Estimation of subdaily riparian evapotranspiration from high frequency streamflow data

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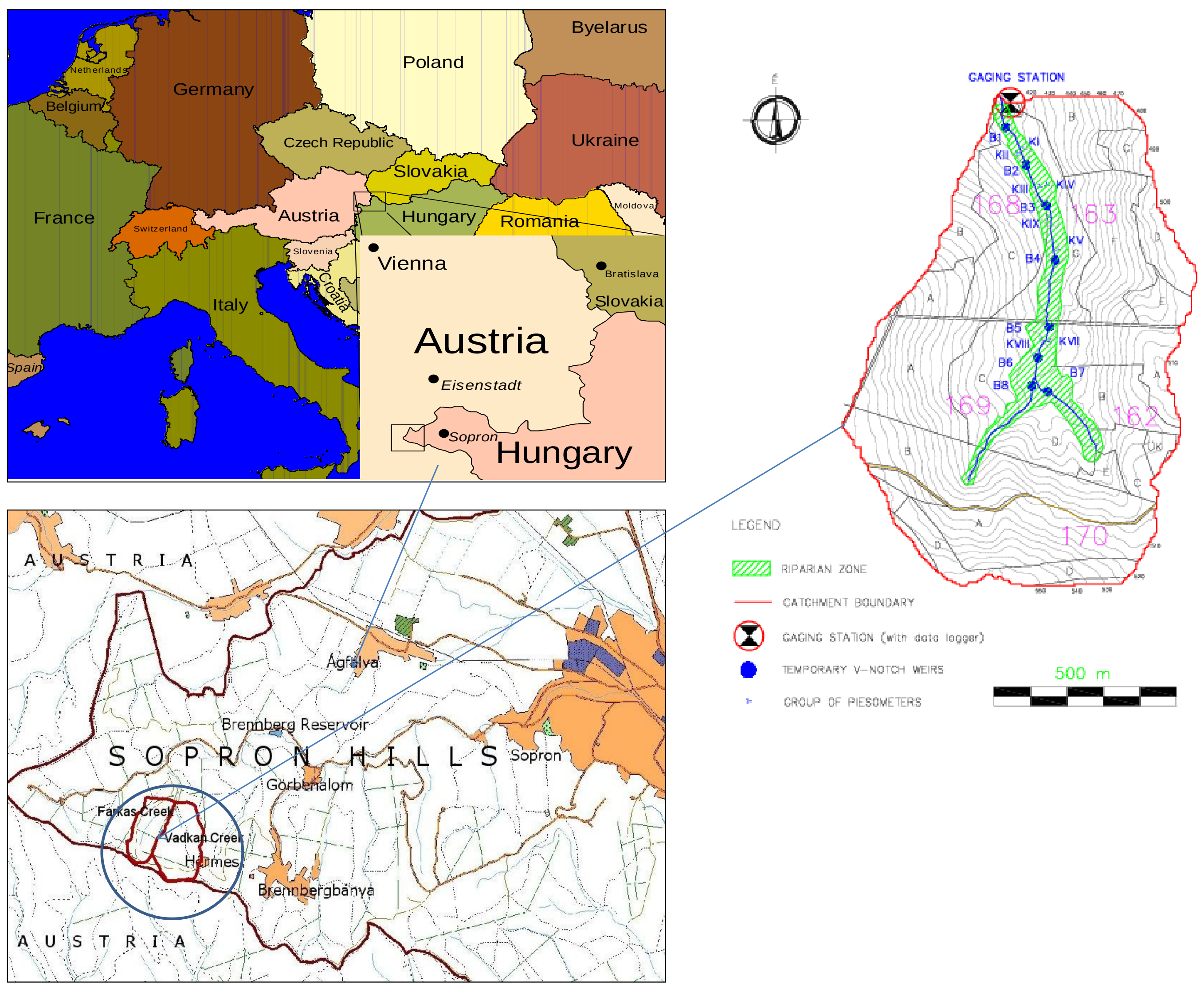
Abstract: Obtaining accurate evapotranspiration rates of riparian ecosystems is very important for natural protection tasks and water resources management. Diurnal patterns of stream baseflow (which can be detected only by high frequency streamflow rate measurements) incorporate useful information for the characterization of hydro-ecological systems. A new technique was developed to calculate evapotranspiration rates in the riparian zone from the stream-baseflow diurnal signal. This method utilizes the water balance equation and a linear reservoir model for the subdaily estimation of groundwater evapotranspiration. The calculations require only basic geometric characteristics of the riparian zone (length, width), but no soil hydraulics parameters. The method was successfully tested with a dataset of the Hidegvíz Valley experimental catchment, (Sopron Hills, Hungary) and verified by numerical model experiments. **Keywords:**, diel baseflow signal, riparian evapotranspiration, linear reservoir model

