The Use of Natural Geological Formations to Decrease Storm Runoff

Lajos Hovány[1], Ognjen Garbrić[2], Nenad Jaćimović[3], Dušan Prodanović[4]

1 University of Novi Sad, Serbia, hovanyl@gf.uns.ac.rs
2 University of Novi Sad, Serbia, ogabric@gf.uns.ac.rs
3 University of Belgrade, Serbia, njacimovic@hikom.grf.bg.ac.rs
4 University of Belgrade, Serbia, eprodano@hikom.grf.bg.ac.rs

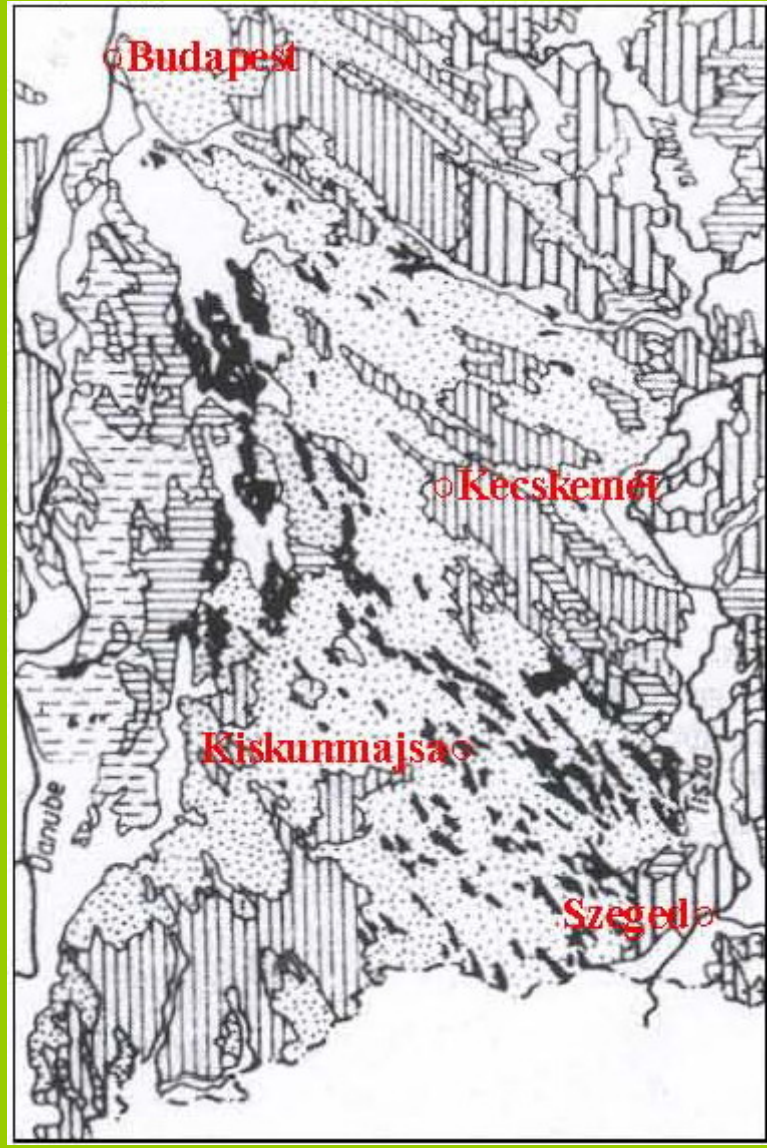
INTRODUCTION

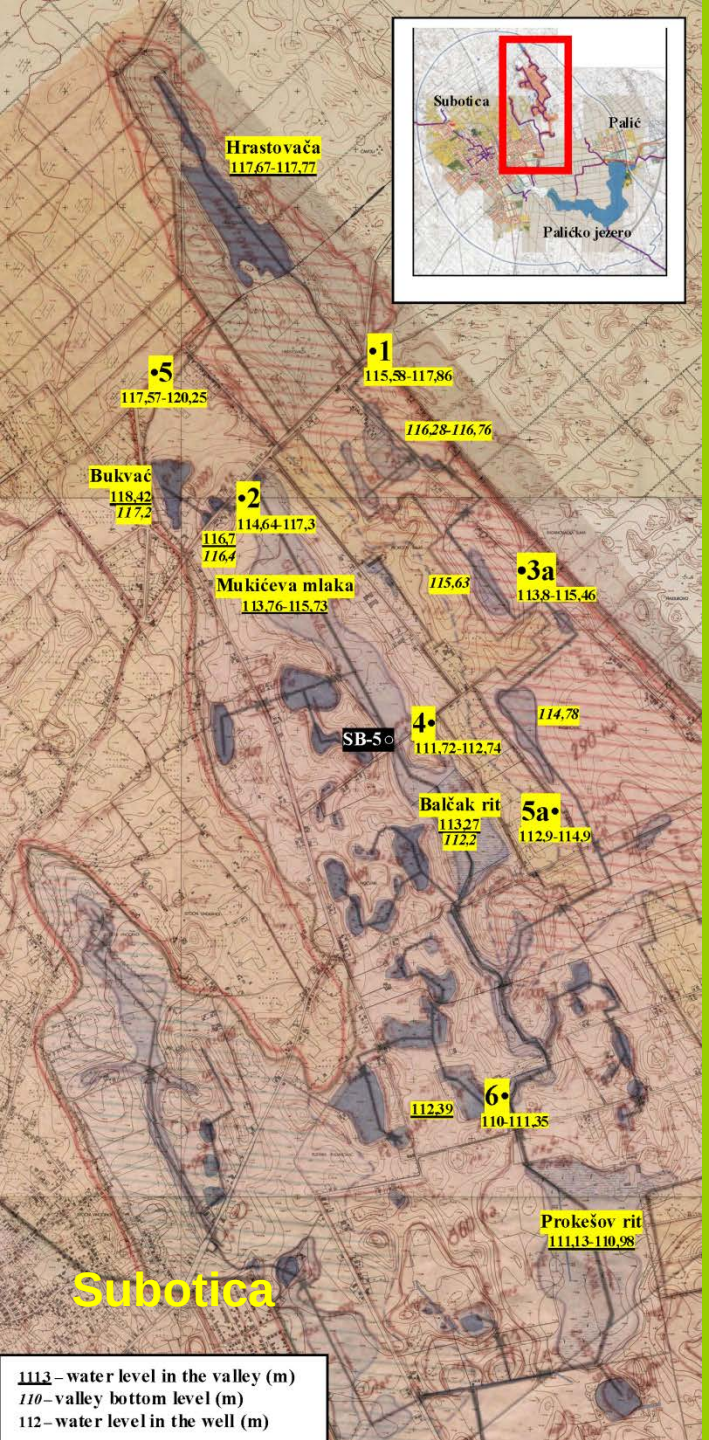
1 and 2 – sand

impermeable floor valleys:

