MODELLING A KARSTIC AQUIFER WITH A MIXED FLOW EQUATION

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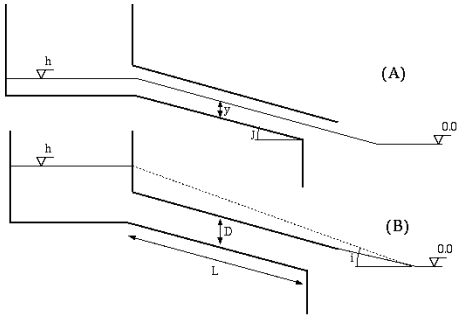
1. Abstract

The flow in karstic conduits is well known to be non laminar. For that reason the Darcy-Weisbach, or other non linear, equation is often used for modelling karstic aquifers. However the flow in the conduit system is not always pressurized. During the dry season the flow in some of the conduits may be conducted with free surface conditions. In this case a formula derived from open channel hydraulics may be more suitable for modelling the karstic aquifer. A mixed flow equation that is suitable for both pressurized flow and free surface flow is presented in this study along with a case study in the intensively karstified aquifer of Bregava spring in Bosnia. The case study showed that the mixed equation improved significantly the model performance especially as far as the simulated water level is concerned.

2. Mixed flow equation

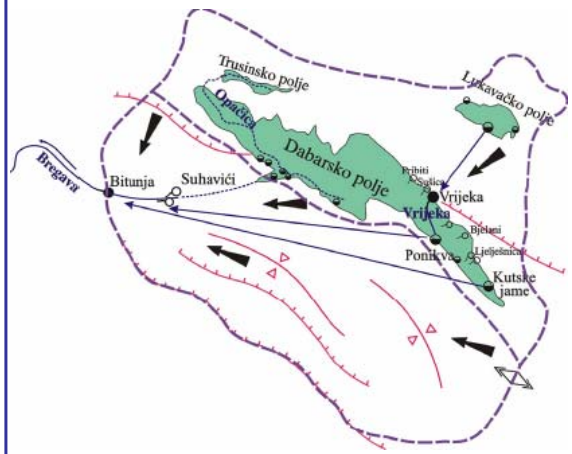


Mixed flow equation (Rozos and Koutsoyiannis, 2006) resembles the function of a tunnel that discharges a reservoir. When the water level in reservoir exceeds the tunnel top, the tunnel functions like a pressurized conduit. When the water level in the reservoir is bellow the top, the tunnel functions like a culvert.

$$Q = C\left(\frac{y}{D}\right)^{\alpha} i^{0.5}$$

C: generalised conductivity [$L^3\ T^{-1}$].
α: constant between 1 and 2.
i: hydraulic gradient when $y>D$, slope when $y \le D$.

3. Modelling the aquifer



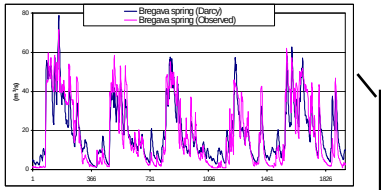
Application area is situated in Eastern Herzegovina and it is the part of Dinaric Karst region (Maksimovic et al., 2004).

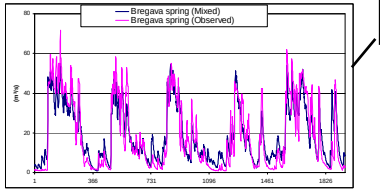
Dabarsko polje is flooded during the period of high precipitation. The polje water is conducted to Bregava spring through large ponors at the bottom of the polje.

Aquifer is modelled using 3 cells. One cell represents the polje and two other cells represent the distant and close to the spring areas.

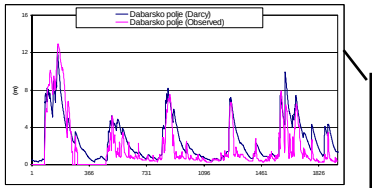
The distant cell discharges to the polje. The polje cell and the close to the spring cell both discharge to the spring.

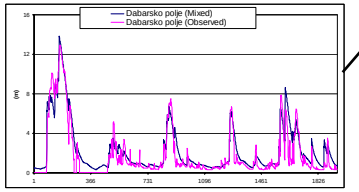
4. Results





Simulation of spring discharge is good both with Darcy and Mixed equation (daily values).



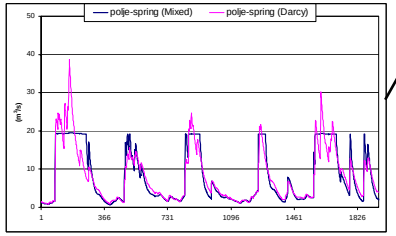


Water level in polje is simulated more efficiently with mixed flow equation (daily values).

	Bregava spring	Dabarsko polje
Darcy calibration	0.81	0.70
Mixed calibration	0.84	0.78
Darcy validation	0.77	0.48
Mixed validation	0.78	0.76

Good determination coefficient of simulated spring discharge by both equations in calibration and validation period. Better determination coefficient of simulated water level in polje by Mixed equation especially in validation period.

5. Why mixed equation helps



Discharge between polje and spring with Darcy and Mixed equation.

The discharge in Darcy equation is always proportional to the hydraulic gradient.

The discharge in Mixed equation depends greatly on the water level when it does not exceed tunnel top and is proportional to the square root of the hydraulic gradient when the water level exceeds the tunnel top.

References

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6. Conclusions

1. Mixed flow equation contributes to better simulation of water level fluctuation in karstic aquifers because it reproduces the capacity threshold of karstic conduits.
2. Although Darcy equation assumptions (laminar flow) do not apply to karstic aquifers, it achieves good results in simulation of discharge.