Study Area (Hidegvíz Valley experimental catchment)



Area: 0.92 km^2
Altitude: between 402 m ASL and 556 m ASL.
Geology, morphology: Tertiary fluvial sediment deposited on crystalline bedrock. Average slope 32 %, wide valley-bottom has 5 % inclination.
Climate: Mediterranean, continental and ocean currents. Total precipitation was 742.5 mm in the study period. (2005)
Vegetation: alder dominated forest in the riparian zone

Figure 1. Location of the forested experimental subcatchment (Vadkan Valley, Sopron Hills, West Hungary)

Measurements, Datasets, Diel Signal Characteristics

Diel signal

Maxima (rounded) in the morning,

Strong depletion before and around midday,

Minima in the middle of the afternoon,

Srong replenishment after minima,

Gently replenishment after midnight.

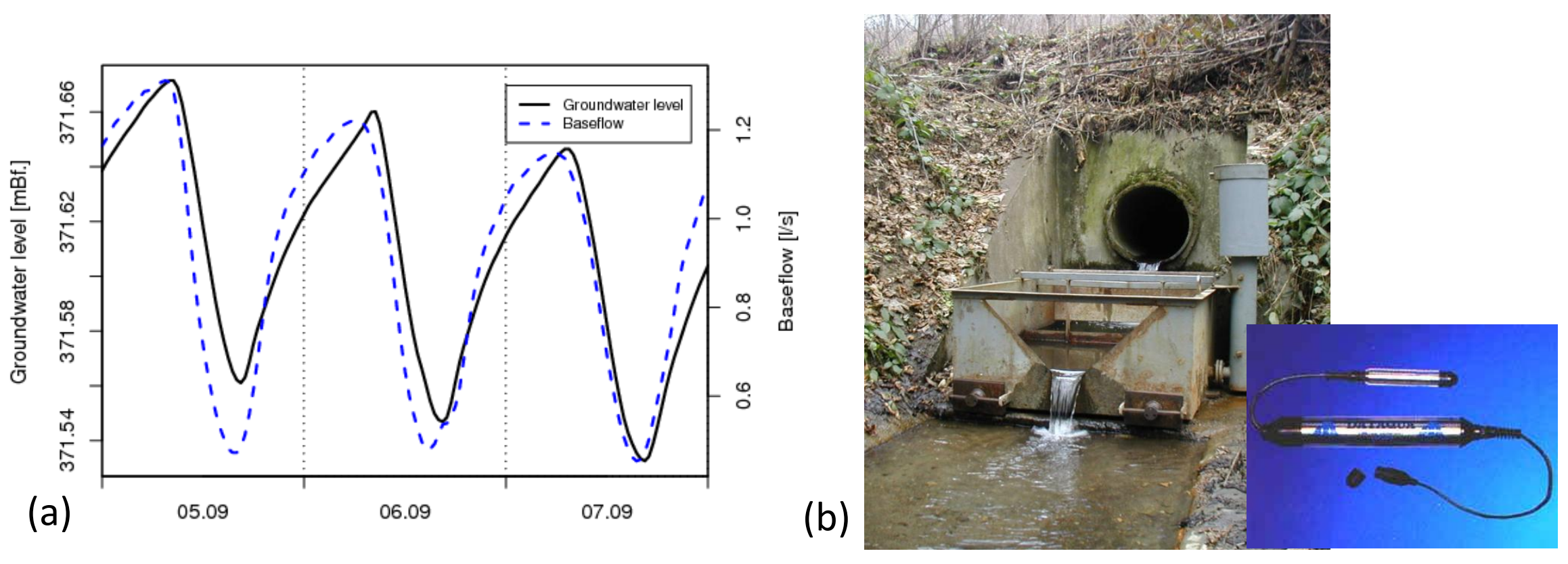


Figure 2. a, Diel fluctuation (a sample period), b, Gauging station and pressure transducer.

