Sediment yield estimation from a hydrographic survey: A case study for the Kremasta reservoir, Western Greece

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Brief Outline of the Presentation

- Introduction (Sediment yield and delivery processes, sediment accumulation in reservoirs, source erosion)
- Research method (Hydrographic survey of the Kremasta reservoir, Western Greece)
- Computation of total mass of the deposited sediments for the total period of the reservoir's operation
- Catchment's sediment yield and delivery ratio estimation
- Comparison with other published data from the international literature

Research Project

Appraisal of river sediment deposits in reservoirs of hydropower dams, **Funded by Public Power Corporation (PPC) and the General Secretariat of Research and Technology (GSRT), 1998-2001**

Sediment delivery processes

- Sediment source (wash load versus river bed material)
- Magnitude and proximity to the outlet of the source erosion areas
- Characteristics of the drainage network (density and frequency, slope gradients, watershed area)
- Frequency, intensity and duration of the erosion producing storms (wash load)
- Geological formations and soil characteristics (erodibility)
- Geomorphologic characteristics (faults, orographic uplifting, etc.)
- Depositional potential of the catchment (surface roughness, depressions, man-made sediment storages)

Sediment yield processes

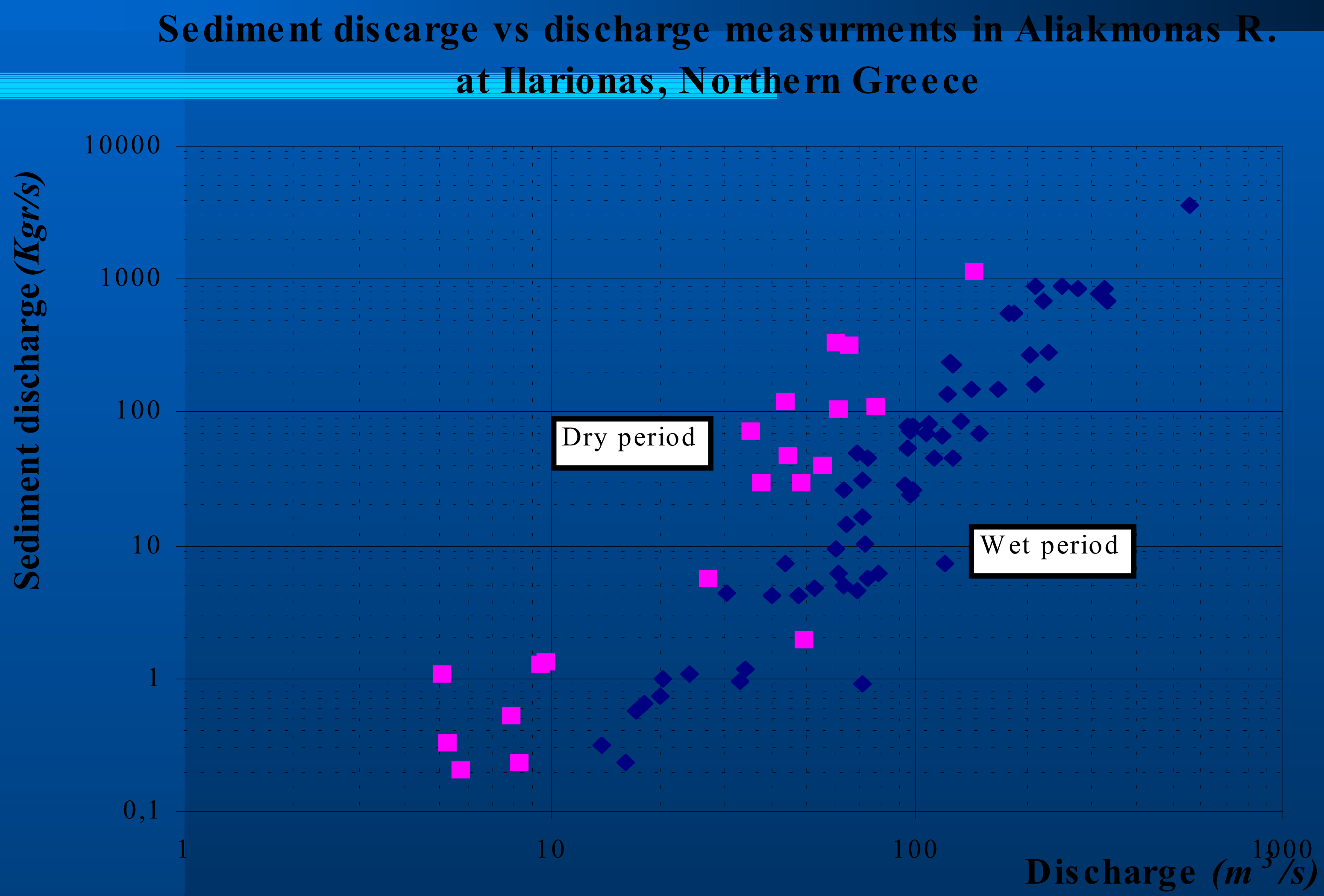
Sediment yield characteristics...

- **Temporal variability both in annual yields but also in inter-storm amounts**
- **Sediment yield processes as functions of spatial scale (e.g. vegetation cover for hillslope scales and partial rainfall coverage and drainage density to watershed scales)**
- **Precise processes still unknown, lack of mathematical expression with universal applicability**
- **Strongly influenced, but not completely determined, by watershed area**

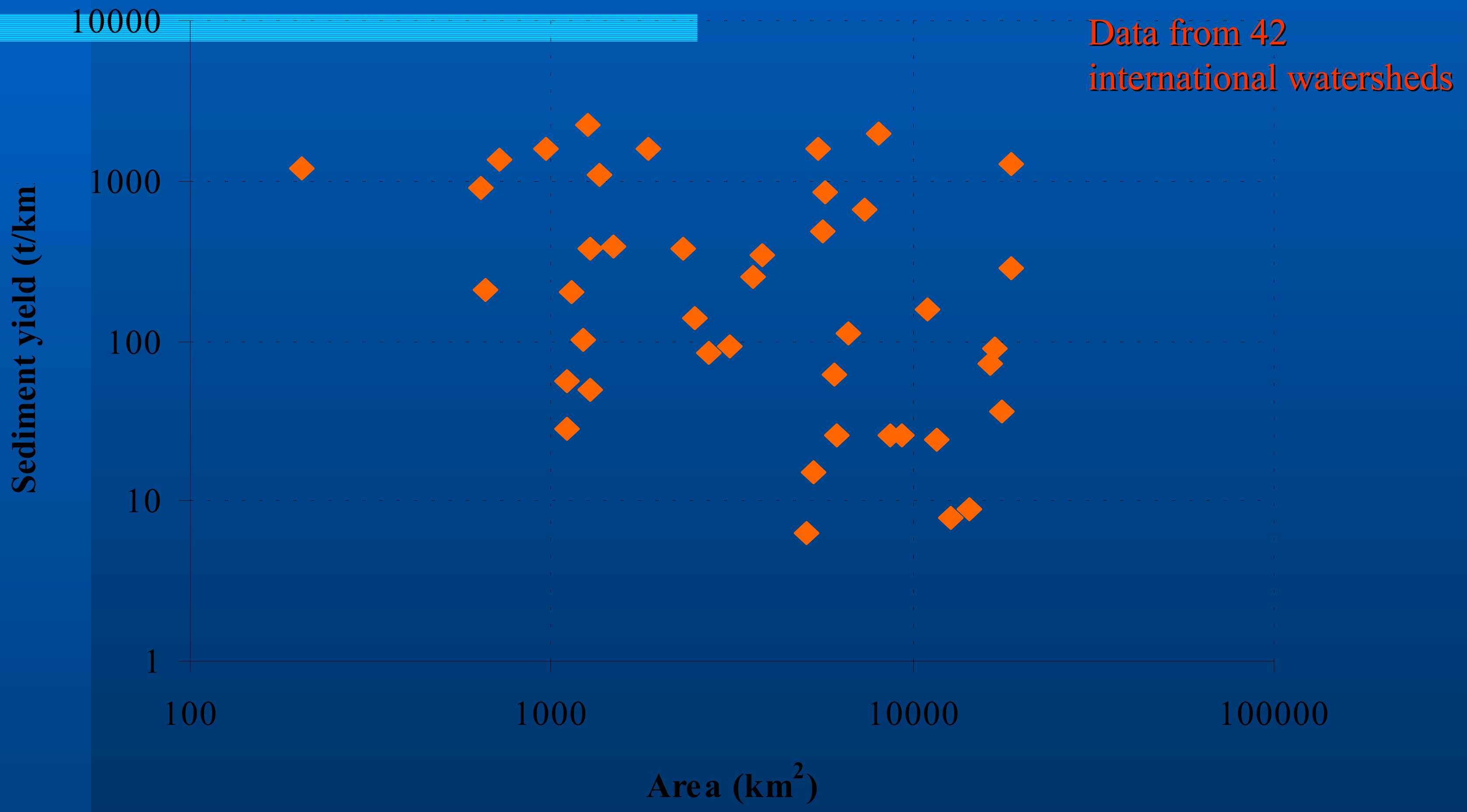
Sediment yield estimates...