overall area 300 km^2

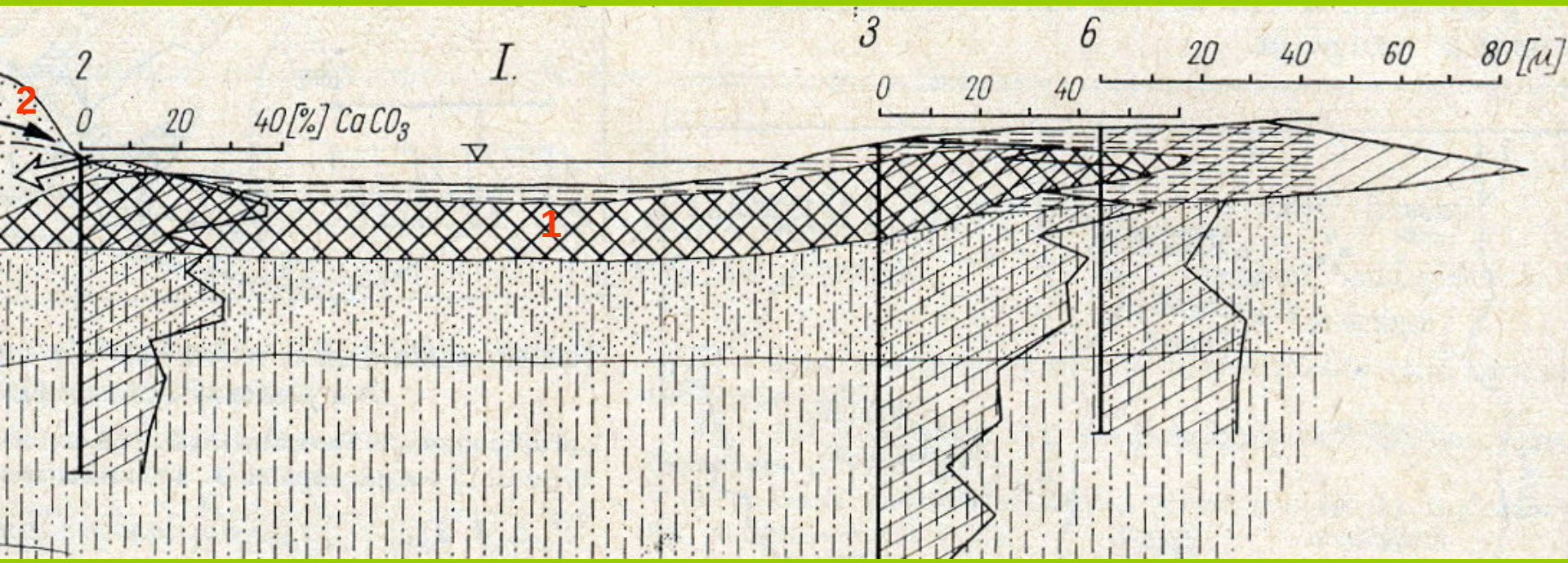
1,5 km^2 is in the vicinity of Subotica





in type A valleys (dark blue areas): the water had uniform level

in type B valleys (light blue areas): the water level was not uniform



1 impermeable material: dolomite or a white, pulpy material

2 sand:

•medium size from 0.1 to 0.5 mm

•angle of the bank's slope from 10^{o} to 30^{o}.

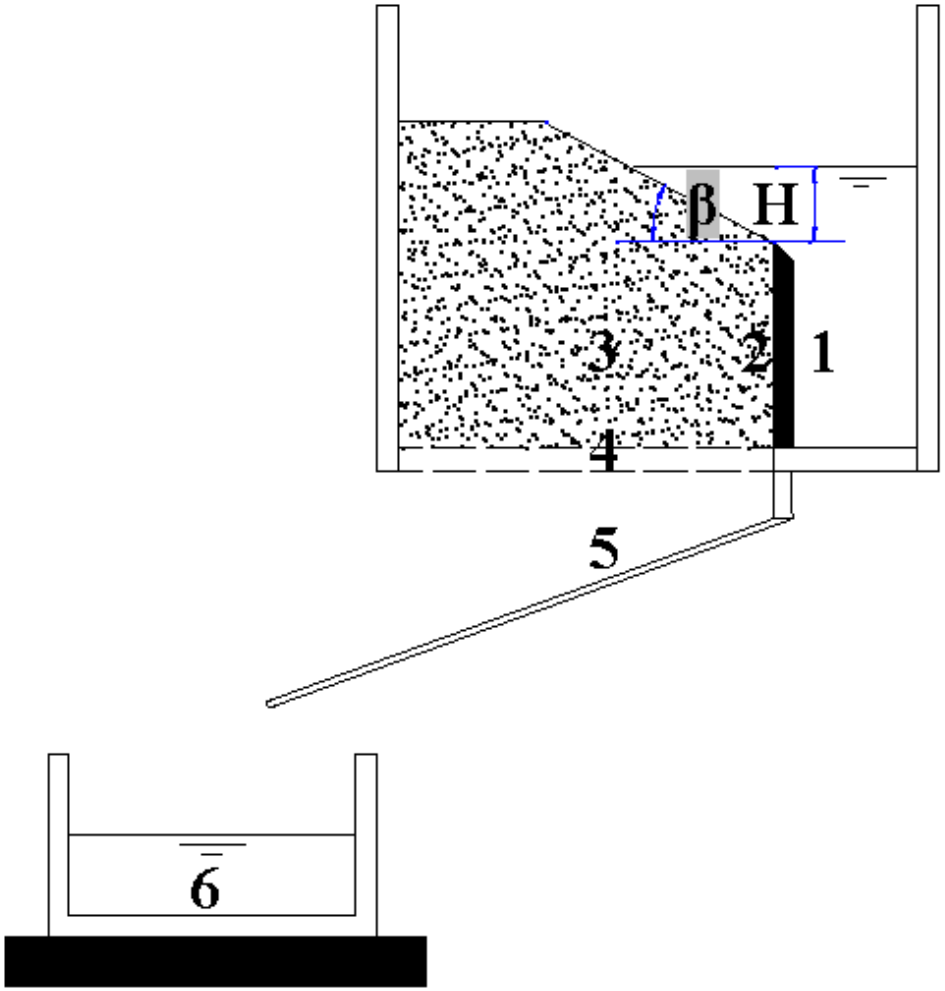
impermeable floor valley (in the Bunjevac language called "mlaka" and "semlyék" in the Hungarian language)