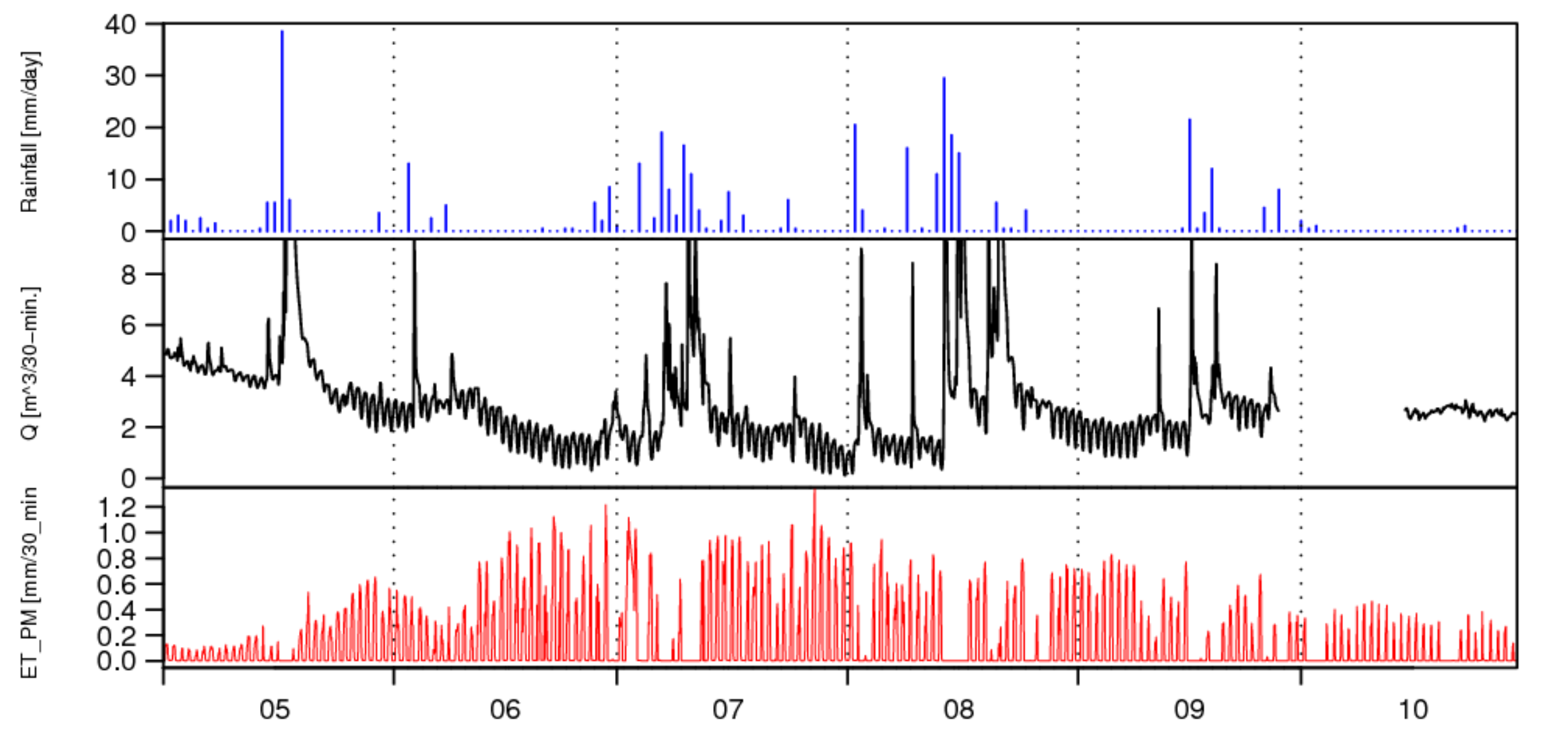


Figure 3. Measured daily rainfall, sub-daily streamflow and estimated Penman–Monteith ET (ET_PM) rates

