.9
Aoos	Konitsa Br.	706	24.9	48.9	2184.3
Aliakmonas	Siatista	2724	22.8	20.2	233.3
Aliakmonas	Grevenon Br.	847	17.0	2.2	81.3
Aliakmonas	M. Ilarionas	5005	48.7	65.8	414.6
Nestos	Temenos	4954	31.0	31.9	203.4

Part II: Results – Comparison with other studies



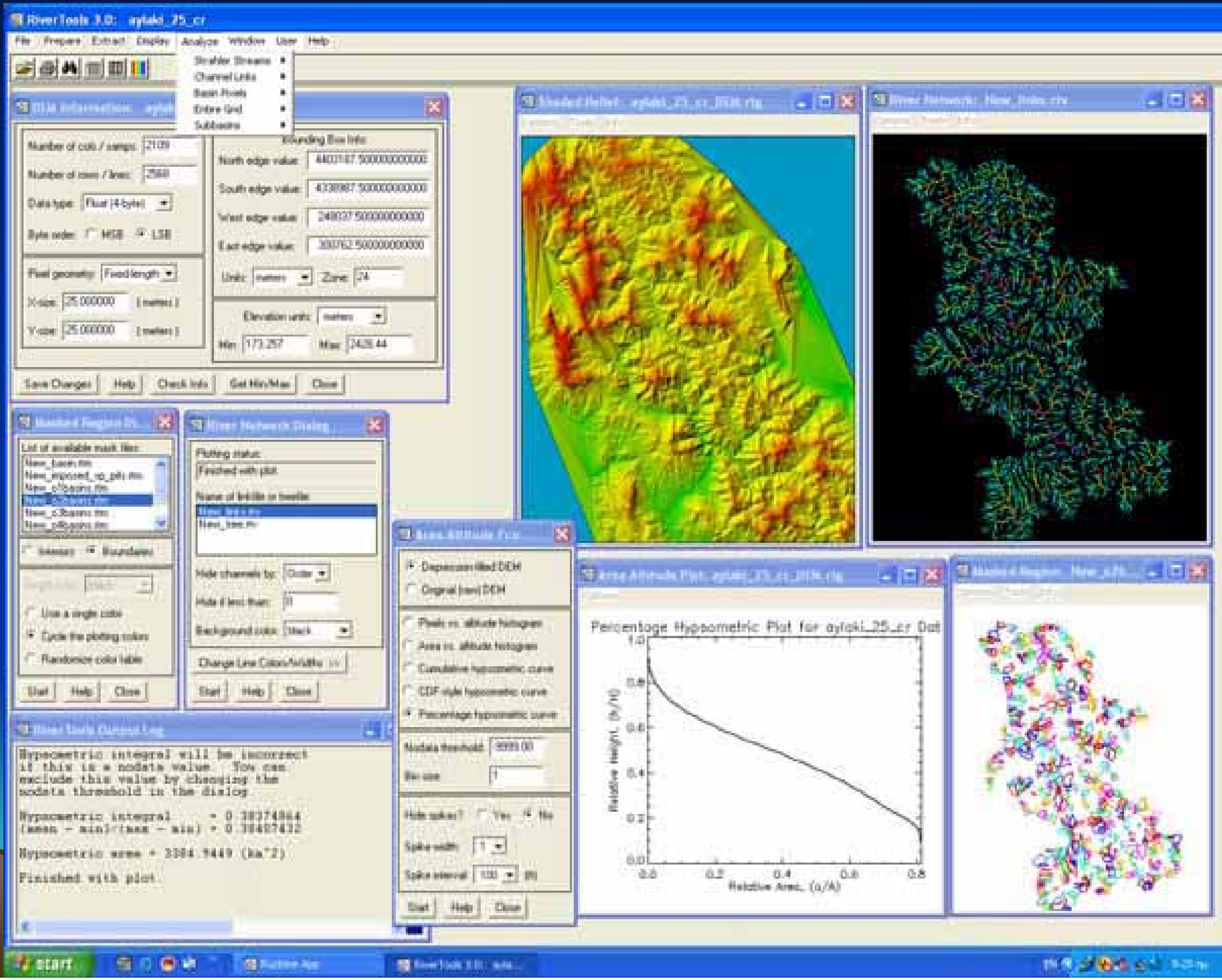
Part II: Comparisons with results from 830 catchments worldwide