The aim of this study is to investigate the possibility of using revitalised valleys for rainfall runoff detention. In order to solve part of the problem, the valley discharge hydrograph was analysed on a physical model in a hydraulic laboratory.

Measured quantities are compared with the results obtained by numerical modelling of filtration in unsaturated environment.

LABORATORY SETUP

in a 9.4 cm wide laboratory channel



2: 16 cm high weir

3: sand (fractions of sizes 0.4-0.5 mm)

4: geotextile

5: channel

6: vessel, scale

At the beginning of the experiment, water level in sector 1 was equal to weir crest level, hence water depth above weir crest level was H=0.

By adding water up to Hmax≈7 cm in sector 1, the water infiltrated through sector 3.
Water level in the sector 1 was measured by a grade with a millimeter accuracy.

At the same time, the water weight in the vessel on the scale and water density were measured and the mass diagram of the water volume infiltrated from sector 3, V=f(t) was determined.

MEASUREMENT RESULTS

β=12.3-12.6; 21.9-22.4 and 27.9-28.5o

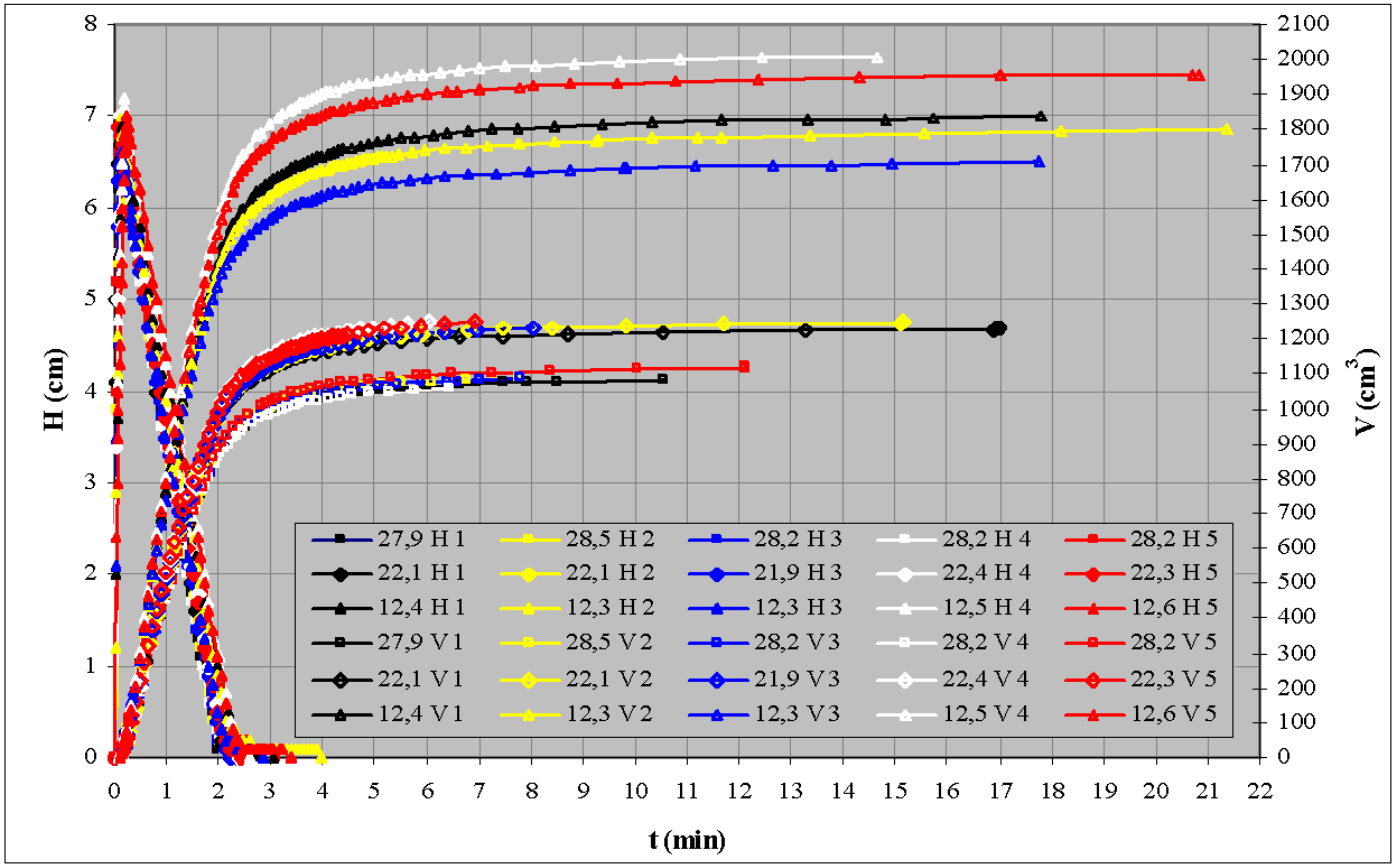
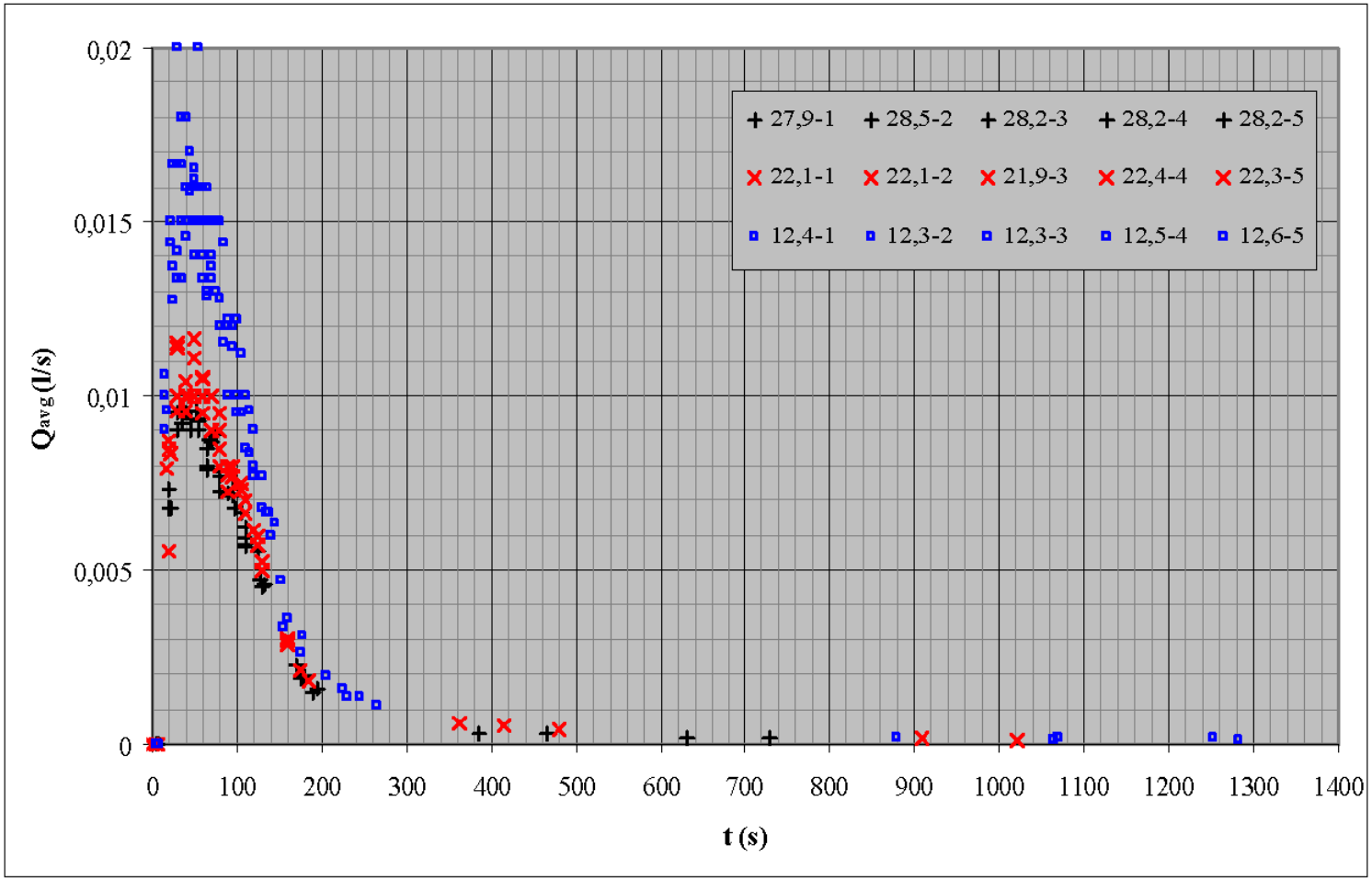