Principle of New Method and Validation by Field Dataset

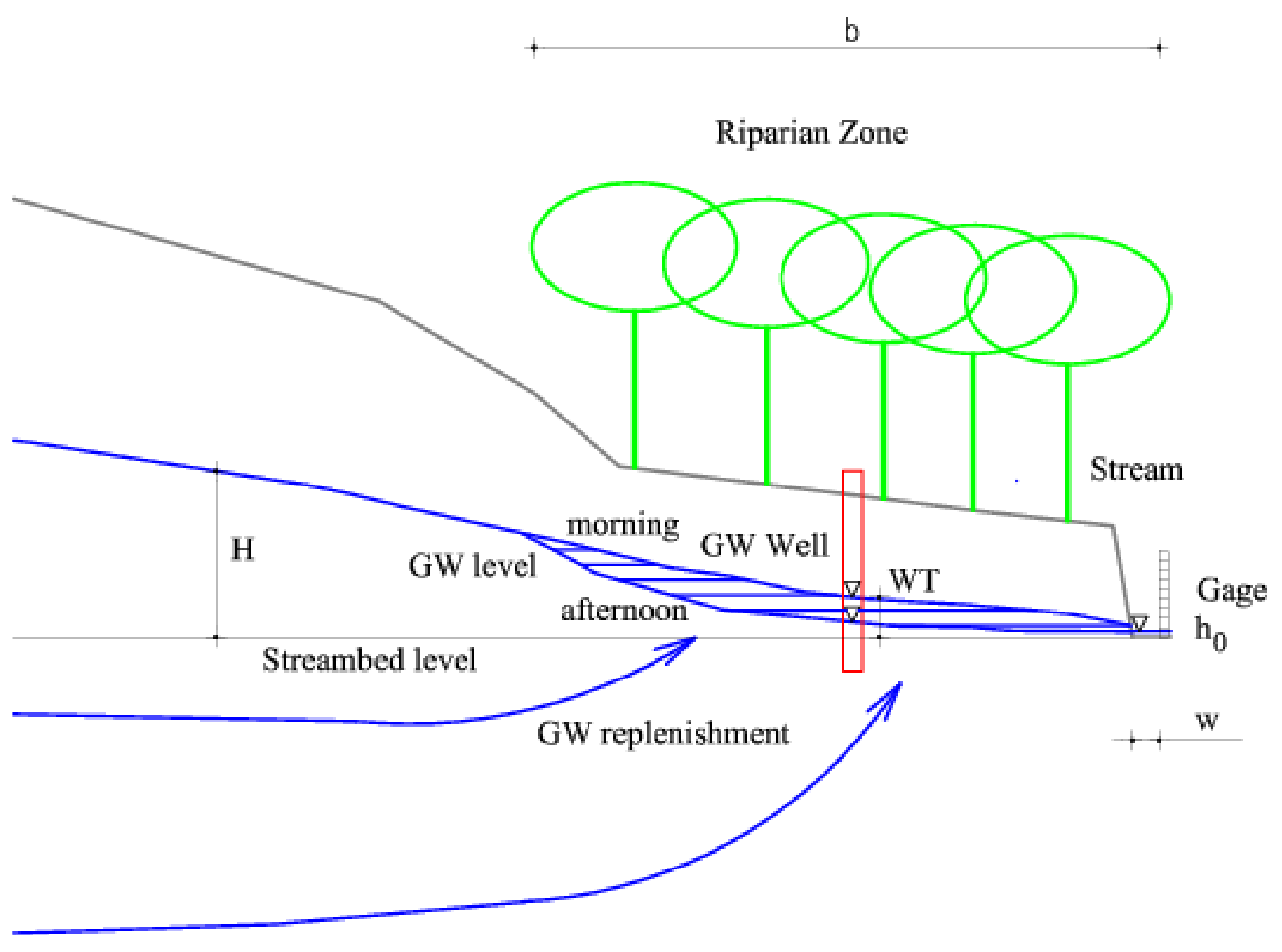


Figure 4. Schematic model of the riparian zone

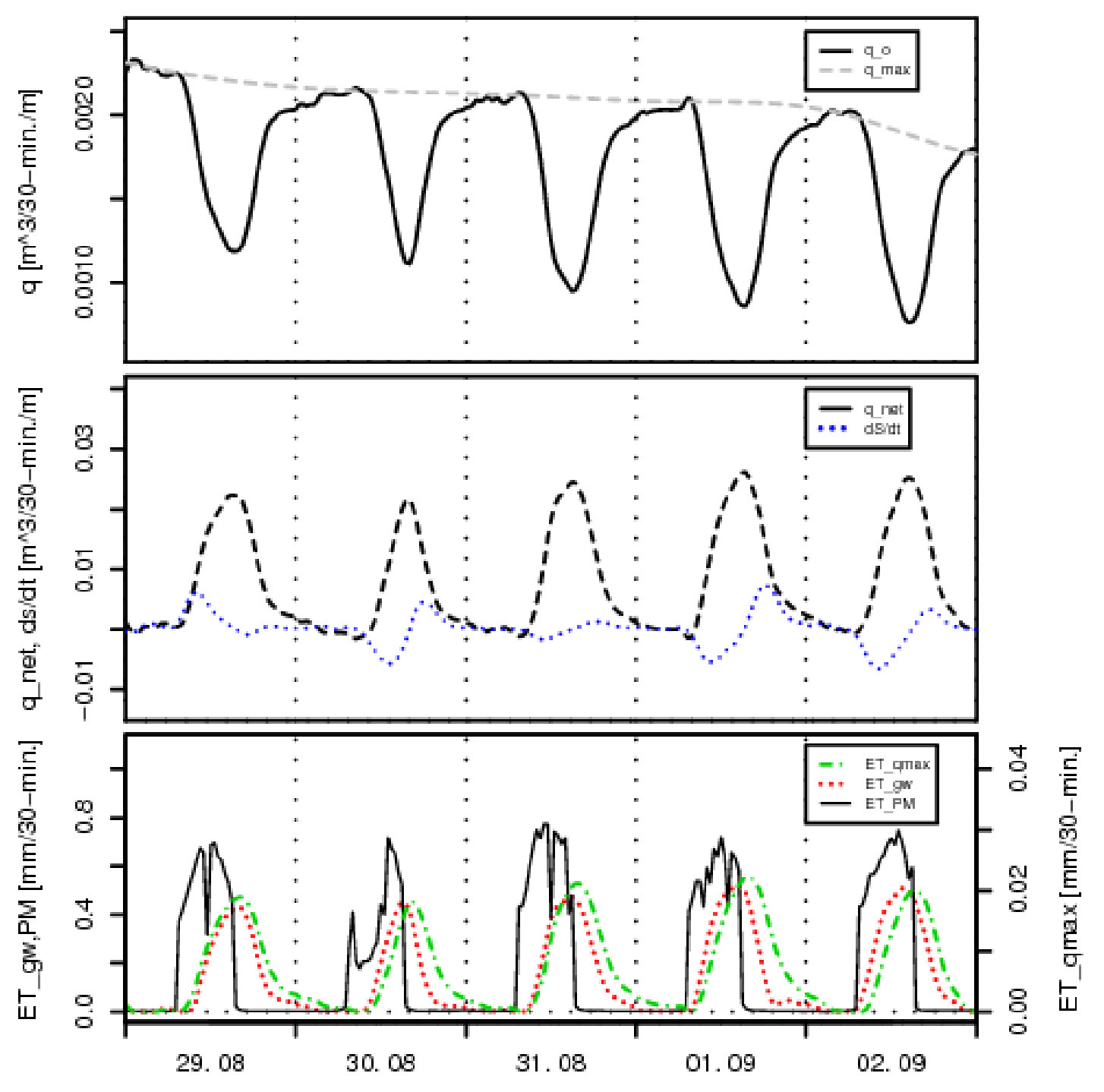


Figure 5. Daily mean ET rates by month of the original diel method (ET_qmax); the Penman–Monteith (ET_PM) method, as