Challenges and conflicts for managing transboundary karst aquifers: examples and case studies in the Dinaric region

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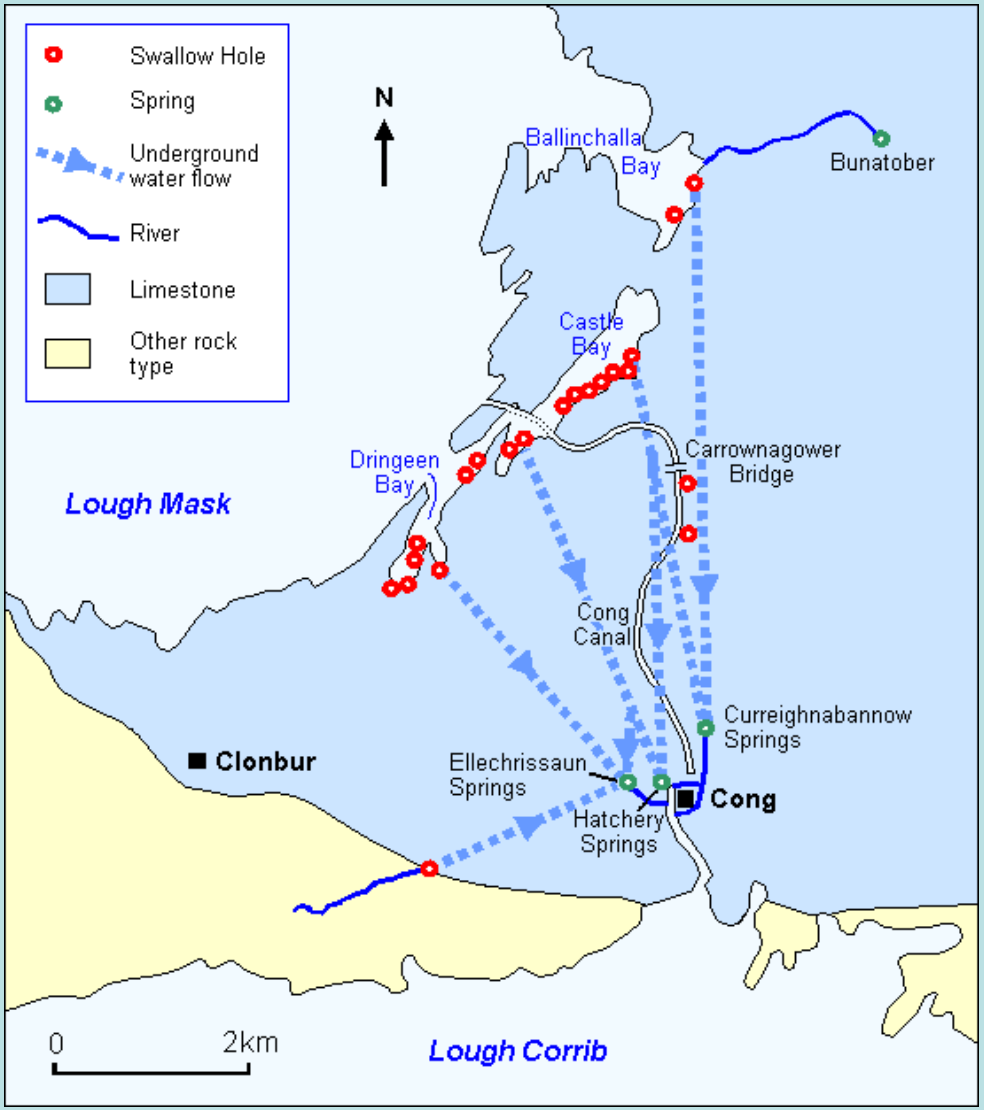
The Cong Canal in Ireland

The Cong Canal, excavated in the 1840's, was intended to provide a navigation channel between two lakes

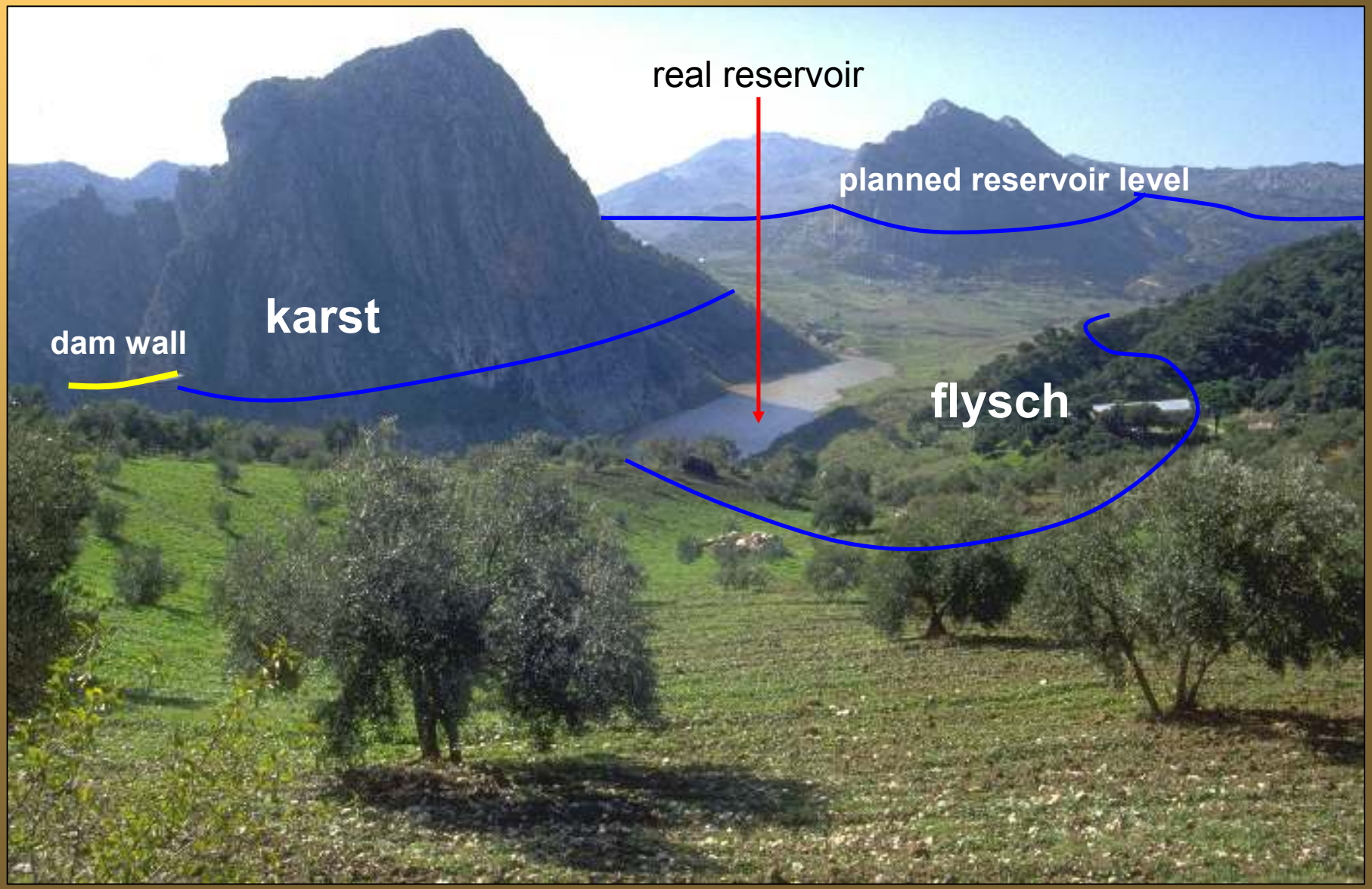
Karst limestones swallow up all water during summer, leaving the channel completely dry

hydrogeological situation



www.gsi.ie/workgsi/groundwater/karstbook/karst-fra.htm

Reservoirs in karst



Sierra de Líbar, Andalusia, Spain

Great Falls Reservoir, Tennessee, USA

Leakage increased from

0.47 m^3/s in 1926

6.60 m^3/s in 1939

12.70 m^3/s in 1945

Dam:
- Build between 1915-16
- 240 m long
- 28 m height

Reservoir:
- 6.6 km long
- ~1 km wide
- ~6 m water level

Bedrock:
- Mainly chert, BUT
- also limestone

Horsetooth Dam, Colorado, USA

Dam:

- Build between 1946-49
- 570 m long
- 47 m height

Reservoir:

- 10 km long
- ~1 km wide
- ~40 m water level

Bedrock:

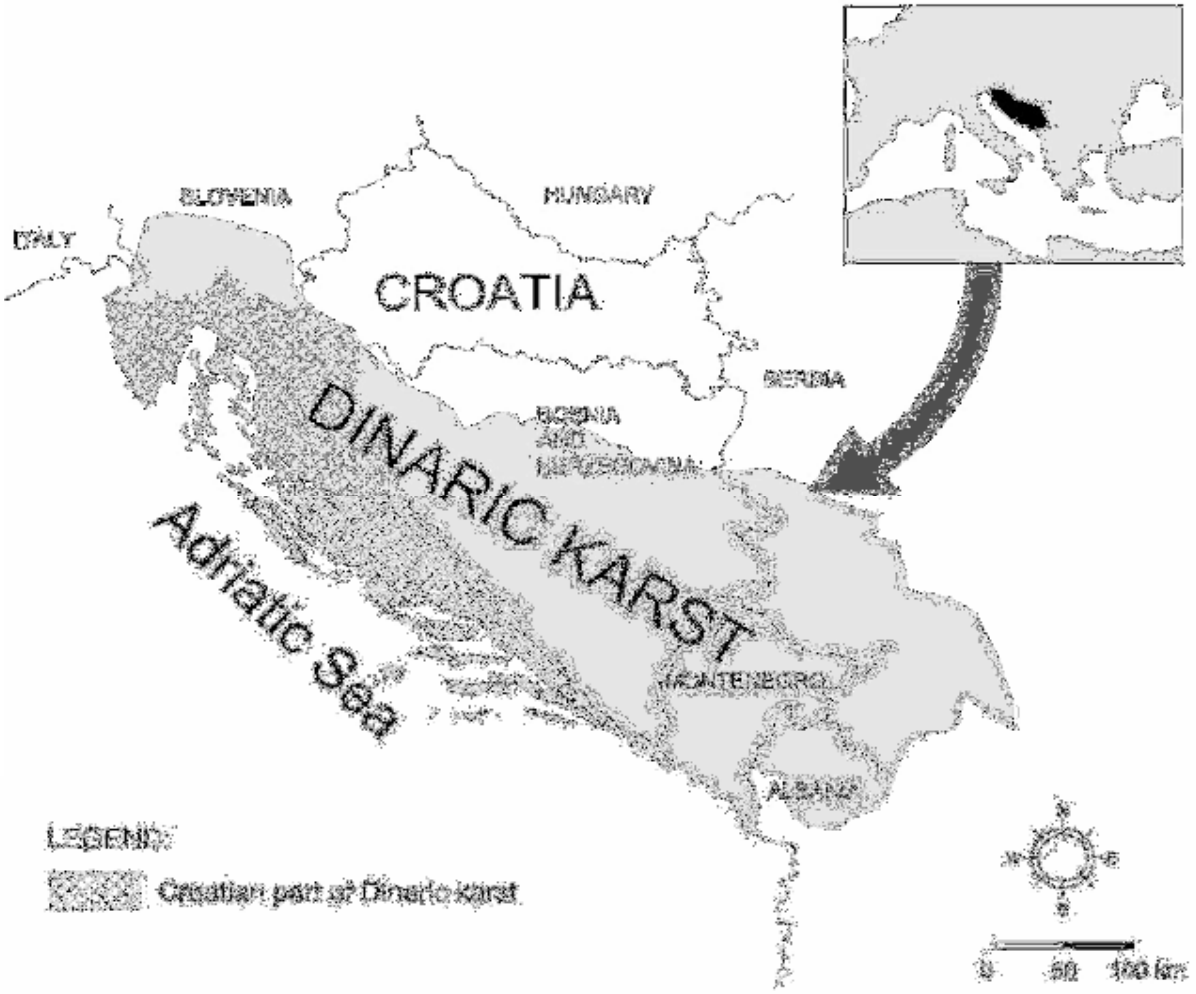
- Mainly sandstone, BUT
- Interspersed gypsum and limestone layers

Sinkholes developed …

The root causes of karst water resources management peculiarity and heterogeneity are :

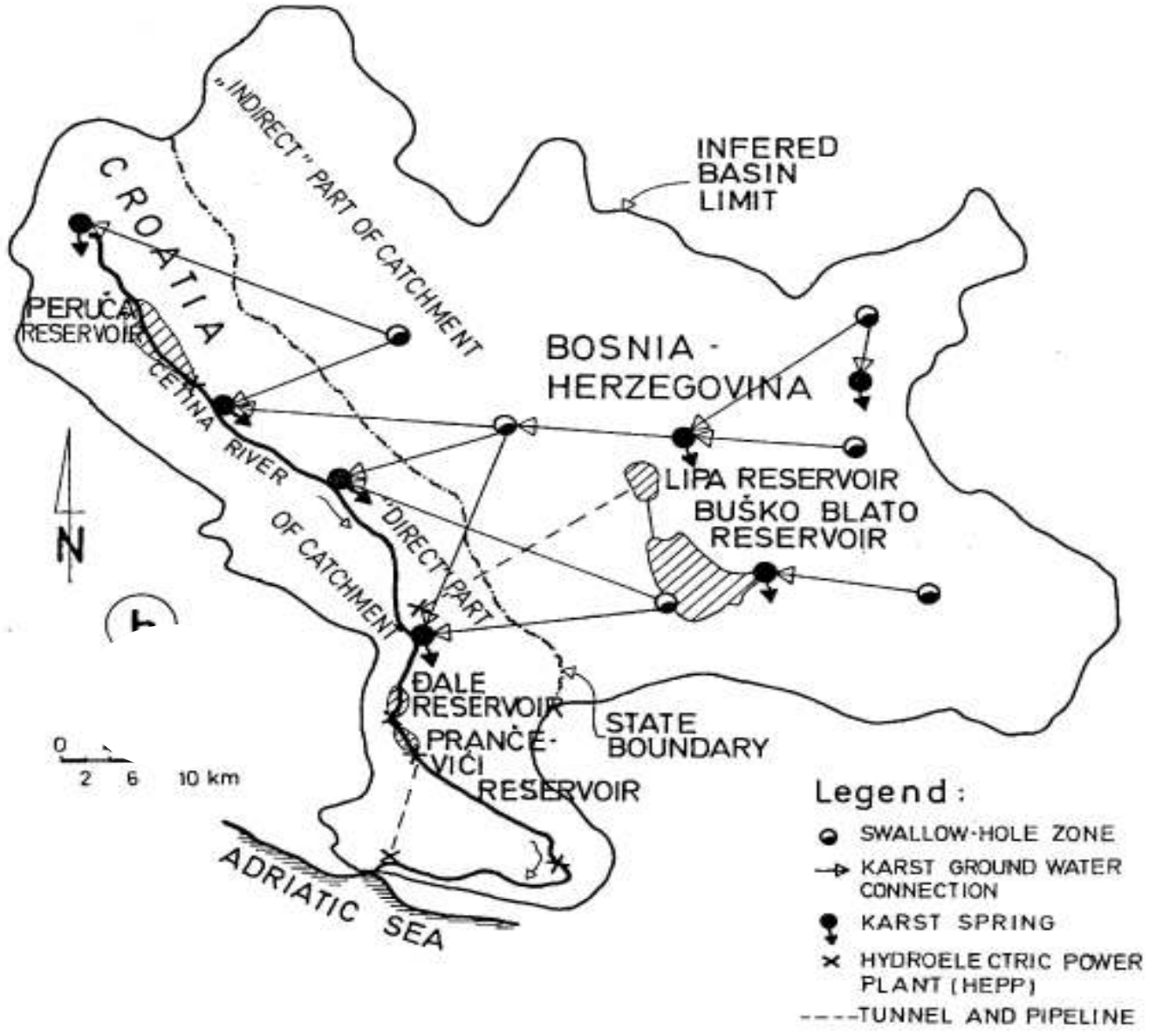
- heterogeneous and anisotropic surface and underground morphologic karst forms;
- existence of well developed, complex, deep, and mostly unknown positions and dimensions of underground karst cracks, joints, fissures, impermeable layers, conduits etc;
- strong interaction between circulation of surface water and groundwater;
- high and fast oscillations of groundwater;
- strong and direct but inadequately known links between inflow (swallow-holes) and outflow (karst springs) karst features;
- generally small storage capacity of the karst medium;
- fast, turbulent groundwater transport through karst conduits and at the same time slow, laminar flow through karst matrix;
- natural endogenic and exogenic processes, and influence of man's induced structures and/or activities (dams, reservoirs, motorways development, water pumping, water abstraction etc) which influence fast and/or slow changes of the water regime;
- different aspects of duality of water circulation in karst

The Dinaric karst covers about 60,000 km^2. It stretches the length of the eastern coast of the Adriatic Sea, from the Bay of Trieste in the north, to the Drim River basin in the south and the Western Morava valley in the east. This karst structure is some 600 km in length, and up to 200 km in width, falling within the borders of seven states: Italy, Slovenia, Croatia, Bosnia and Herzegovina, Serbia, Montenegro and Albania. The first detailed karst studies as well as the first theories on water circulation and storage in karst were developed as part of the investigations of the Dinaric karst. The Dinaric karst region is an area of dramatic variety of species, habitats, landscapes and peoples.