1. **Simple statistical regression models (e.g. sediment rating curves, sediment yield with catchment area)**
2. **Conceptual or physically-based mathematical models (e.g. LISEM, WEPP, EUROSEM)**
3. **Reservoir deposits' measurements by (repeated) hydrographic surveys**

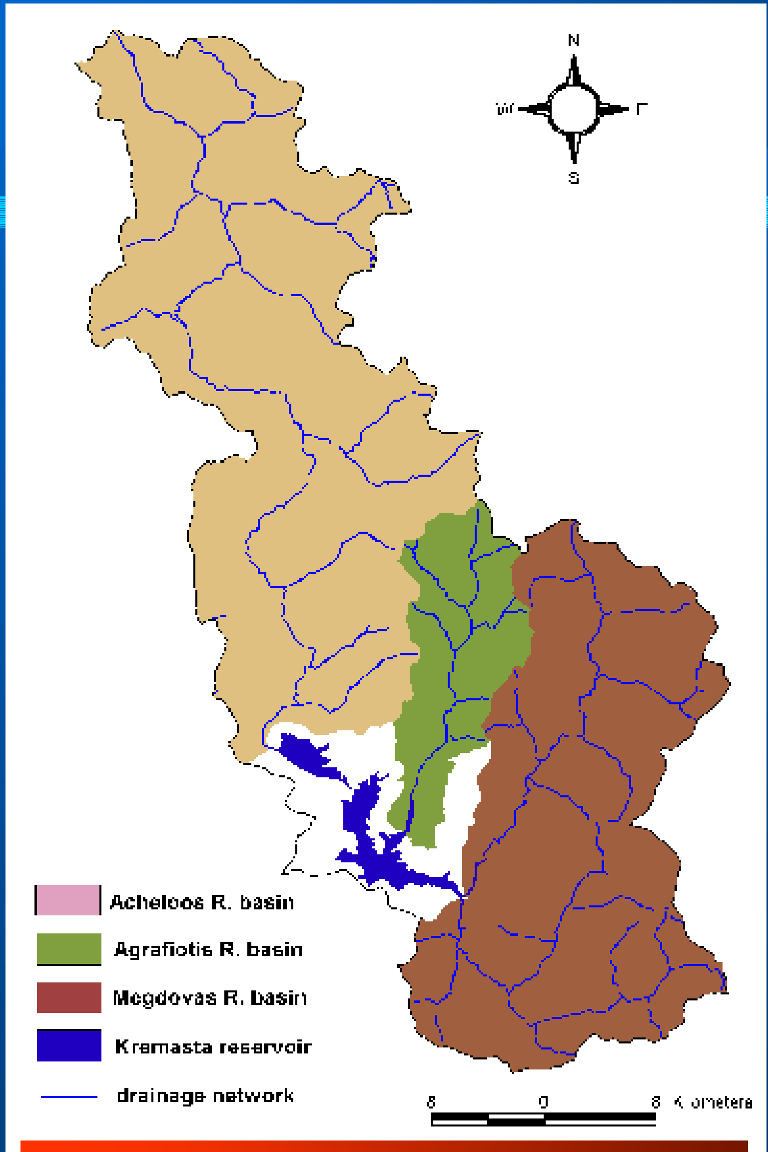
Temporal variability of sediment discharges



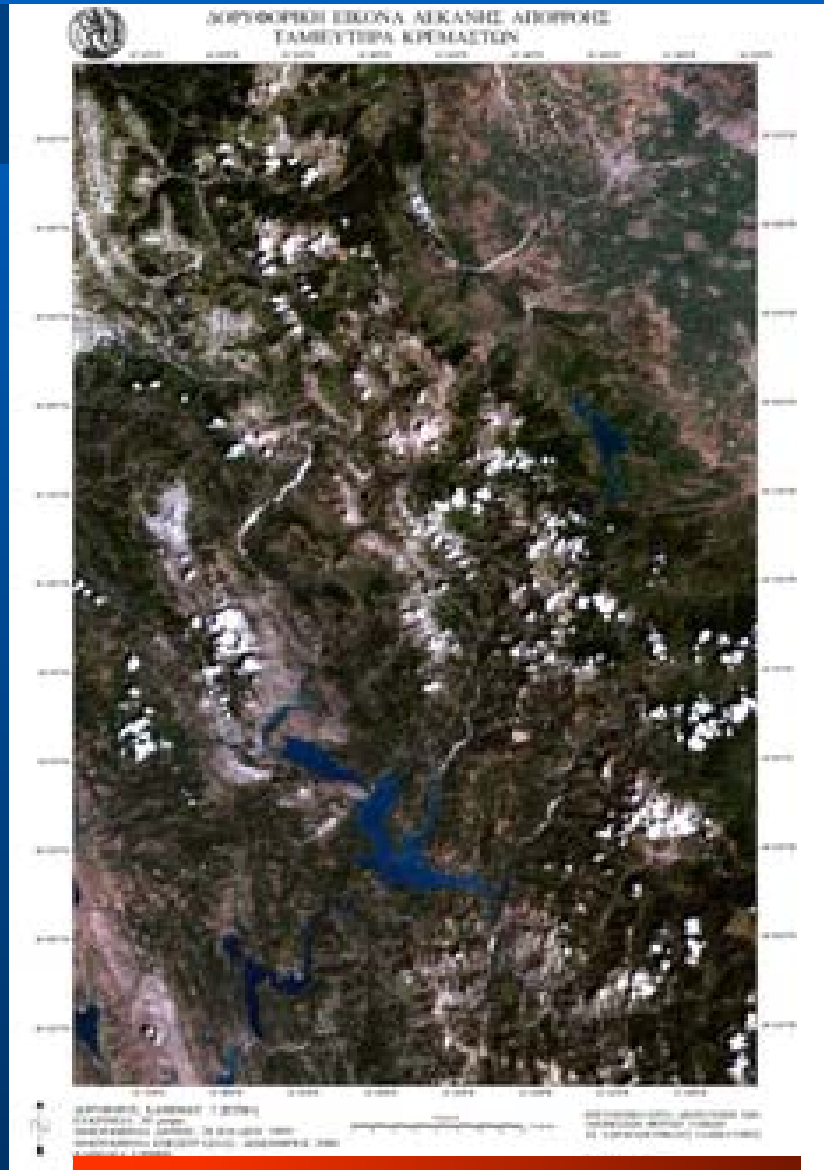
Spatial variability of sediment yield (lack of universal expression)