well as the upgraded White method (ET_rip) for the 2005 growing season.

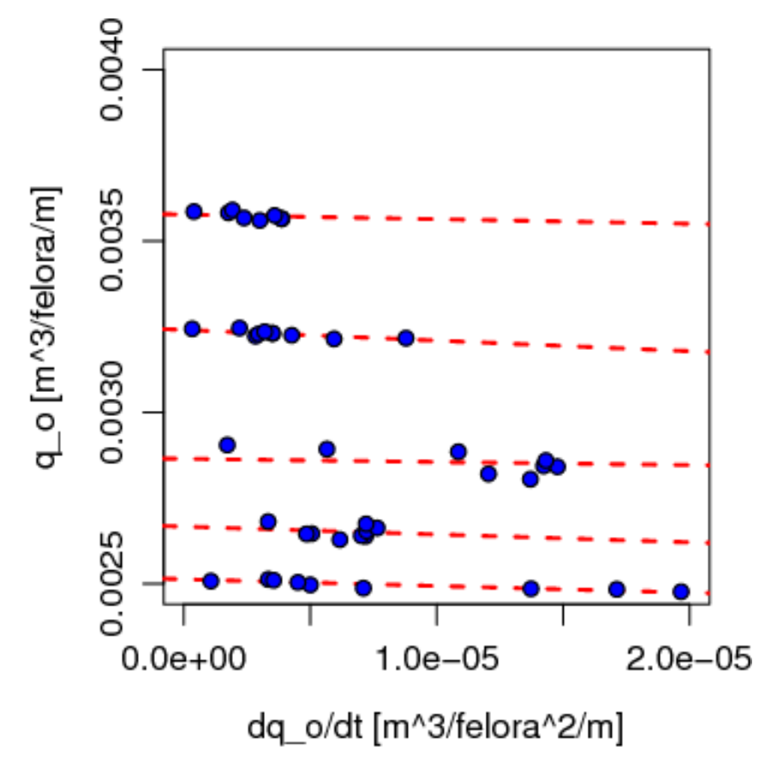


Figure 6. The dq0 / dt vs q0 values (dots) with the fitted first-order polynomials (one line per day) from the late-night hours

Groundwater (GW) replenishment rate (r)
r maximal – in the afternoon
r minimal– in the morning

Simplified Water Balance for rip zone

$$\frac{dS}{dt} = S_y(t,WT)\frac{dWT}{dt}\cdot A_{rip} = Q_{net} - ET\cdot A_{rip}$$

Diel GW and Baseflow signal
At maxima and minima dS / dt = 0,
dS / dt > 0 and Qnet > ET at rising limb,
dS / dt < 0 and Qnet < ET at falling limb.