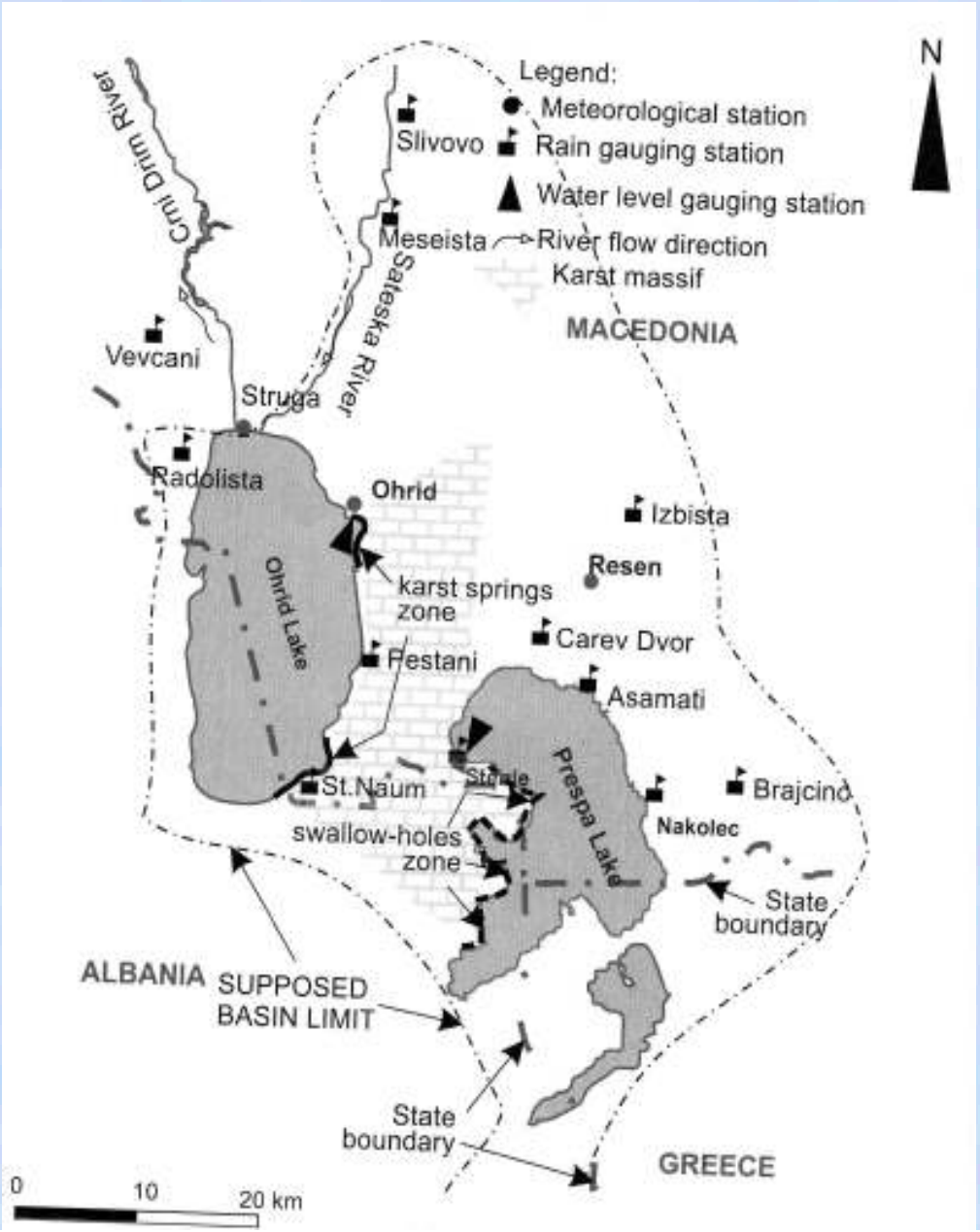


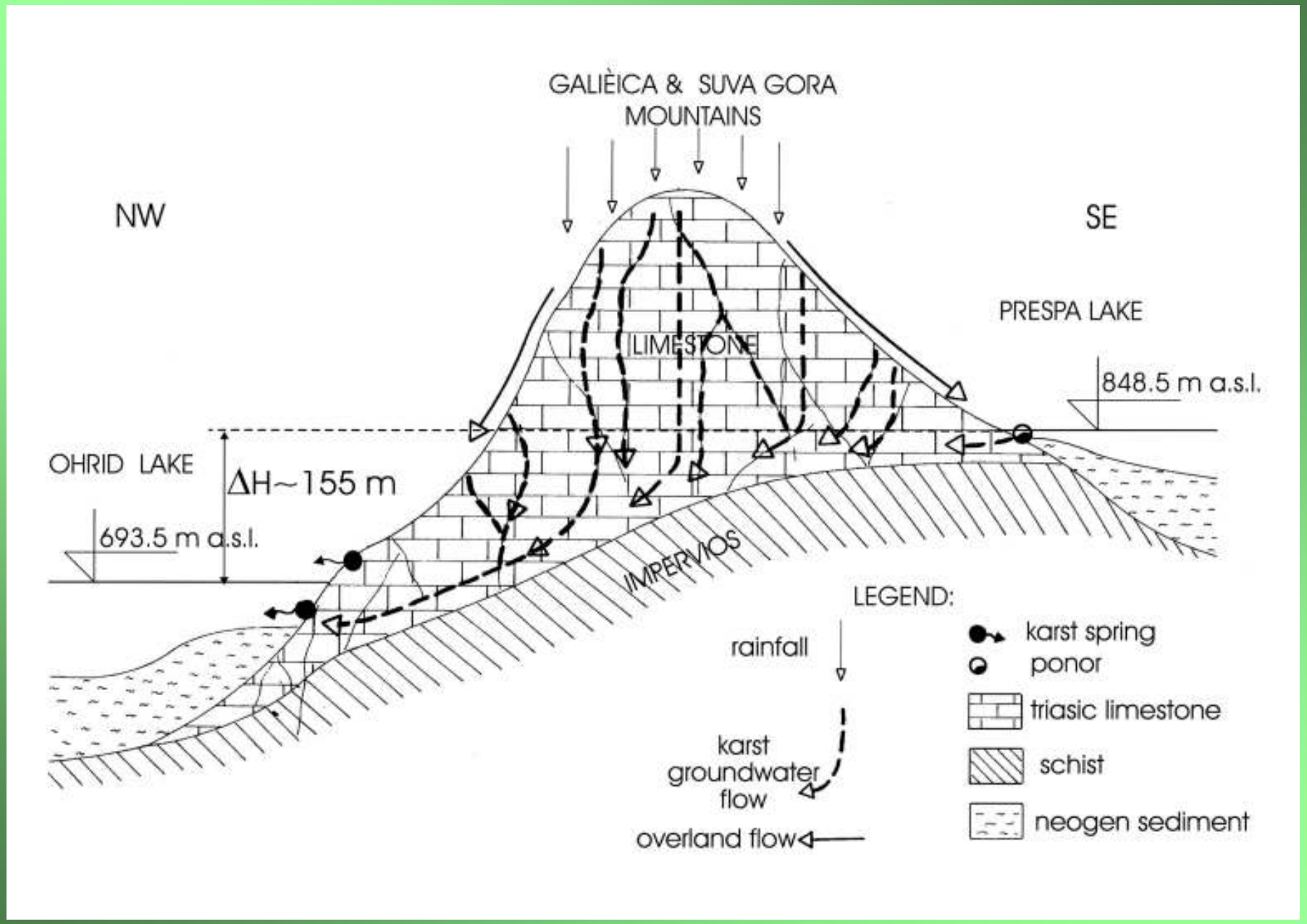

SPLIT
BRAČ
HVAR
VIS
Kaštel
Makarska
Hrvatski kanal
Viški kanal
Neretvanski kanal

THE CETINA RIVER CATCHMENT

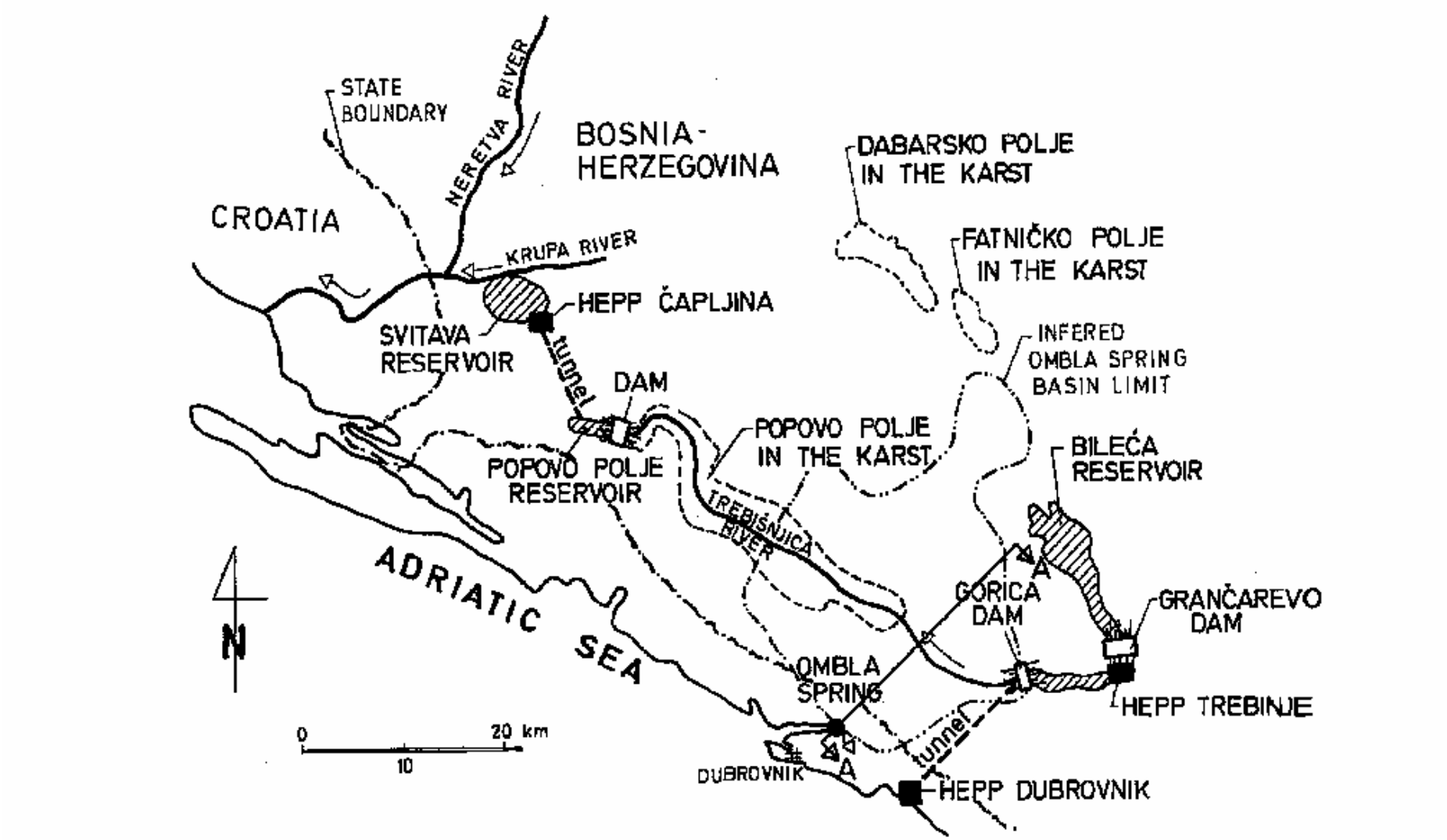


OHRID AND PRESPA LAKES
(ALBANIA, MACEDONIA AND GREECE)




GALIÈICA & SUVA GORA
MOUNTAINS
NW
SE
PRESPA LAKE
LIMESTONE
848.5 m a.s.l.
OHRID LAKE
ΔH~155 m
693.5 m a.s.l.
IMPERVIOS
LEGEND:
rainfall
karst
groundwater
flow
overland flow
karst spring
ponor
triasic limestone
schist
neogen sediment

THE MAP OF THE TREBIŠNJICA RIVER BASIN



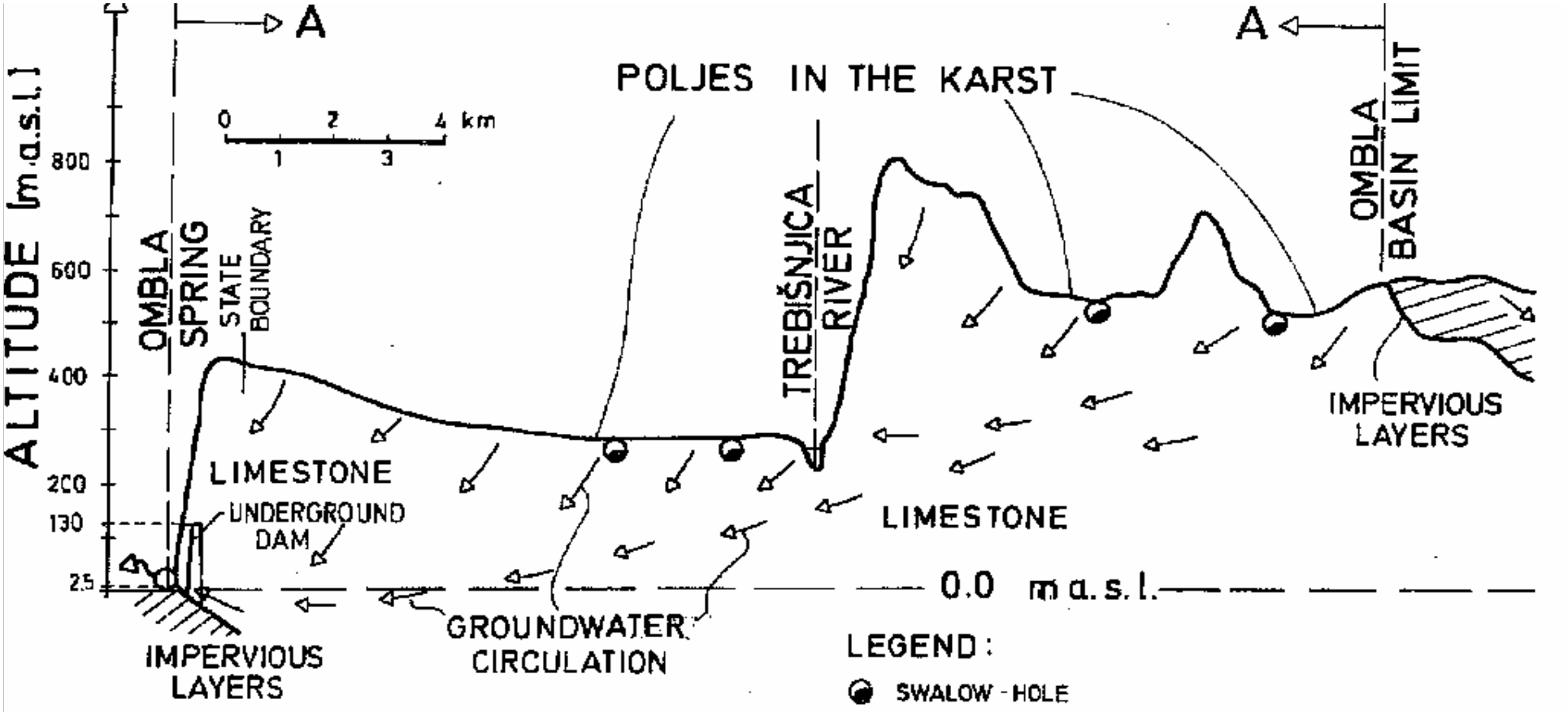
The section of an open streamflow of the Trebišnjica River is included in the catchment of the Ombla Spring. There are permanent water losses into the karst underground along the given section caused by the cracks located at the bottom and banks of the Tebišnjica River. The water losses of the open streamflow along this section, flowing through the Ombla Spring hydrologic catchment, depend upon the inflow discharge and the groundwater levels. The infiltrated water feeds the spring. Thus, the spring catchment area is increased, whereas the open streamflow catchment area is decreased respectively. The relation changes in time.