Kremasta reservoir watershed

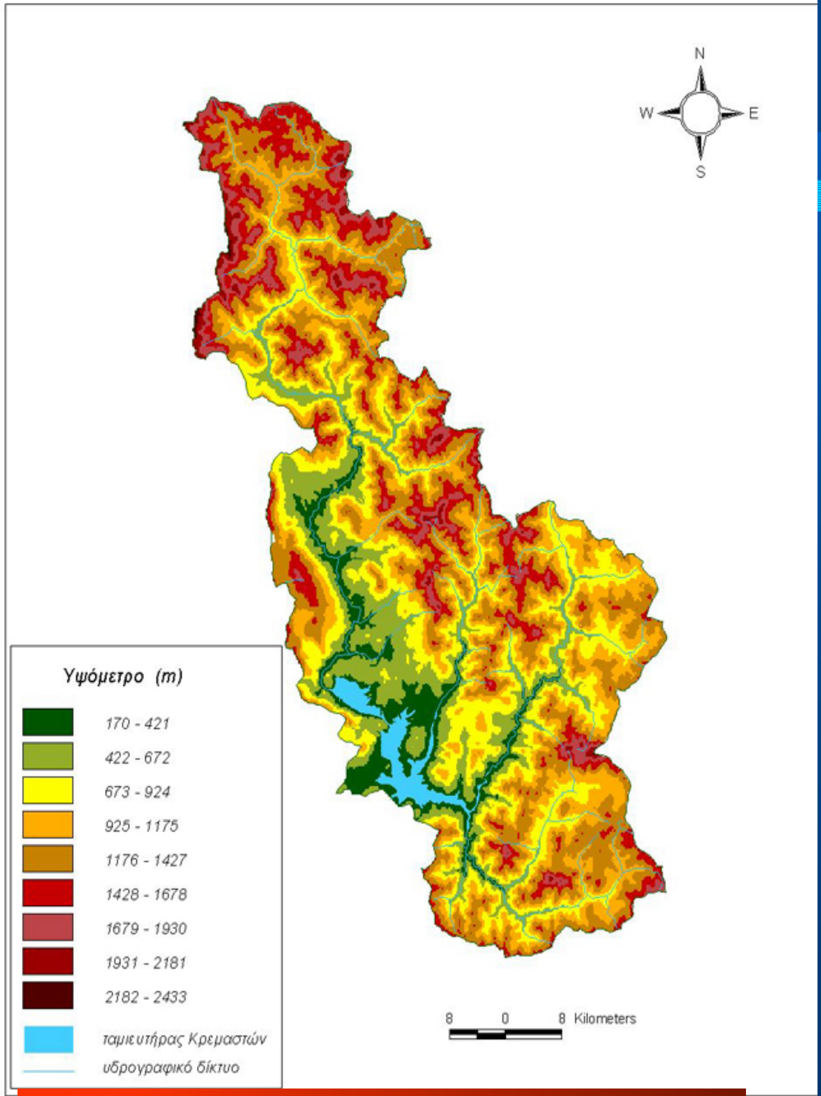


Catchment drainage network

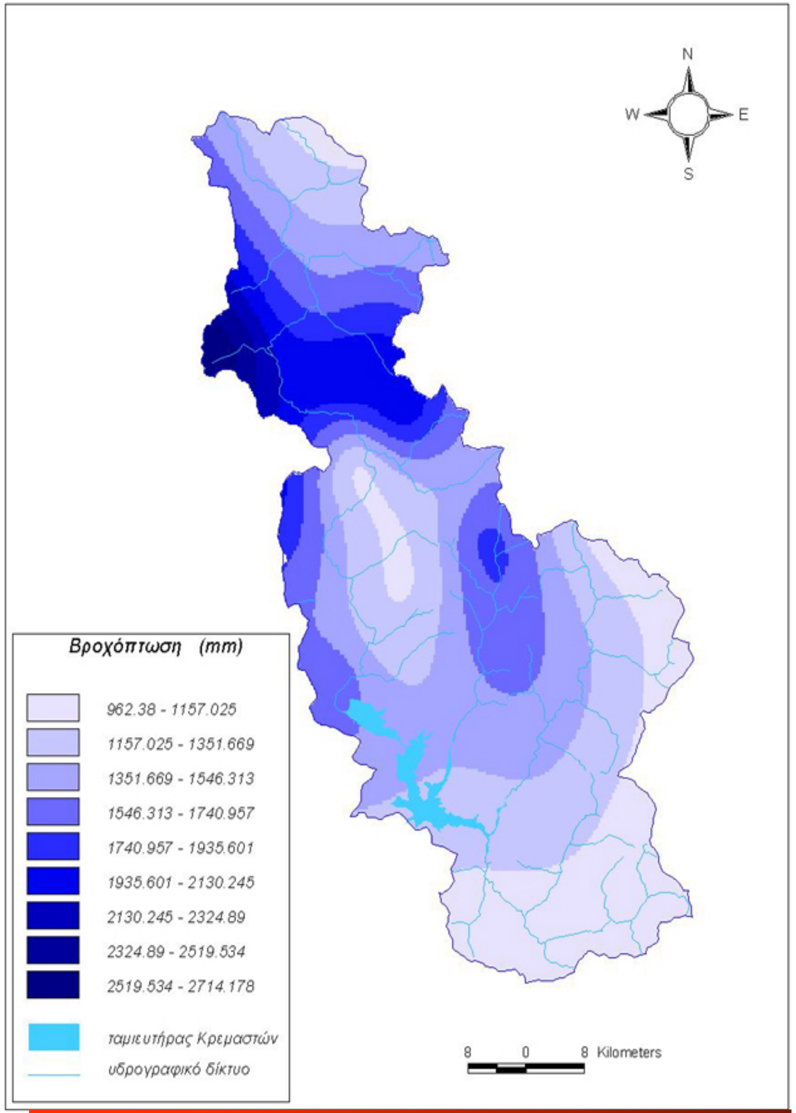


LANDSAT 7 (ETM+) Image

Kremasta reservoir watershed (cont.)

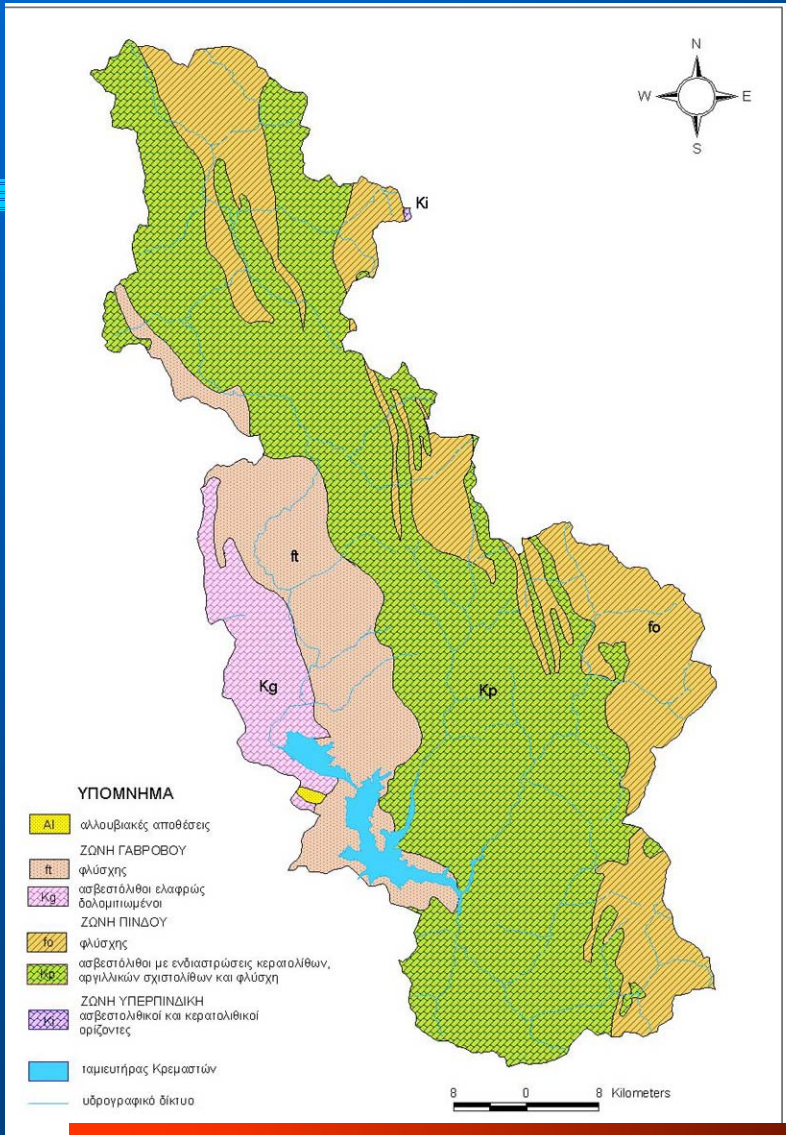


Digital Terrain Model (DTM)