Late night period Water Balance and Linear Reservoir model combination

$$\frac{dS_r}{dt} = Q_i - Q_o = Q_{net} \qquad Q_o = \frac{1}{T*}S_r \qquad T*\frac{dQ_o}{dt} = Q_i - Q_o$$

Combination of above equation and Darcy law in a linear form and making regression (Fig. 6) for late night periods

$$q_o = \frac{2\cdot k\cdot H}{\left(\frac{b}{w}+1\right)} - \frac{T*}{\left(\frac{b}{w}+1\right)}\frac{\partial q_o}{\partial t}$$

Equation for ET calculation (Figure 5.)

$$ET_{gw}\cdot 2b = q_{net} - T*\frac{\partial q_o}{\partial t} \approx 2\cdot k\cdot H - q_o\left(\frac{b}{w}+1\right) - T*\frac{\partial q_o}{\partial t}$$

Compairison with other methods (Fig. 7. 8. 9.)

Q max-Q (Figure 5.)

$$ET = (Q\max - Q)/A_{rip}$$

Penman-Monteith Ref. ET

$$L\cdot E = \frac{\Delta\cdot(R_0 - S) + \rho\cdot \mathrm{c_p}\cdot(\mathrm{E}-\mathrm{e})\cdot 1/\mathrm{r_a}}{\Delta + \gamma\cdot(1+\mathrm{r_c}/\mathrm{r_a})}$$