In 1978 the river bed of the Trebišnjica River was regulated by building a concrete canal for the discharge of 45 m^3/s. As a consequence the average annual discharge of the Ombla Spring decreased from 30 to 22 m^3/s, whereas changes in minimum and maximum annual discharges were not observed.

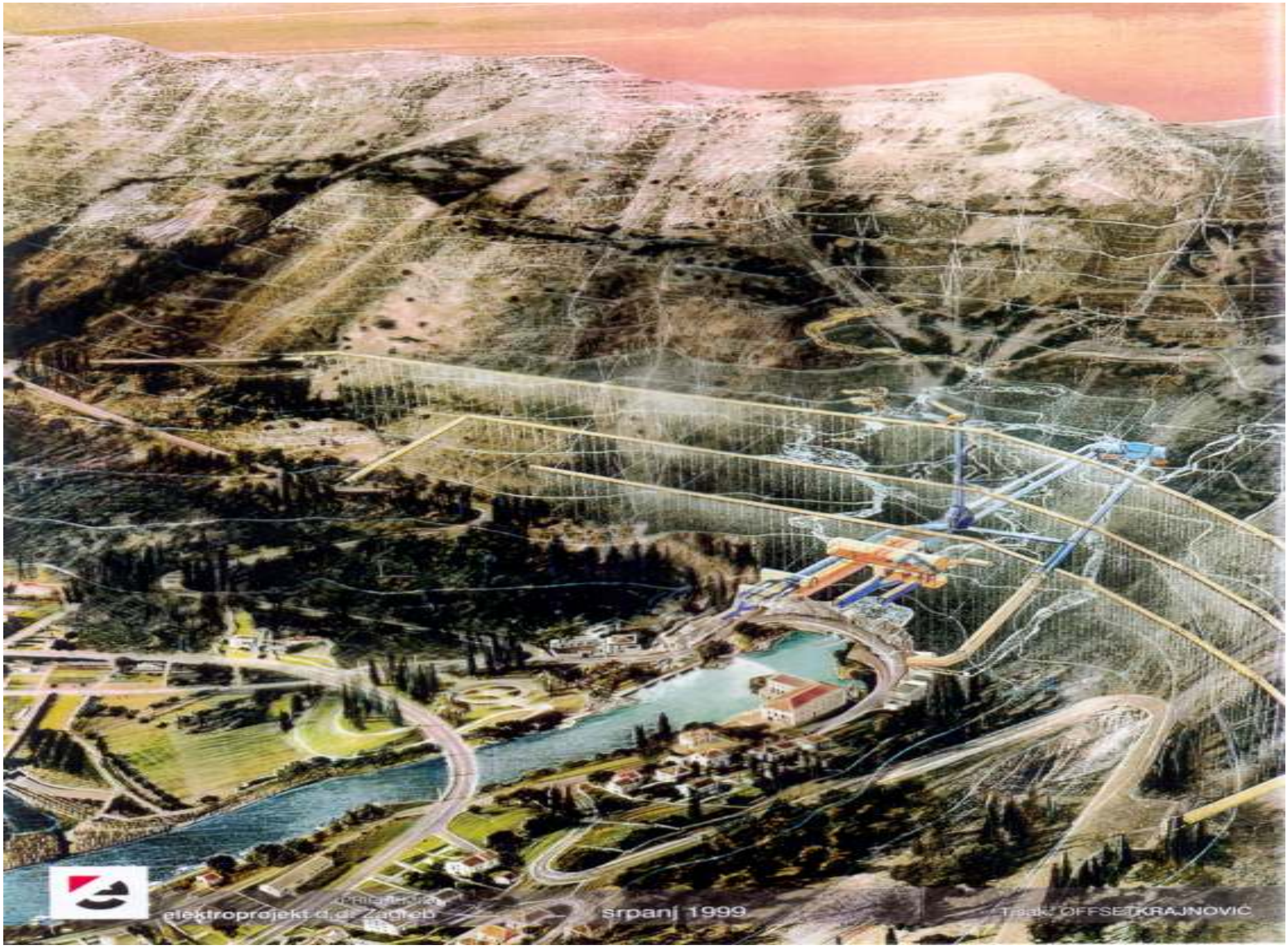
TREBIŠNJICA RIVER


HE OMBLA
HRVATSKA
ZAGREB
DUBROVNIK
DUBROVNIK
O. KOLOČEP
O. DAKSA
O. LOKRUM
KANAL DAKSA
HRIDI GREBENI
Mokošica
Rijeka Dubrovačka
Zaton
Orašac
Lapad

CROSS-SECTION



The cross-section A-A given on the Figure 2 with designated positions of the Ombla Spring, the HEPP Ombla underground dam (in project), the state boundary between Croatia and Bosnia-Herzegovina, the Trebisnjica River and the inferred Ombla Spring basin limit.


elektroprojekt d.d. Zagreb
srpanj 1999
Tisak: OFFSET KRAJNOVIĆ

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available at www.sciencedirect.com

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journal homepage: www.elsevier.com/locate/jhydrol

ELSEVIER

A multi-model approach to the simulation of large scale karst flows

C. Makropoulos [a,*], D. Koutsoyiannis [b], M. Stanić [c], S. Djordjević [a], D. Prodanović [c], T. Dašić [c], S. Prohaska [d], Č. Maksimović [e], H. Wheater [e]

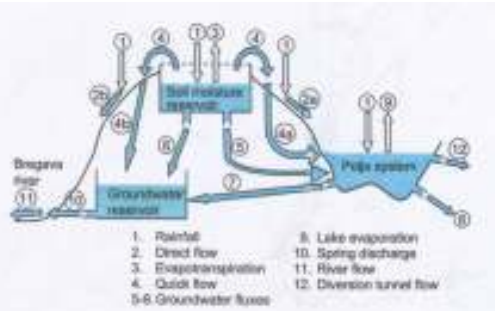


Figure 5 Schematic of the conceptual model.