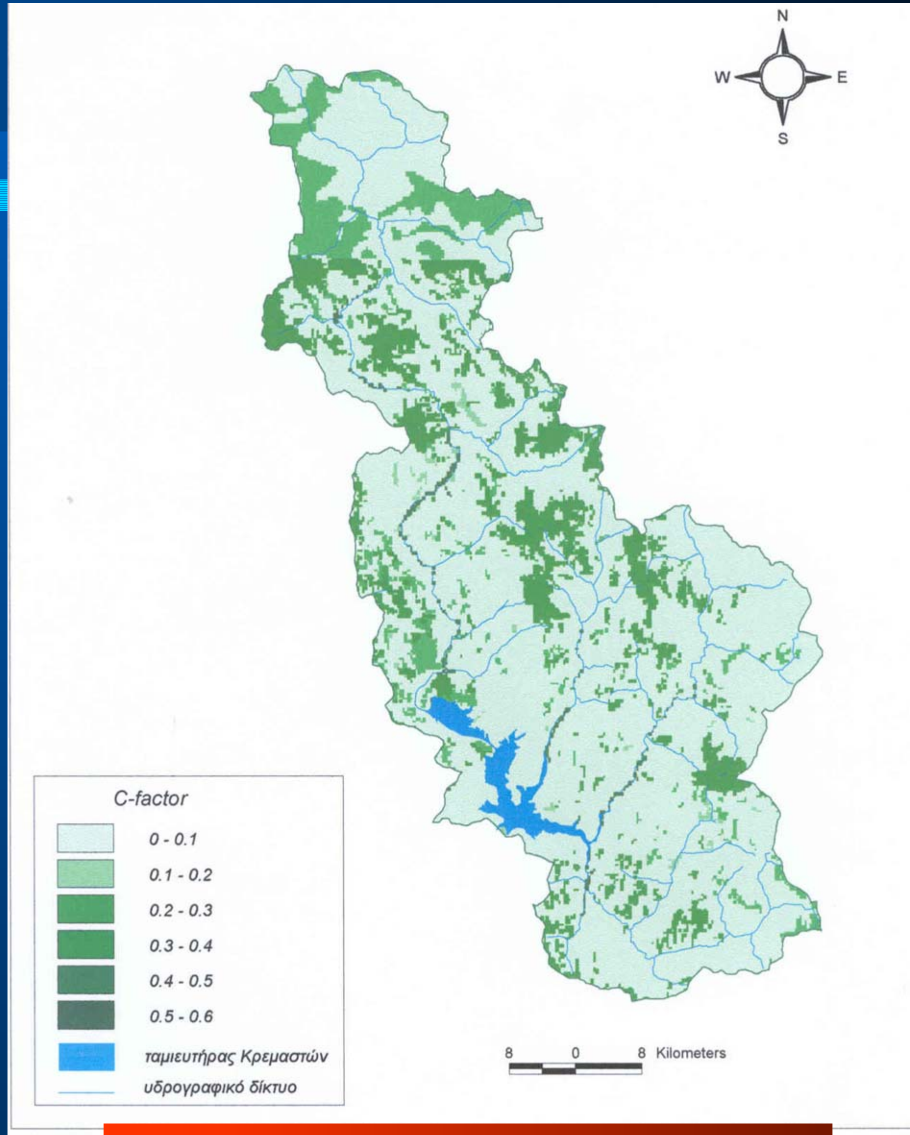


Mean annual rainfall (mm)

Kremasta reservoir watershed (cont.)



Geologic formations



Land uses

Kremasta reservoir hydrographic survey

- **Positioning: Differential Global Positioning System (DGPS) (reference station and moving receiver) with accuracy in horizontal plane 2-5 m[1]**
- **Distance between echo-sounding routes ranging from 50 to 150 m, additionally to check routes**
- **Depth measurement: Hydrographic echo-sounder Raytheon DE 719B operating at the frequency of 200 kHz[2]**

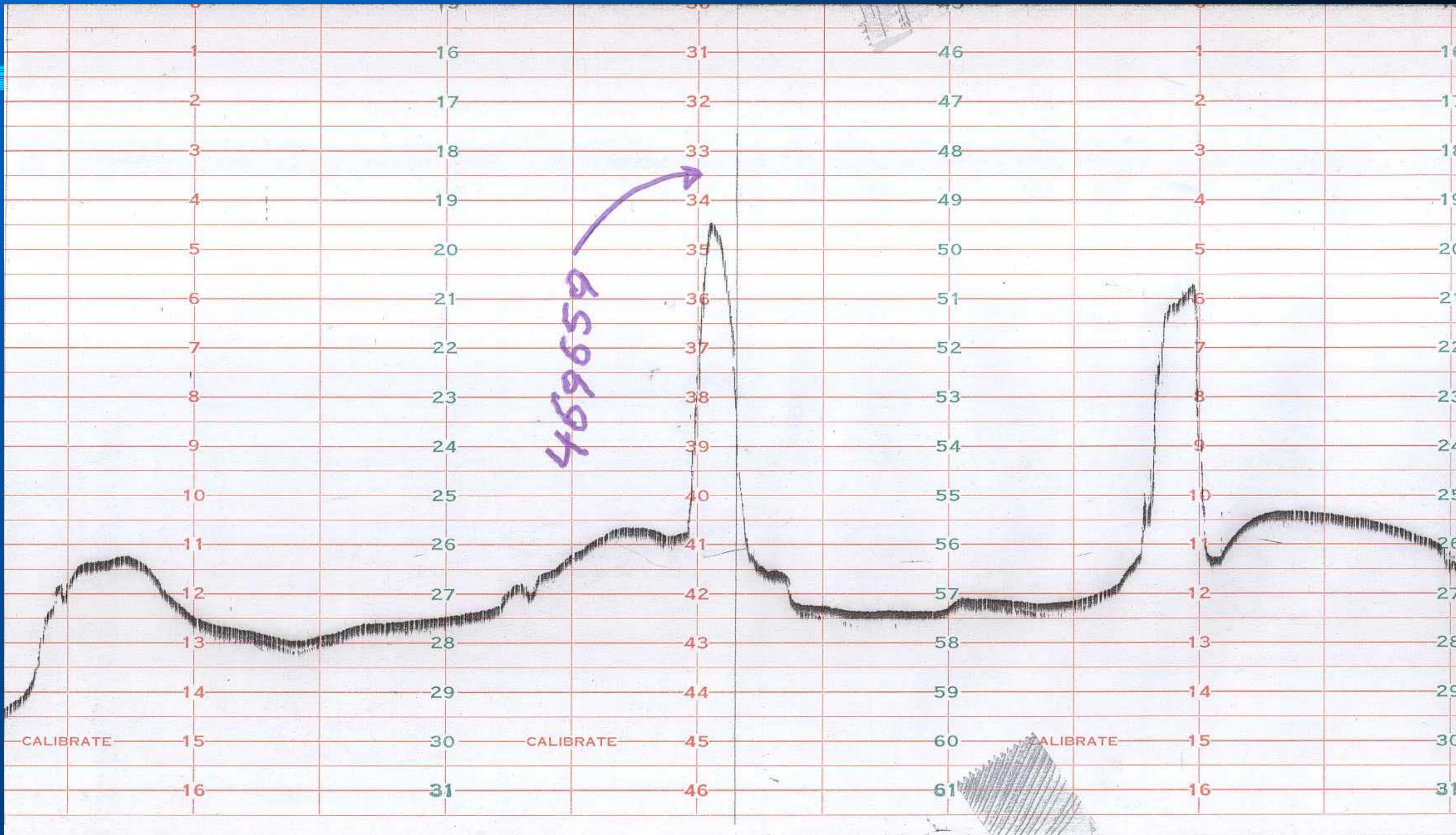
Additional information...