Diagram H=f(t) for sector 1 and V=f(t) for sector 3

The time of filling for sector 1 lasted 5-15 s, and the water started to overflow from sector 3 after 6-9 seconds, measured from the start of inflow into sector 1.

Hydrographs for sector 1: By increasing angle β, the mass diagram final value of the water volume infiltrated from sector 3 decreases.

$$Q_{avg} = \frac{\Delta V}{\Delta t}$$



Discharge hydrograph from the sector 3

From the start of water inflow into sector 1, the maximum discharge value (Qavg) appeared at 29-55 seconds. Maximum discharge value (Qavg) is decreased by the increase of angle β.

NUMERICAL MODEL FORMULATION

$$\frac{\partial \theta}{\partial t} = \frac{1}{J}\frac{\partial}{\partial \xi^i}\left(JK_e \frac{\partial \Pi}{\partial \xi^j} g^{ij} \right)$$

$$K_e = K_s \, K_r$$

$$p_c = \frac{\rho g}{\alpha}\left(S^{-1/m} - 1\right)^{1/n}$$

$$K_r = S^{1/2}\left\{1 - \left(1 - S^{1/m}\right)^m\right\}^2$$

Θ - volumetric water content

t - time

J - Jacobian of the transformation to Cartesian coordinates

ξi, ξj - coordinates in '*i*' and '*j*' direction

Ke - effective permeability

gij - metric tensor

Π - piezometric head

Ks - saturated hydraulic permeability of the soil

Kr - relative permeability

pc=pa-pw - capillary pressure

r - water density

g - gravitational acceleration

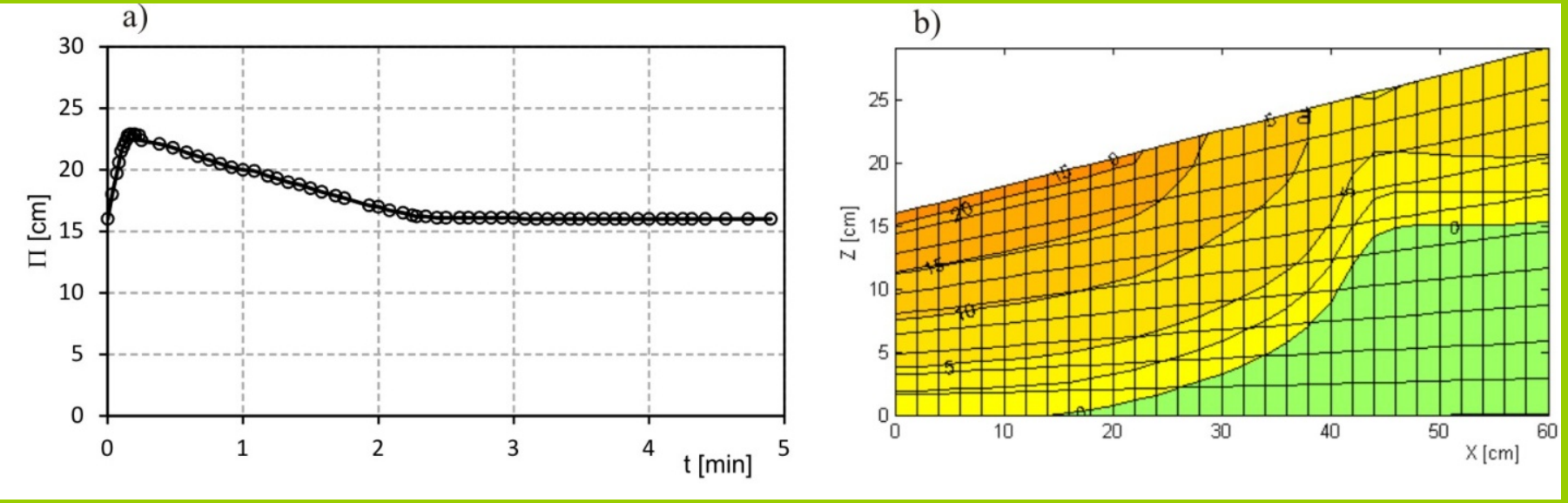
S - effective soil saturation

m=1-1/*n*