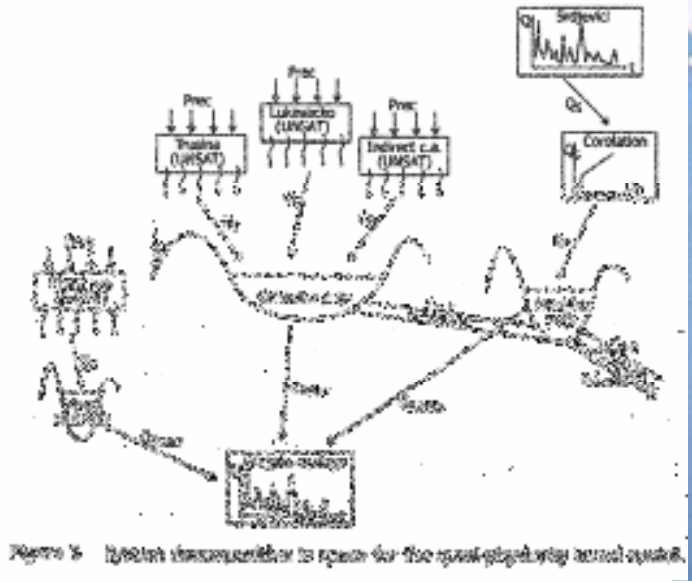
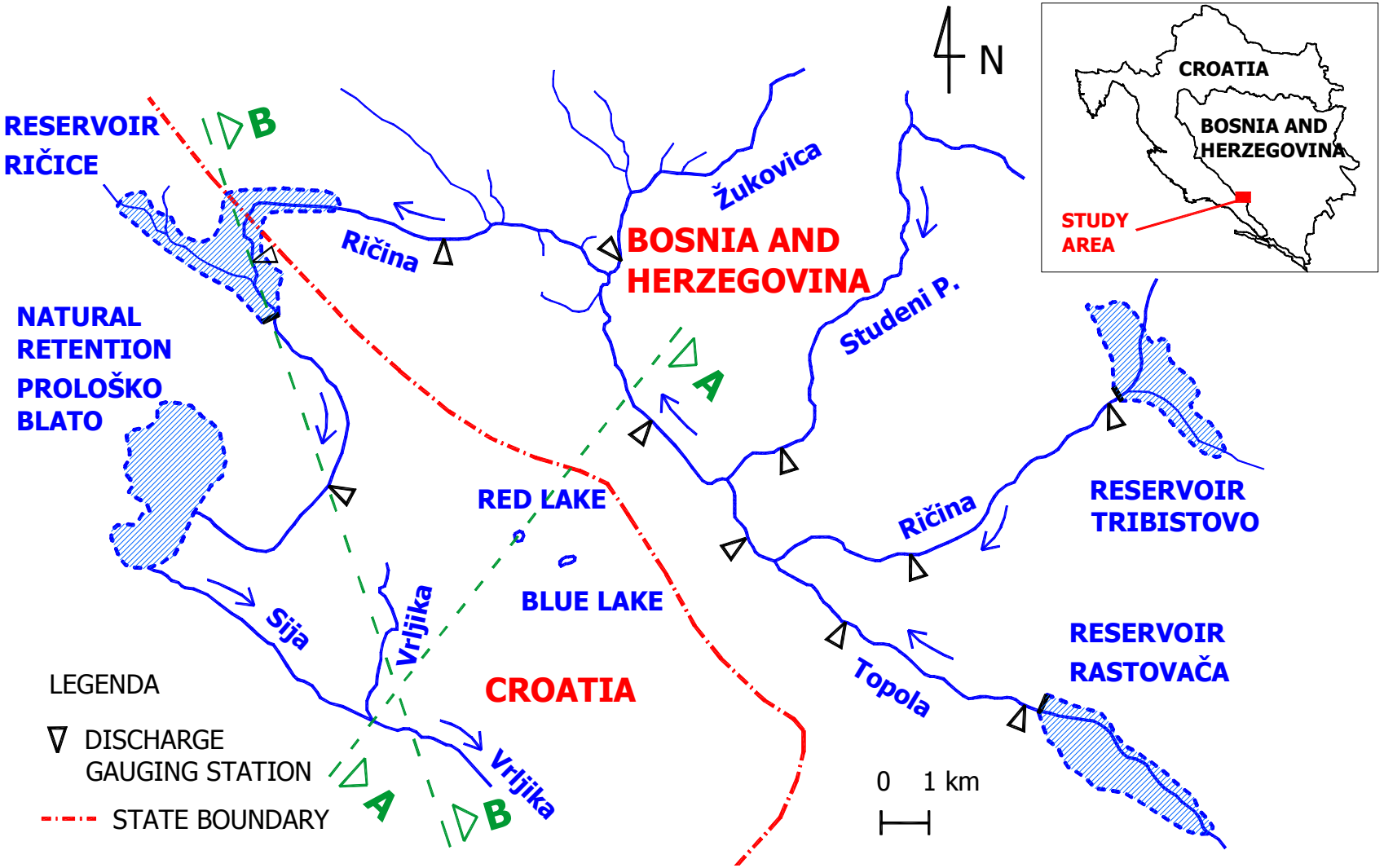


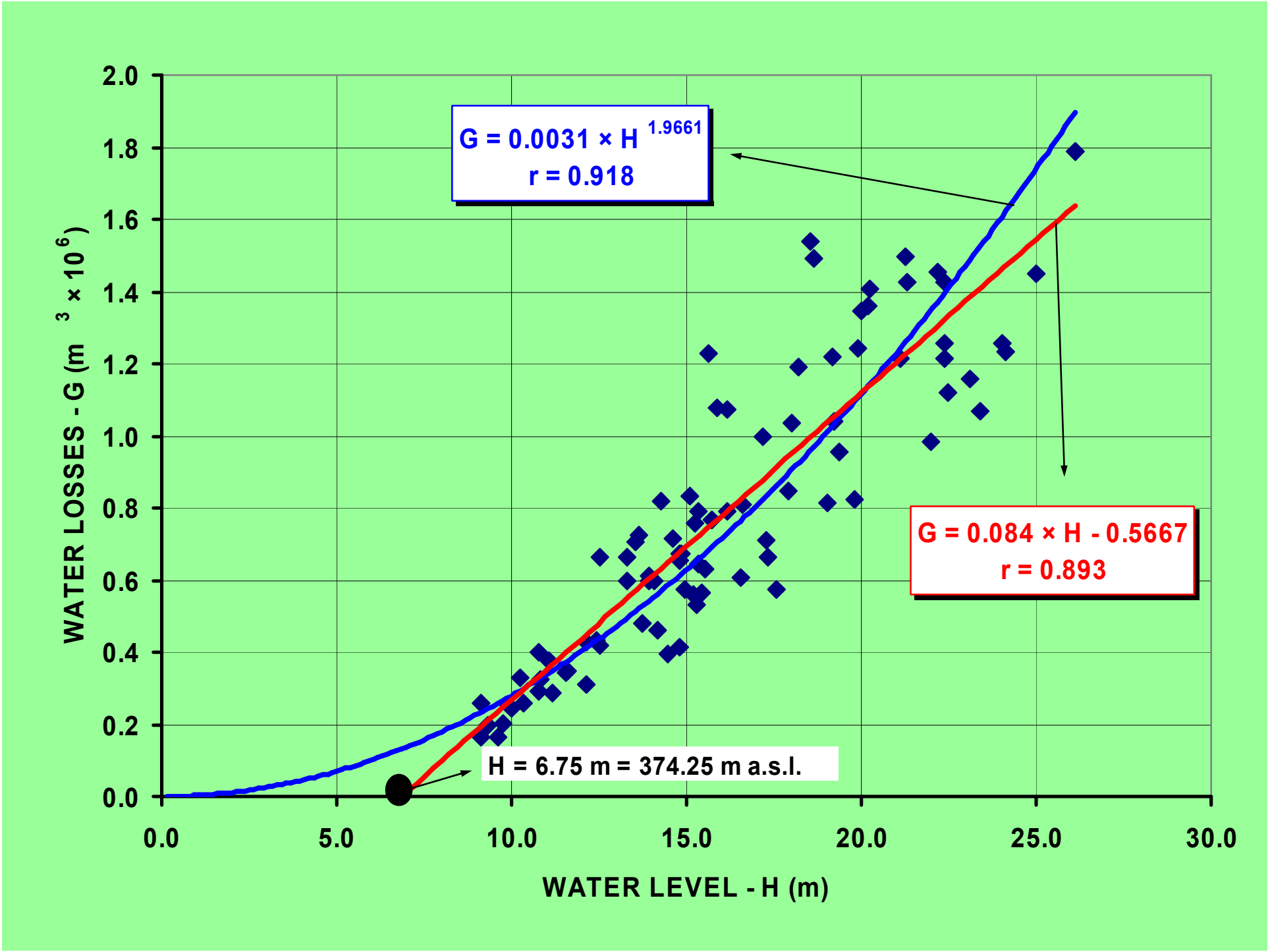
Figure 6 System configuration in space for the semi-distributed conceptual model.

The RIČICA reservoir was impounded by construction of 45 m high dam on the intermittent Ričina river course situated in the central part of the bare Dinaric karst, on the boundary between Croatia and Bosnia and Herzegovina.

<u>There are considerable water losses from the reservoir.</u>

Tectonic fractures, fissures, joints and other karst features intensify the permeability of the karst deposits.




G = 0.0031 × H 1.9661
r = 0.918
G = 0.084 × H - 0.5667
r = 0.893
H = 6.75 m = 374.25 m a.s.l.
WATER LOSSES - G (m 3 × 10 6)
WATER LEVEL - H (m)
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0
0.0
5.0
10.0
15.0
20.0
25.0
30.0

Cross section A - A

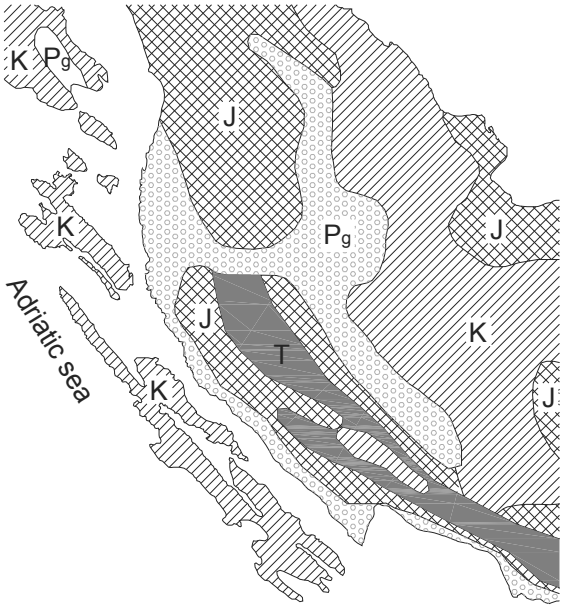
CONCLUSION

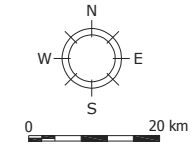
Hydrology and in karst regions hydrogeology are the bases for any kind of dialog about transboundary karst water resources management. Managing water resources for sustainable development primarily required improved methods for quantifying components of the hydrological cycle on a regional and catchment scales.