1. In level of significance 95% with selected availability
2. Depth measurement error: 0.5%±1 in of the total depth

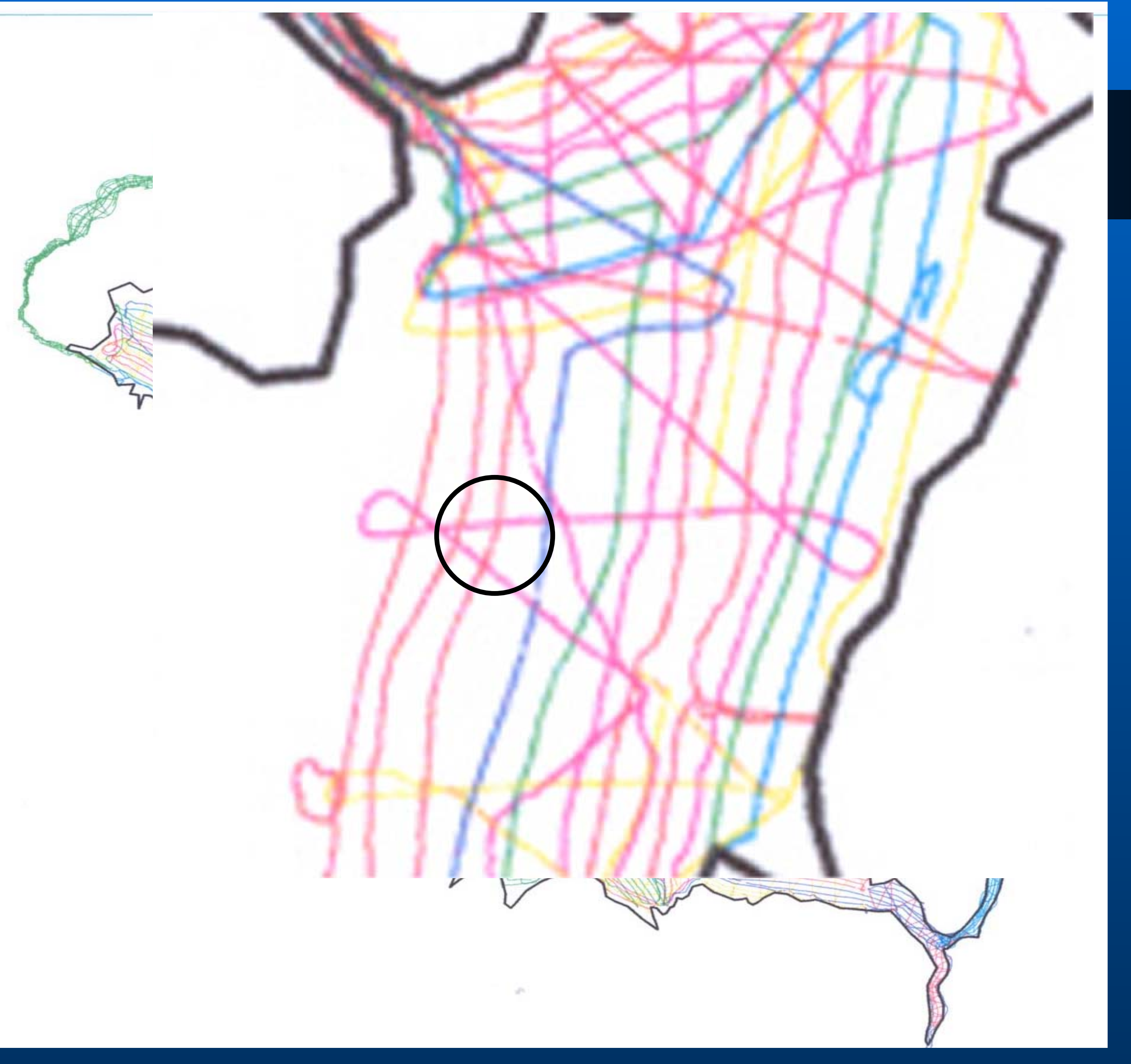
Valuable contribution by...

Dionysos Satellites Centre, Department of Topography, Faculty of Surveying and Rural Engineering, National Technical University of Athens