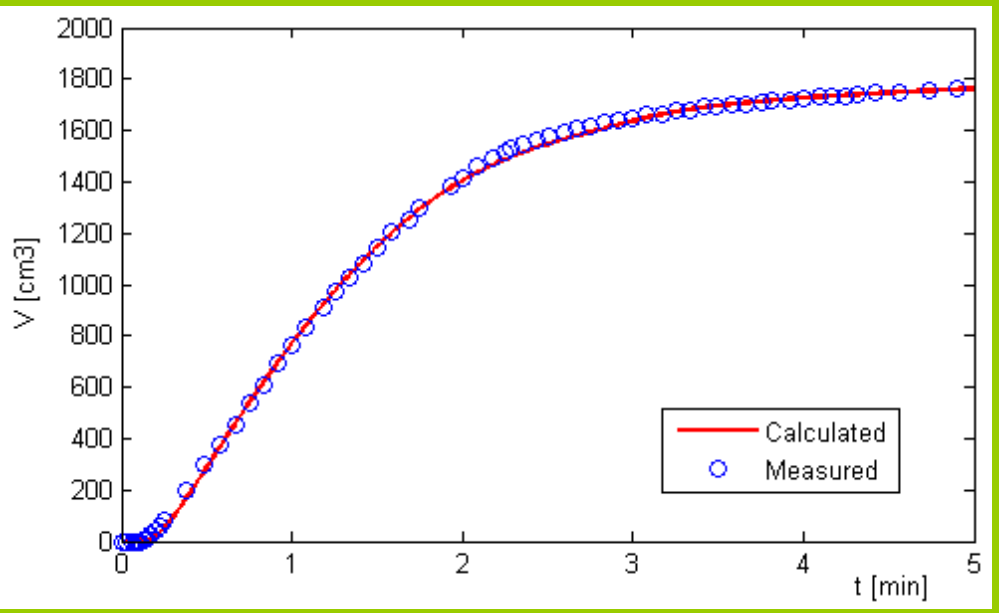
Obtained soil parameters in the process of model calibration

Parameter	Value
Hydraulic permeability	5.3 x 10^{-4} [m/s]
Porosity	0.21 [-]
Residual water content	0.09 [-]
α	12.2 [1/m]
n	2.5 [-]

RESULTS AND DISCUSSION



a) Upstream boundary water elevation during simulation, as observed during the experiment, b) calculated heads 40s after start of experiment/simulation



Comparison of calculated and measured cumulative water volumes at the downstream boundary.

CONCLUSION

•Based on the geological characteristics of these valleys (explored in Hungary) a physical model was set in the hydraulic laboratory. Based on measurement results (water level up to Hmax=7 cm) it can be concluded that the increase of the valley slope angle β, the final value of the mass diagram for water volume infiltrated from the valley and the maximum value of infiltrated water flow decreases.

•A code for simulation of water filtration in unsaturated environment has been developed and applied on water infiltration from the valleys. Comparison with physical model measurements showed a good agreement.

•With known morphology and geologic characteristics of the valley (edge level of the impermeable material, valley slope angle, hydraulic characteristics of sand slope), and with valley hydrograph as an input, infiltration from the valley may be estimated by application of developed code.