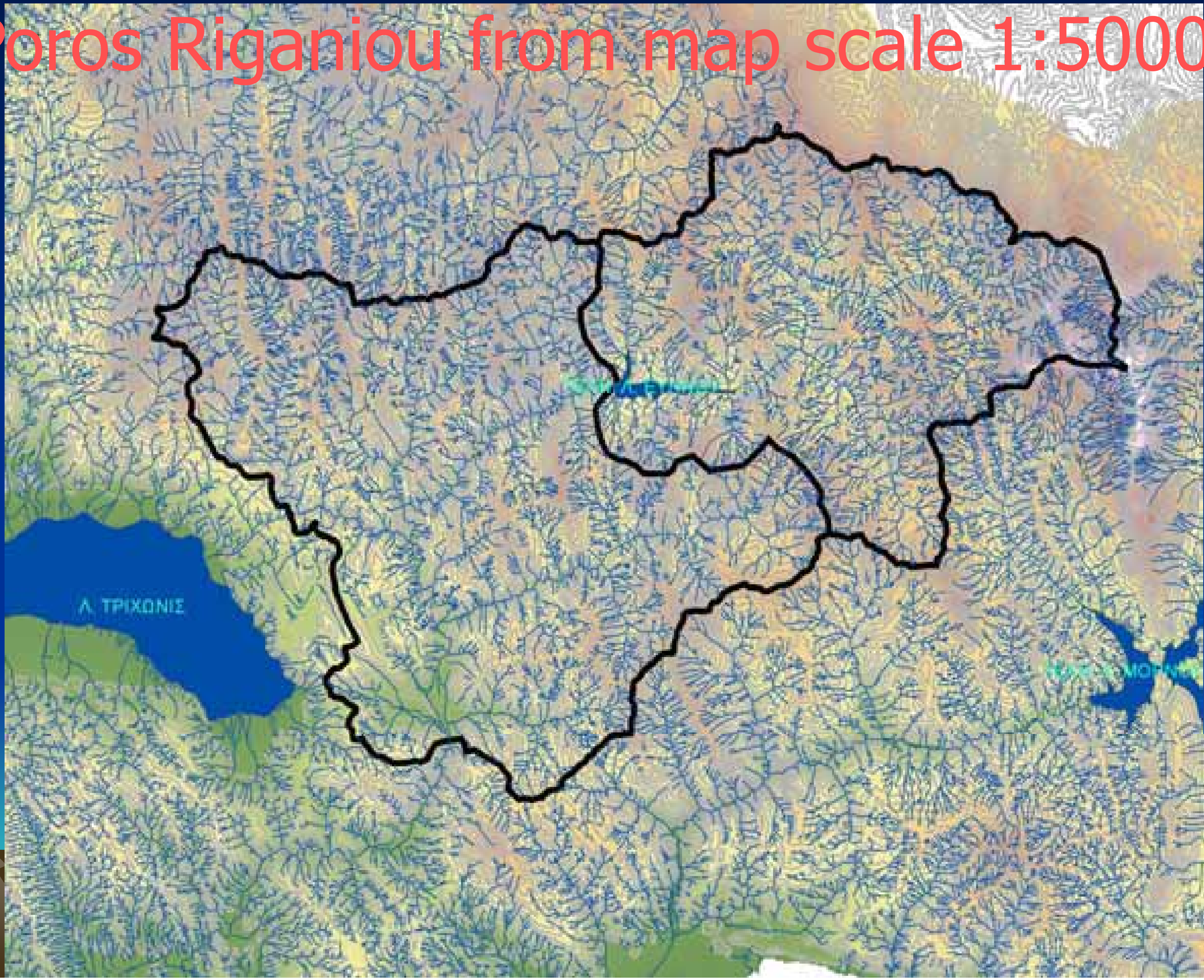
Part III: Hydrologic and Geomorphologic properties of the examined catchments

- Mean annual river discharge and mean annual flood for daily time step (daily data kindly supplied by the PPC)
- The Digital Terrain Models (DTMs) of all the catchments with cell size 25m were introduced to the RiverTools 3.0 software
- RiverTools 3.0 software simulates the stream network and was "calibrated" against the real stream networks digitized from 1:50000 topographic maps until a satisfactory level is reached
- RiverTools 3.0 software calculates all the geomorphologic variables for each catchment that are shown in a next slide
- Correlation coefficients between sediment yield/discharge with all the geomorphic variables are computed

The RiverTools 3.0 software



Part III: Stream network for Evinos R. at Poros Riganiou from map scale 1:50000



Hydrologic/Geomorphologic parameter	Influence on erosion and transport processes	Correlation Coefficients	
		Sediment Yield Sy	Sediment Discharge Qs
Catchment Area (A)	Global parameter	-0.45	0.49
Mean annual discharge (Q_{av})	Runoff Potential	-0.14	**0.73**
Mean annual flood (Q_{max})	Stream Power, Transport Potential	0.14	**0.89**
Hypsometric Integral (HI)	Distribution of elevation with catchment	**0.81**	0.27
Catchment Length Lb_{max}	Catchment size index	-0.16	**0.67**
Mean Slope	Flow velocity and momentum	**0.61**	-0.15
Drainage Density (DD)	Balance between erosive forces and surface resistance	0.20	-0.33
Drainage Frequency (DF)	Stream network texture, Relief disruption	-0.31	-0.35
Circularity Index (CI)	Rate of sediment delivery, deposition potential	-0.09	-0.50
Elongation Ratio (ER)		-0.38	-0.40
Bifurcation Ratio (R_B)	Internal processes index, branches development grade, stream network dynamic equilibrium	**0.55**	0.14
USLE Rainfall Erosivity Factor (R)	Driving force of erosion	**0.76**	-0.004
USLE Soil Erodibility Factor (K)	Main source of erosion processes	-0.37	0.005