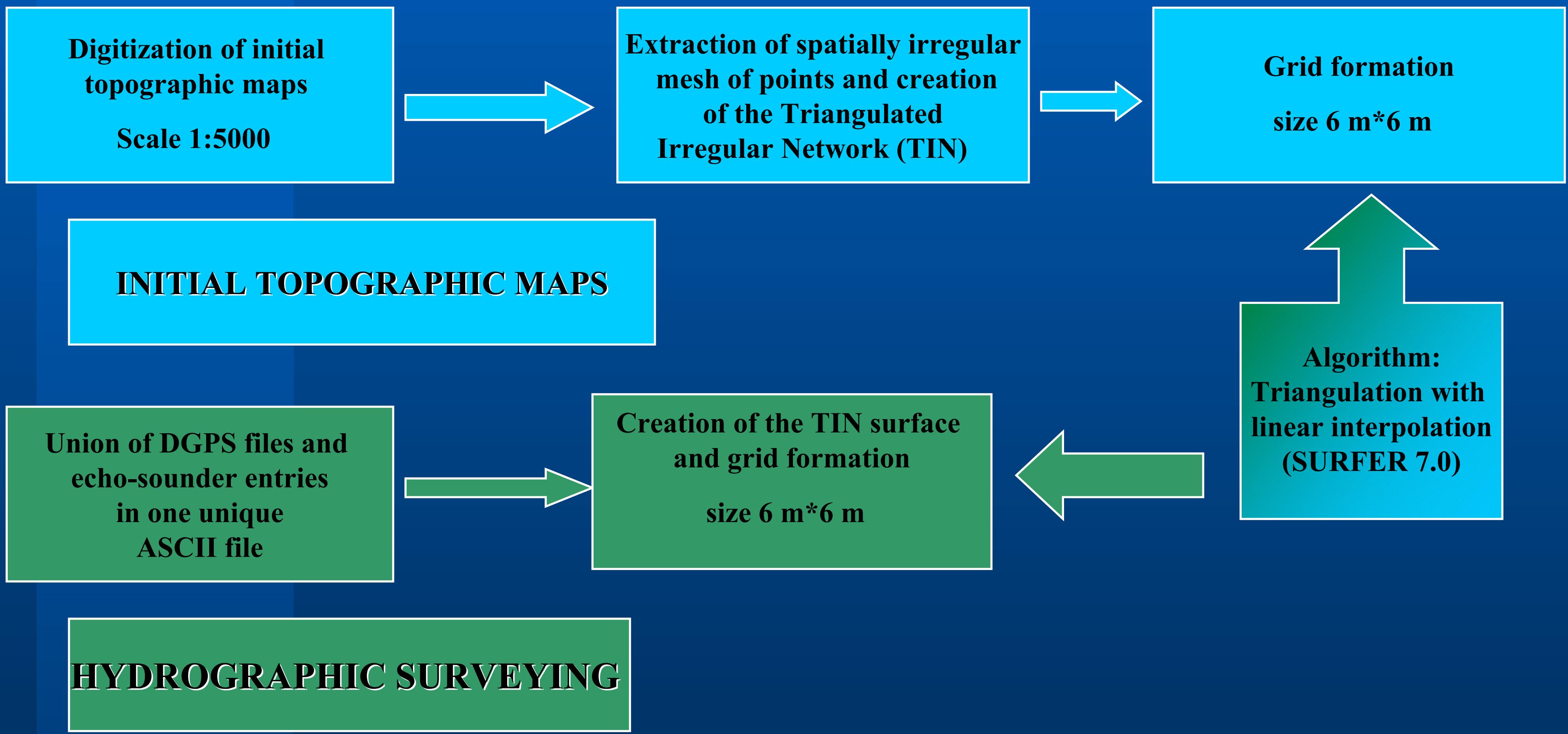
Depth measurement illustration



Hydrographic routes for reservoir scanning



DTM Generation and Calculation of Deposits' Volume

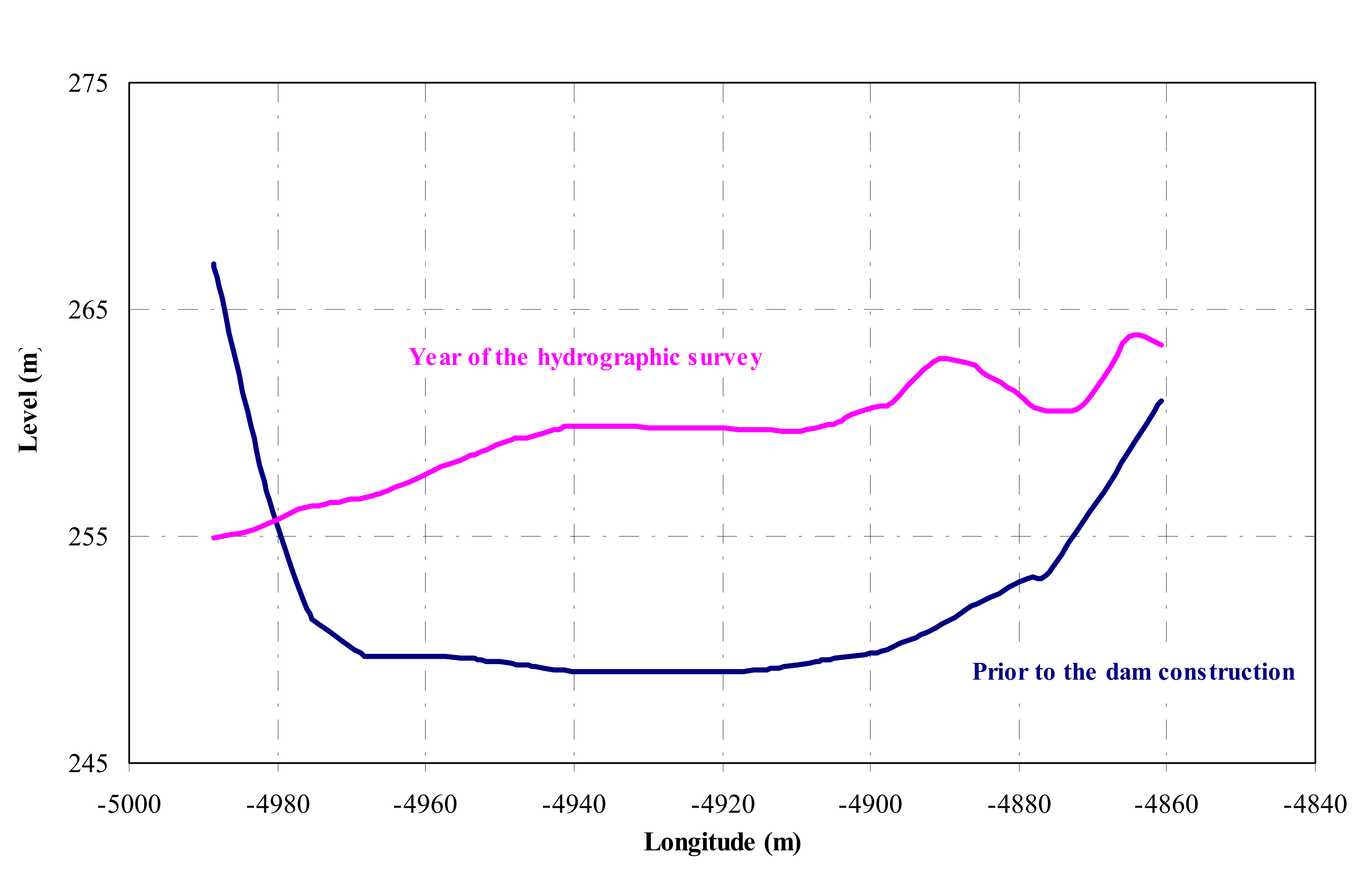


Typical errors of hydrographic surveying

- **DGPS accuracy on horizontal plane (due to selected availability)**
- **Obscure definition of the water-mud interface**
- **Variation of the hydrographic boat speed**
- **Errors in x-y-z plane from the construction of the initial topographic maps prior to the dam construction**
- **Digitization errors both of the initial topographic maps but also from the echo-sounder charts**

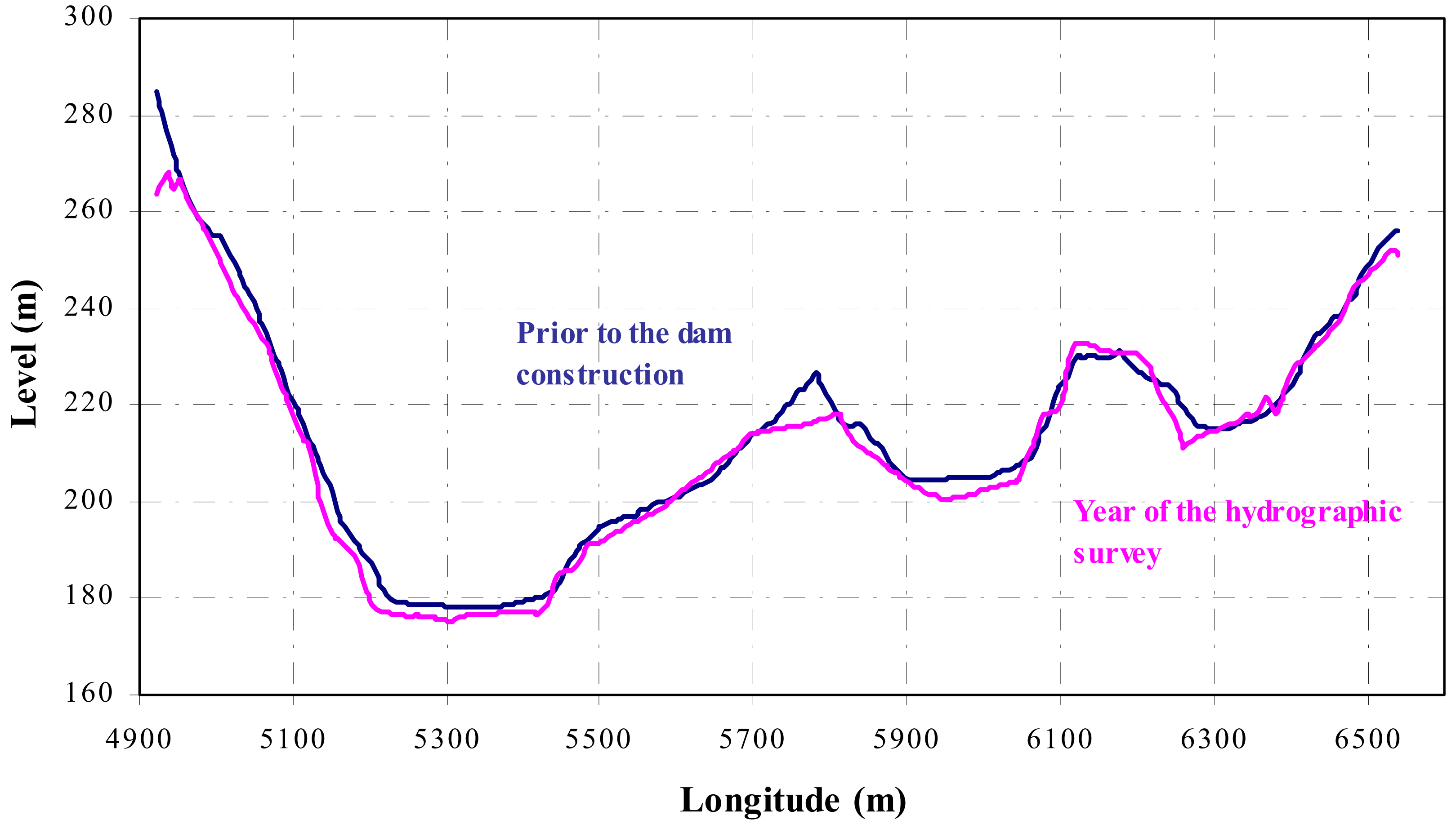
Significant non-typical error (uncertainty): Areas as earth material banks for dam construction not known

Indicative profile of fluvial sediment deposits (a)