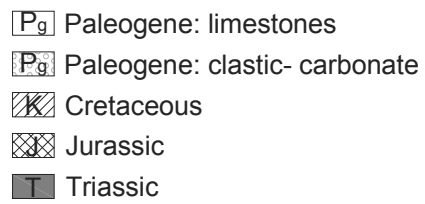
Scientists frequently organise symposiums, congresses, conferences, workshops etc. It is an initiative that has to be supported and intensified. However, it is necessary to face that hydrologists, limnologists, geographers, chemists, layers, ecologists, politicians, agronomists, sociologists and all other involved in water related problems in the transboundary karst areas should start to work together. At the moment each scientific and engineering as well as other branches works separately from the other.

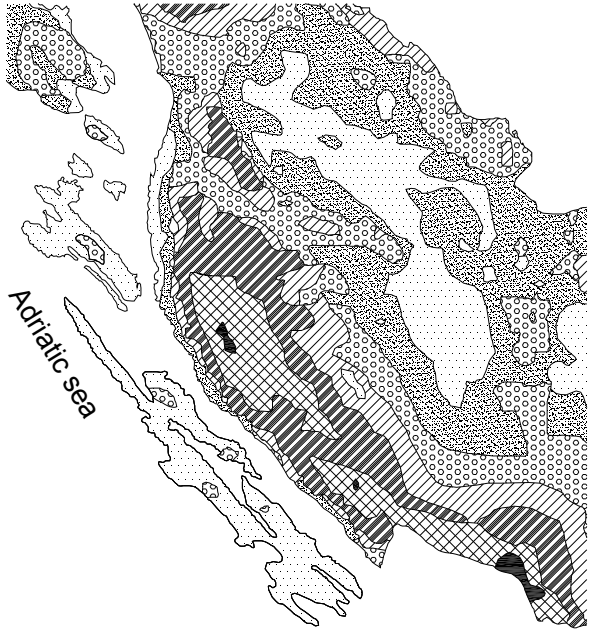
- **Transboundary karst water related problems will be better and more efficiently solved if professional and scientific principles are fully recognised and not affected or influenced by daily politics. In case of the states, which were established after disintegration of former Yugoslavia, official contacts of experts should be strengthened. Friendship and appreciation between experts and institutions that were created over many years, and privately still exist, should be used at best for efficient solution of current problems that do not have political background. Unfortunately, at the present, some positive experiences from the former country and political system are insufficiently used because the opinion (mainly from politicians) that nothing from the former system was good.**
- **Of paramount importance is to ensure a stable exchange of technical information and to create institutions and space where a public, free and open discussion among all the partners in process will be conducted. It is the way to create a long-term strategy for a more efficient internationally shared transboundary karst water management respecting the principles of sustainable development.**

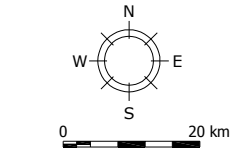

CROATIA
Gacka River
Lika River
Adriatic sea

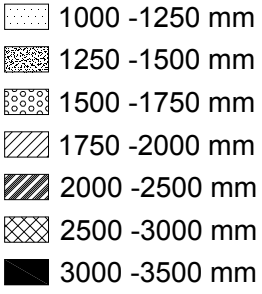

K
Pg
J
K
Pg
J
J
T
K
K
J
Adriatic sea

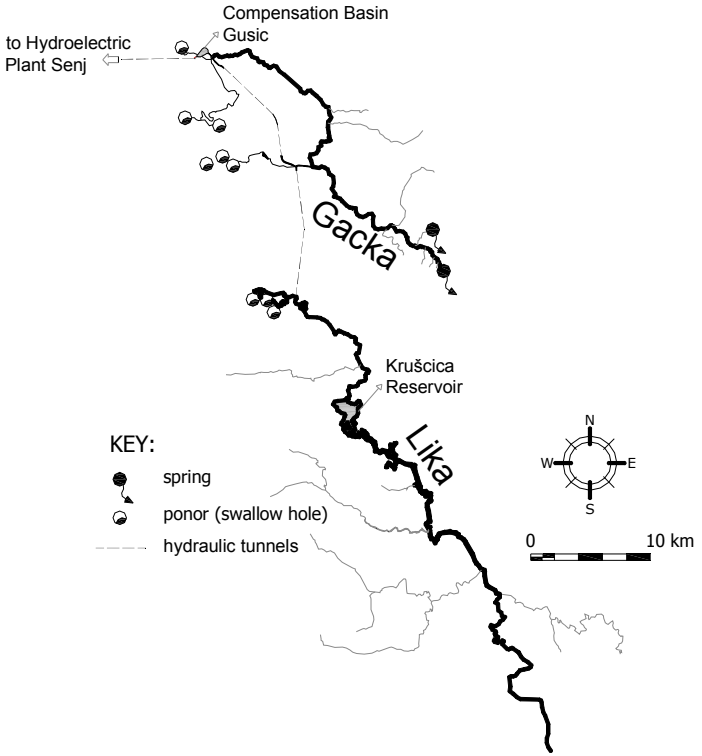

N
W
E
S
0
20 km

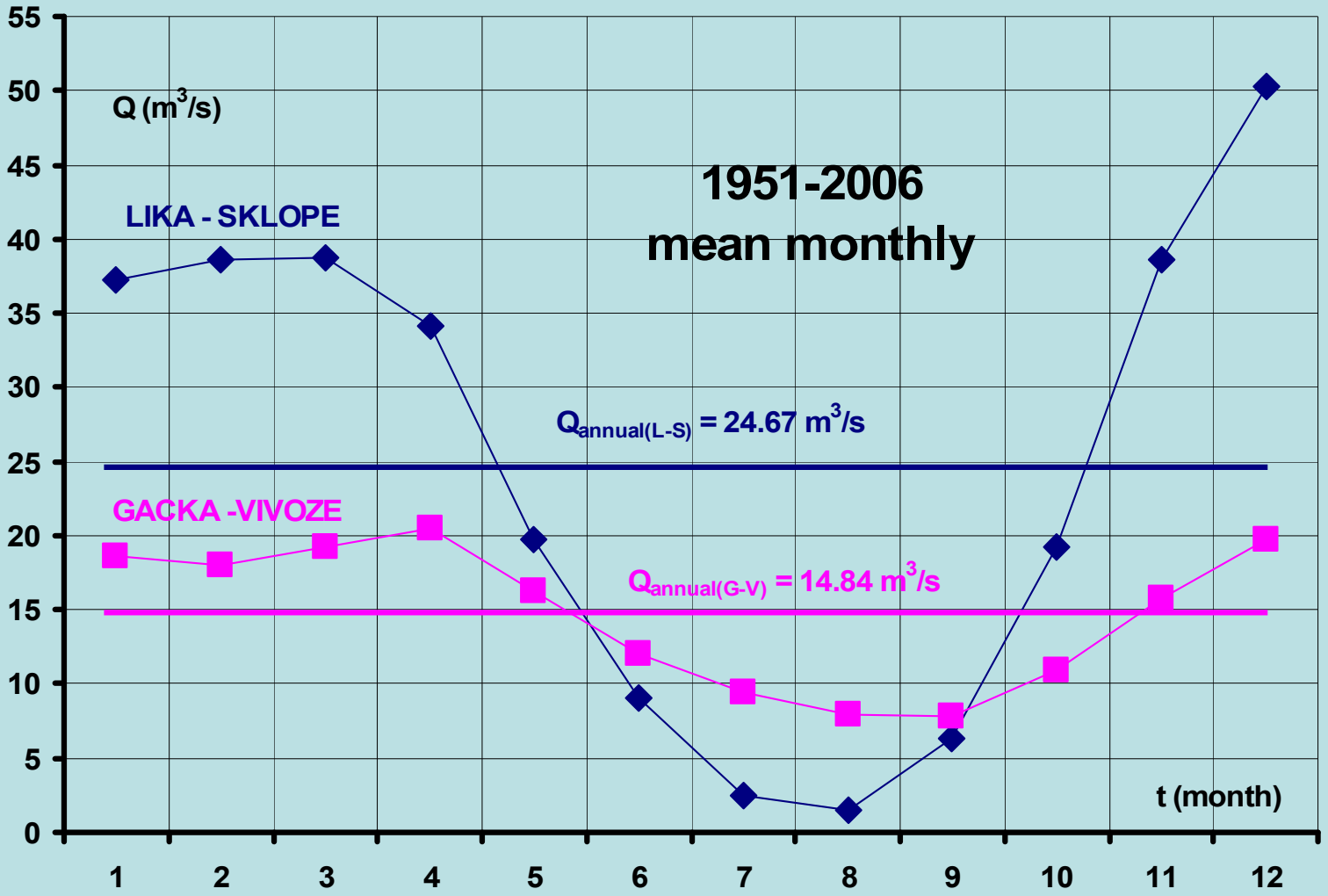

Pg Paleogene: limestones
Pg Paleogene: clastic- carbonate
K Cretaceous
J Jurassic
T Triassic