Part IV: Non-linear, multiple-regression models

$$S_y = 31.4 * HI^{2.03} * R_B^{1.90} * R^{0.30}$$

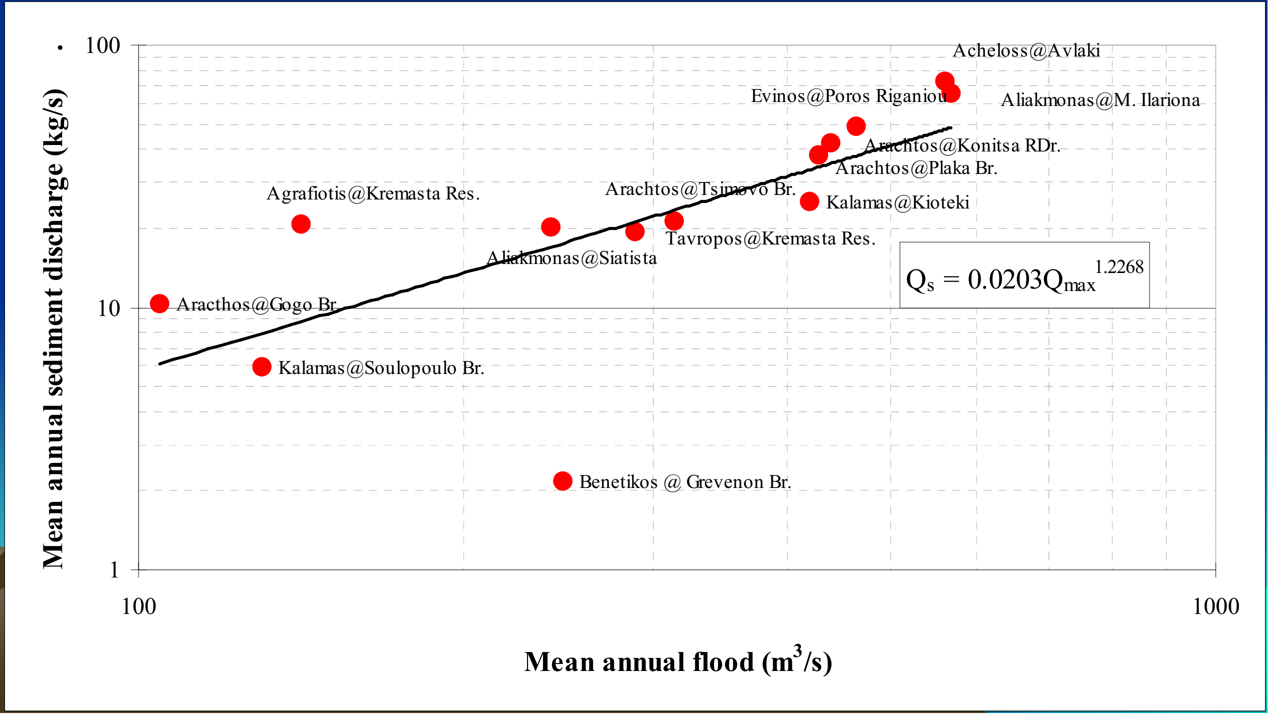
R^2=0.78

$$Q_s = 0.189 * Lb_{max}^{0.57} * Q_{av}^{0.866}$$

R^2=0.70

$$Q_s = 0.02 * Q_{max}^{1.2268}$$

R^2=0.79



Roehl (1962)

$$DR = 18620 A^{-0.23} \left(\frac{L}{R}\right)^{-0.51} R_B^{-2.79}$$

Example of landslide erosion forms at Aracthos River catchment

Conclusions & Recommendations

- Mean annual suspended sediment yield/discharge have been recomputed for a number of river cross sections in NW Greece with (in most cases) the broken line rating curve. There were serious inconsistencies with previous estimates at least for certain locations.
- Regression analysis between sediment yield/discharge and mean annual flood reveals that river discharge around peak conditions is the limiting factor of the erosion – transport – deposition continuum in a sense that whether the transport capacity of the stream is capable to carry the eroded sediment downstream.
- Mean annual sediment yield is an increasing function of the Hypsometric Integral, the Bifurcation Ratio and the Rainfall Erosivity Factor (as computed by the USLE approach).

Conclusions & Recommendations

- The sample data cover a small time domain and the equations presented are not intended to be used as design tools but only as qualitative indices
- It is extremely important to plan and implement an extensive nationwide measurement program for suspended sediment discharge since the current knowledge for the erosion rates and loss of storage capacities in vital reservoirs is totally unknown
- Unfortunately, the Water Framework Directive (WFD 2000/60) does not focus on sediment yield issues, although it is believed that they constitute a major part of the "integrated water resources management" context

THANK YOU VERY MUCH FOR YOUR ATTENTION

Please feel free to download all relevant papers from the ftp site:

http://www.itia.ntua.gr/~zarris/