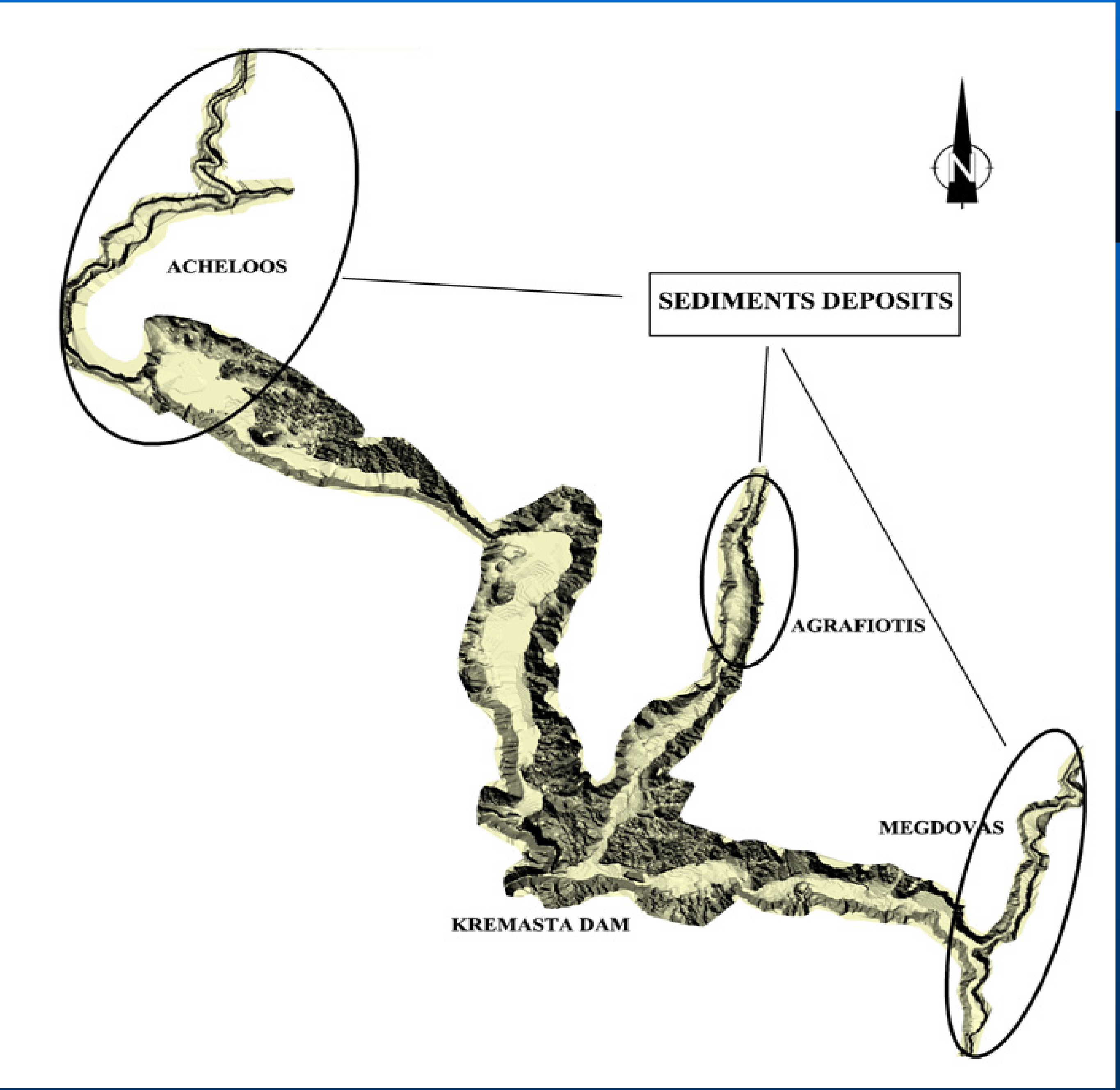
Section near the reservoir delta at Acheloos R. branch

Indicative profile of fluvial sediment deposits (b)

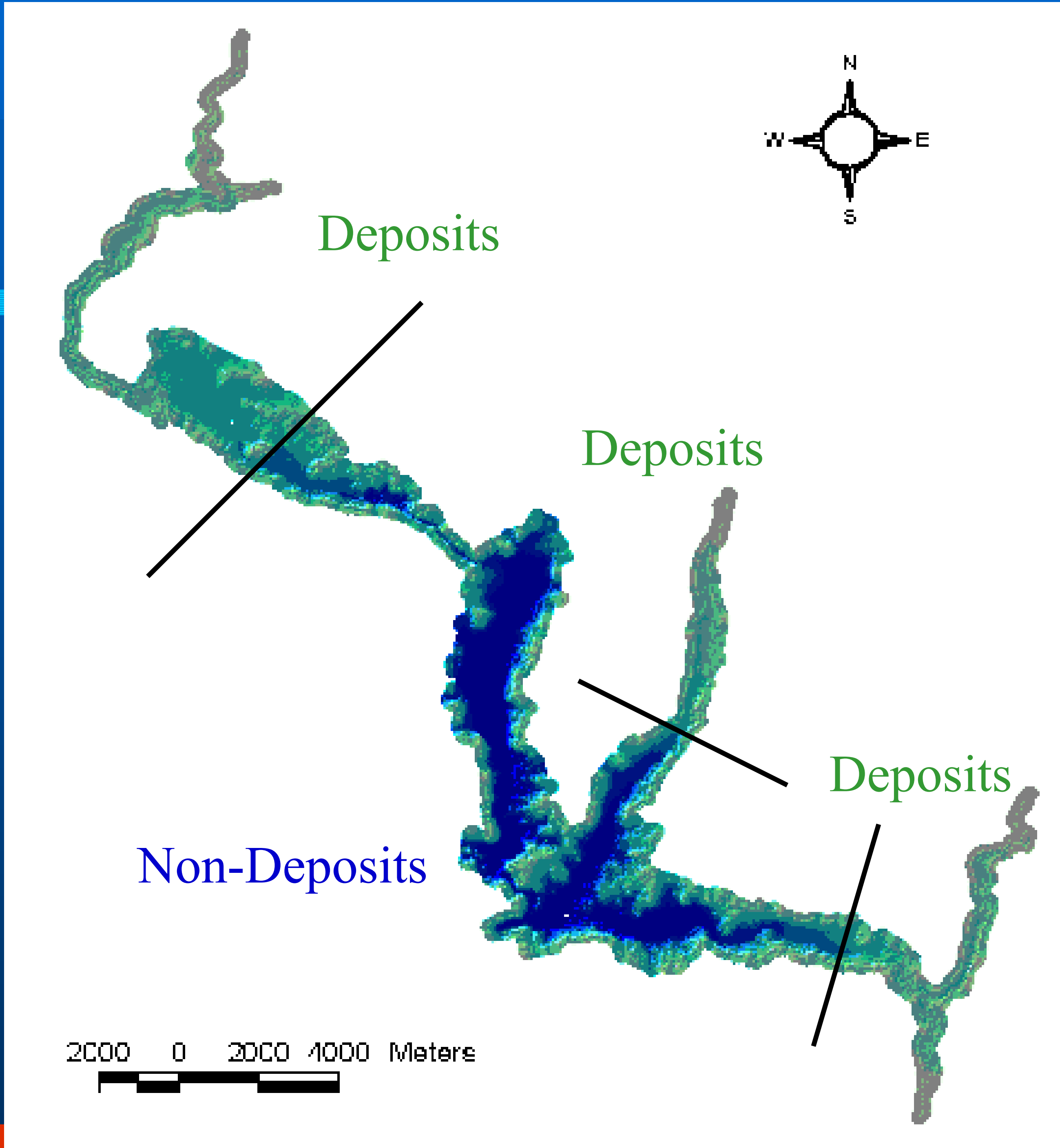


Section at the inner part of the reservoir

Identification of reservoir segments with sediment deposits (a)



Identification of reservoir segments with sediment deposits (b)



Results – Deposits' Volume

Reservoir Sections	Deposits' Volume (hm^3)	Deposits' area (km^2)
ACHELOOS R.	41.3	5.7
AGRAFIOTIS R.	13.1	
MEGDOVAS R.	12.2	
TOTAL	66.6	

INITIAL DESIGN STUDY ESTIMATE FOR DESIGN PERIOD 50 YEARS
394 hm^3

Results – Deposits' Mass

- Collection of two core samples from the reservoir's invert
  -
  - …osition
  -
  -
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TOTAL DEPOSITS' MASS
112.5 Mt