Adriatic sea

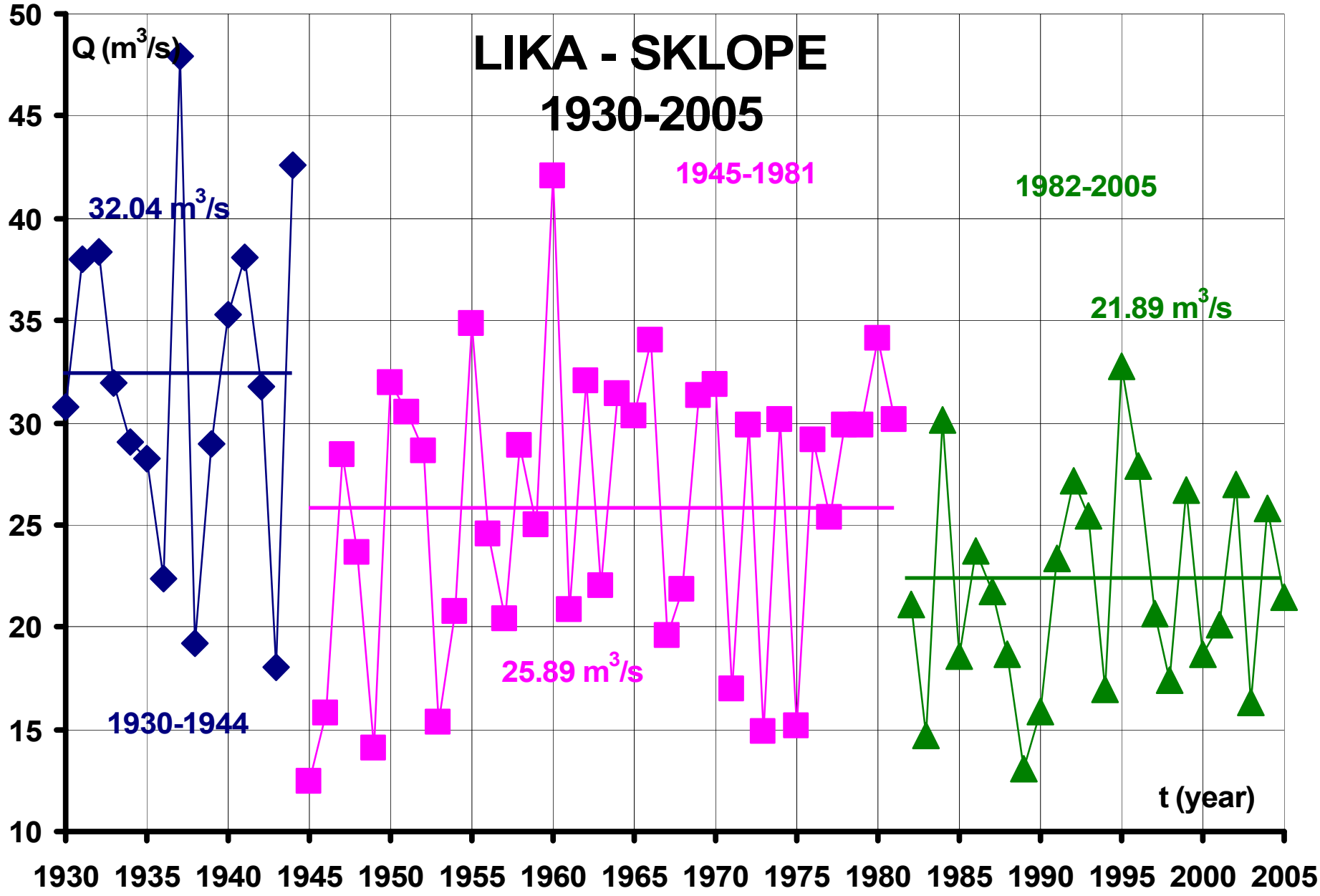

N
W
E
S
0
20 km

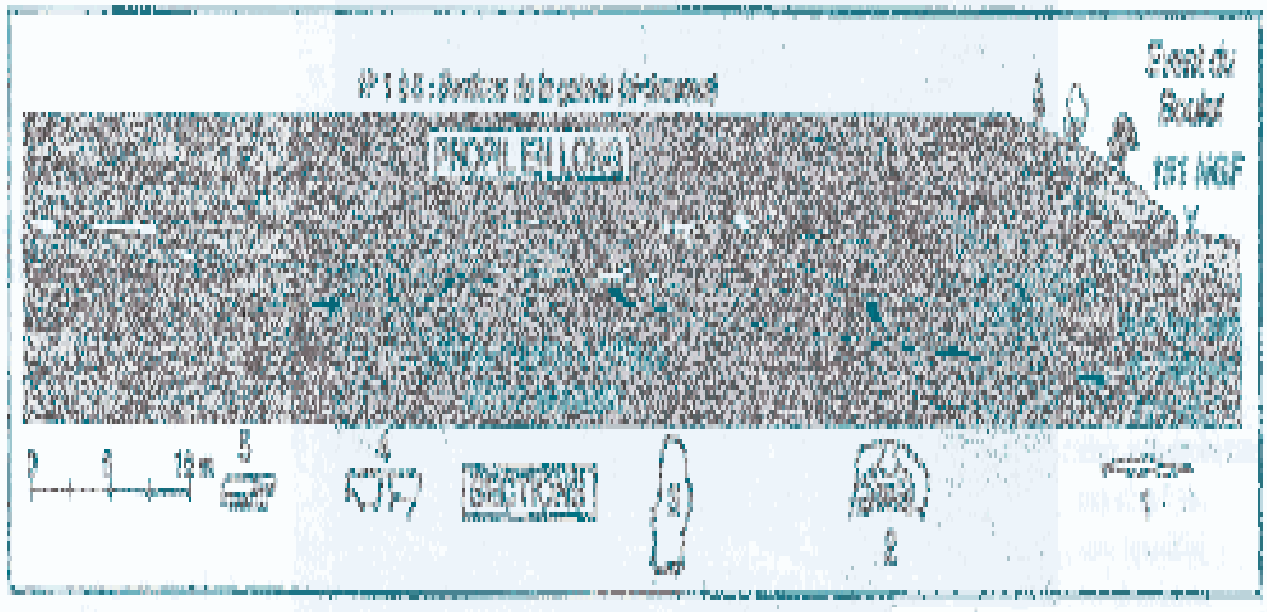

1000 -1250 mm
1250 -1500 mm
1500 -1750 mm
1750 -2000 mm
2000 -2500 mm
2500 -3000 mm
3000 -3500 mm


Compensation Basin
Gusic
to Hydroelectric
Plant Senj
Gacka
Kruščica
Reservoir
Lika
KEY:
spring
ponor (swallow hole)
hydraulic tunnels
N
W
E
S
0
10 km



The Lika River has torrential water regime. Its minimum, mean and maximum discharges in the 1951-2005 period are: 0 m^3/s (dry); 24.5 m^3/s; 729 m^3/s. During the same period the Gacka River has next characteristic discharges: 2.2 m^3/s; 14.7 m^3/s; 75.5 m^3/s. Along some sections of their open watercourses there are considerable water losses. They appear when the regional groundwater level is low, mostly during hot, dry summer period. The water loses are especially great on the Lika River watercourse. Because of topographic relations, as well as karst geological setting it is possible that water from the Lika River watercourse recharges the karst springs of the Gacka River.


LIKA - SKLOPE
1930-2005
Q (m3/s)
32.04 m3/s
1930-1944
1945-1981
25.89 m3/s
1982-2005
21.89 m3/s
t (year)
50
45
40
35
30
25
20
15
10
1930
1935
1940
1945
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005



Ci-dessous : Vue en perspective