ACHELOOS	AGRAFIOTIS	MEGDOVAS
69.8 Mt	22.1 Mt	20.6 Mt

- Unc… due to the …

Additi…

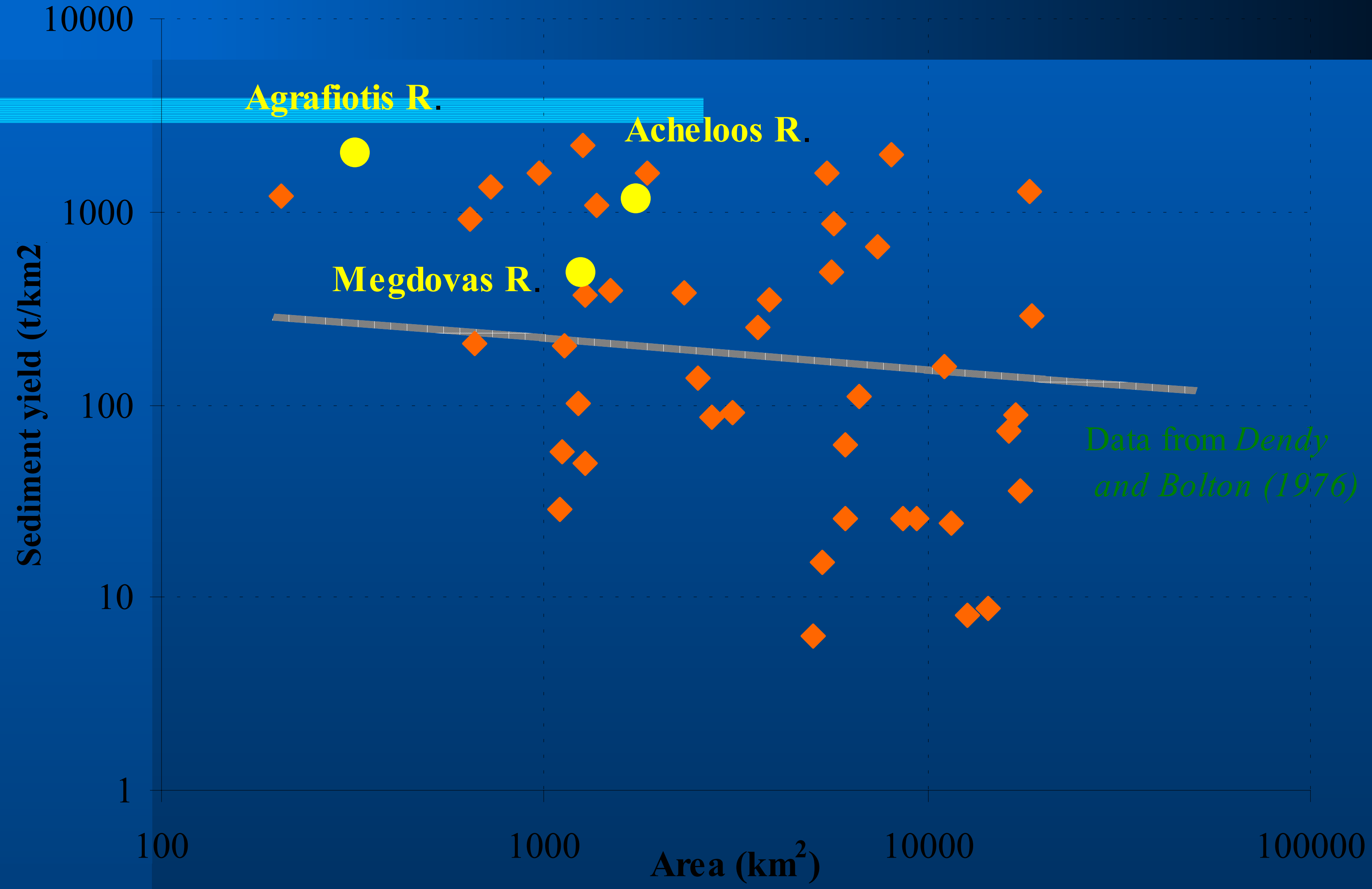
(1) Lane and Kolzer formula from percentage quantities of sand, silt and clay (correspondingly 71.9% sand, 23.3% silt and 4.8% clay)

(2) Density estimation after 34 years of reservoir operation 1692 kg/m^3

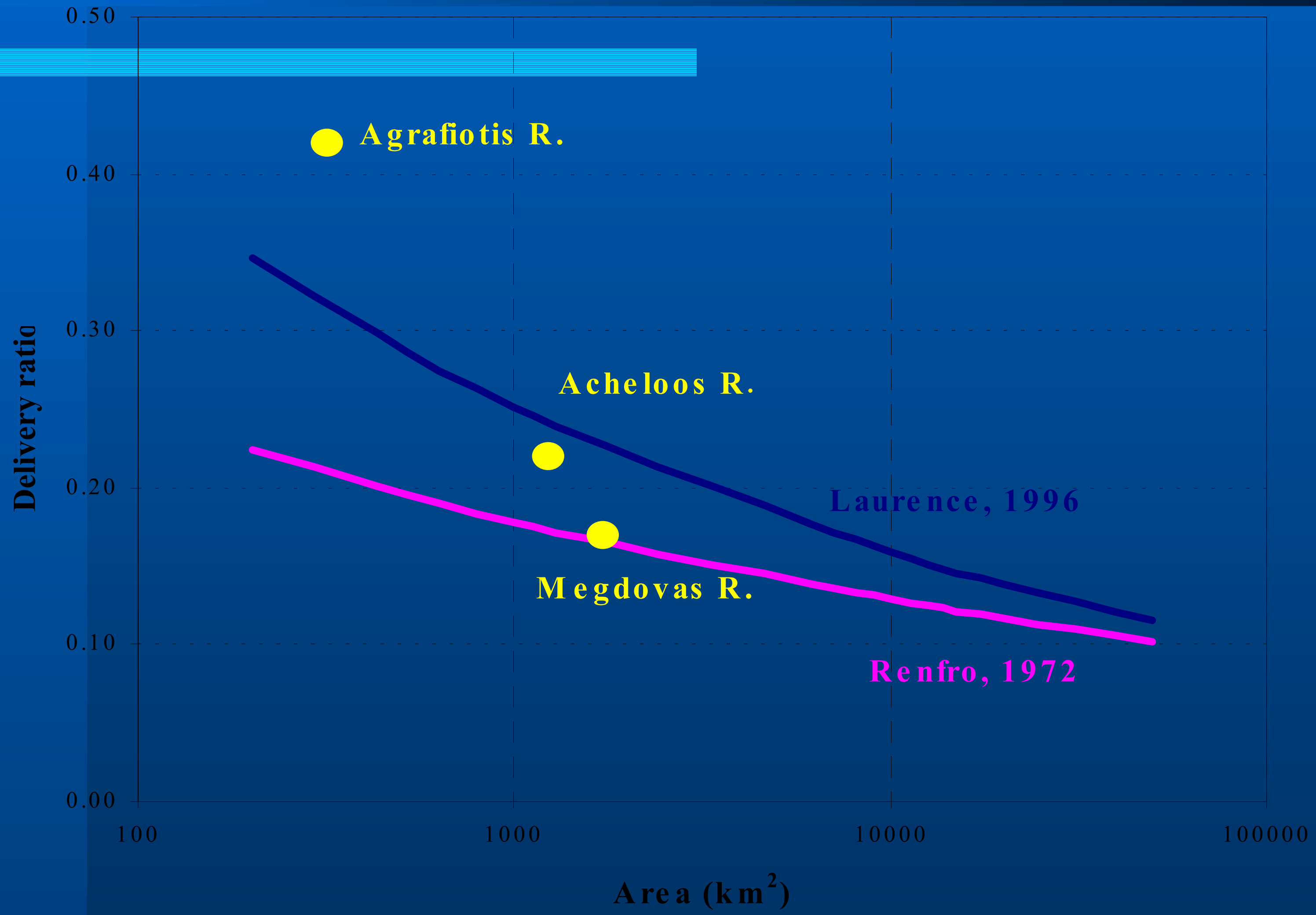
Sediment yield of Kremasta reservoir watershed

Subcatchment	Mean annual sediment yield S_y (t/km^2)	Mean annual sediment discharge Q_s (kg/s)	Subcatchment area A (km^2)
ACHELOOS R.	1184.6	66.0	1733
AGRAFIOTIS R.	2034.8	20.9	320
MEGDOVAS R.	489.4	19.5	1239
TOTAL	1005.6	106.4	3292

Comparison with internationally published data
a) Sediment yield



Comparison with internationally published data
b) Sediment delivery ratio



Soil erosion and sediment delivery ratio estimation

Subcatchment	Mean annual sediment yield S_y (t/km^2)	Soil erosion A (t/km^2/y)	Sediment delivery ratio
ACHELOOS	1184.6	7077	0.17
AGRAFIOTIS	2034.8	4847	0.42
MEGDOVAS	489.4	2251	0.22
TOTAL	1005.6	5040	0.20

Soil erosion computed from a GIS based model of the Universal Soil Loss Equation (USLE)

Conclusions

- Measurements of deposited sediments within a reservoir could be an effective method for reconstructing long term catchment sediment yields
- The reservoir under study should be large enough so that trap efficiency could be assumed as unity
- This method is unable to estimate sediment yield of finer time scales (e.g. annually) unless more frequent hydrographic surveys are accomplished
- This method combined with sediment discharge measurements in an upstream site and/or alternative measurement techniques (e.g. turbidity) can be an effective tool on integrated catchment management

Conclusions (cont.)

- Dead volume principle, at least for large reservoirs, should be reconsidered in terms of the spatial accumulation of deposited sediment as described
- Catchment sediment yields under study exhibit considerably higher values than other published data from throughout the globe
- Geomorphologic controls such as tectonic activity, orographic uplifting, hydrological parameters (e.g. intense storms) and also the dominant geological formation (e.g. highly erodible flysch) are responsible for this considerable difference