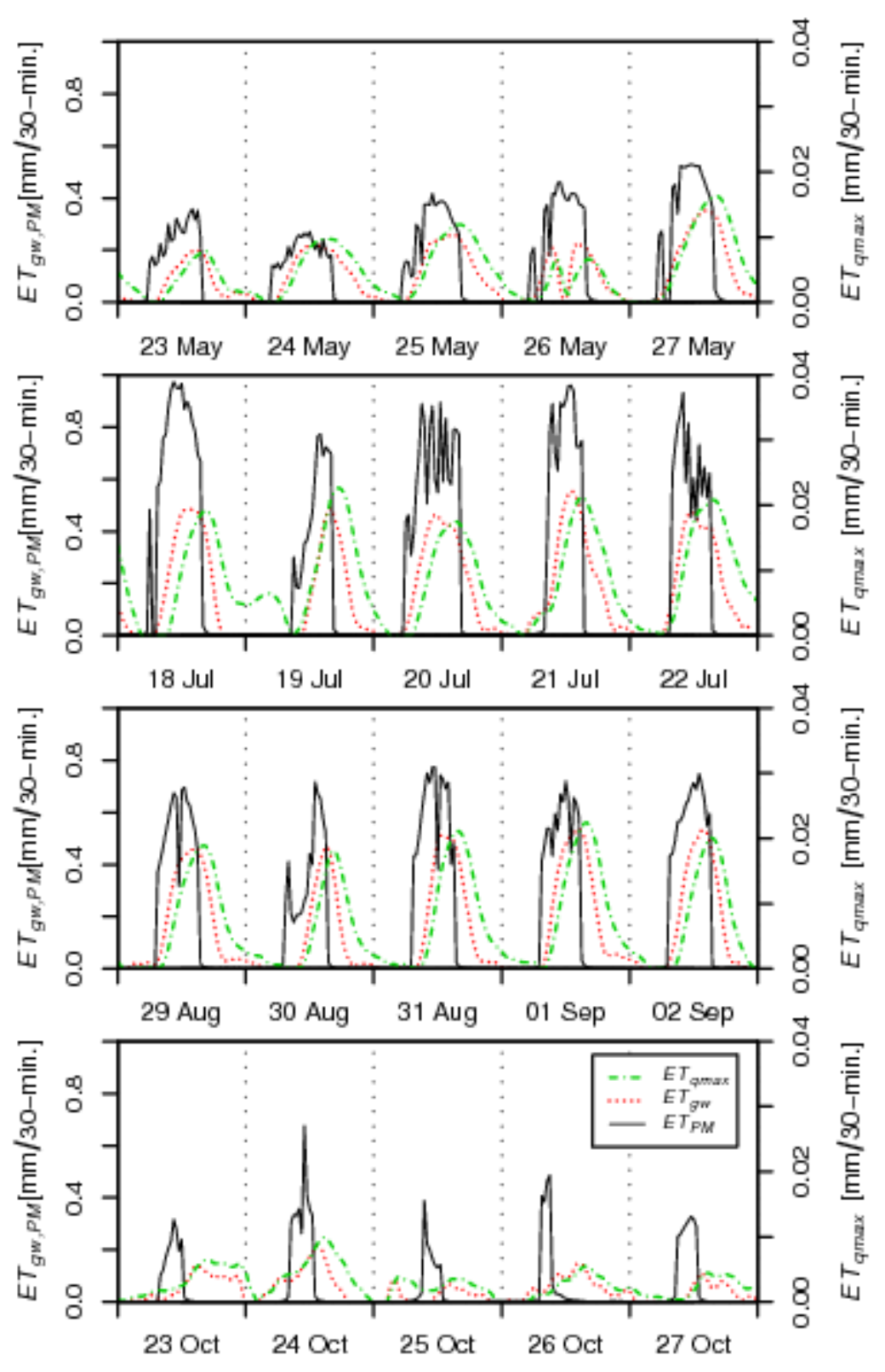


Figure7. Comparison of the present 30-min ET estimates (ETgw) with those of the Penman–Monteith (ETPM) and qmax (ETqmax) methods for four selected 5-day periods of the 2005 growing season.

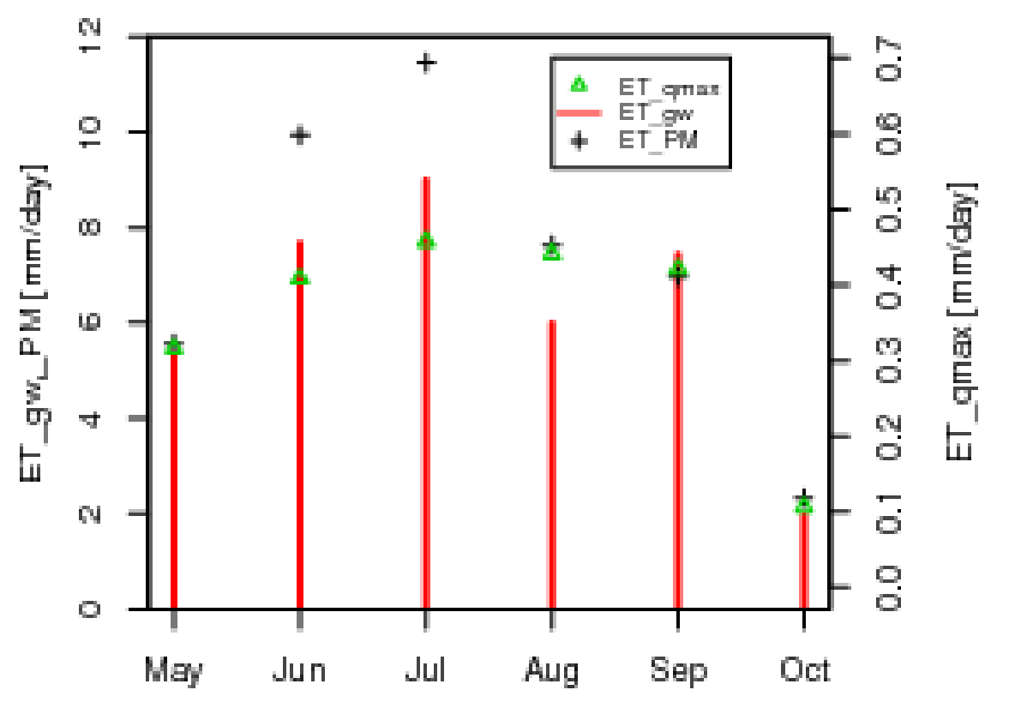


Figure 8. Monthly mean daily ET rates of the rainless periods by the different methods

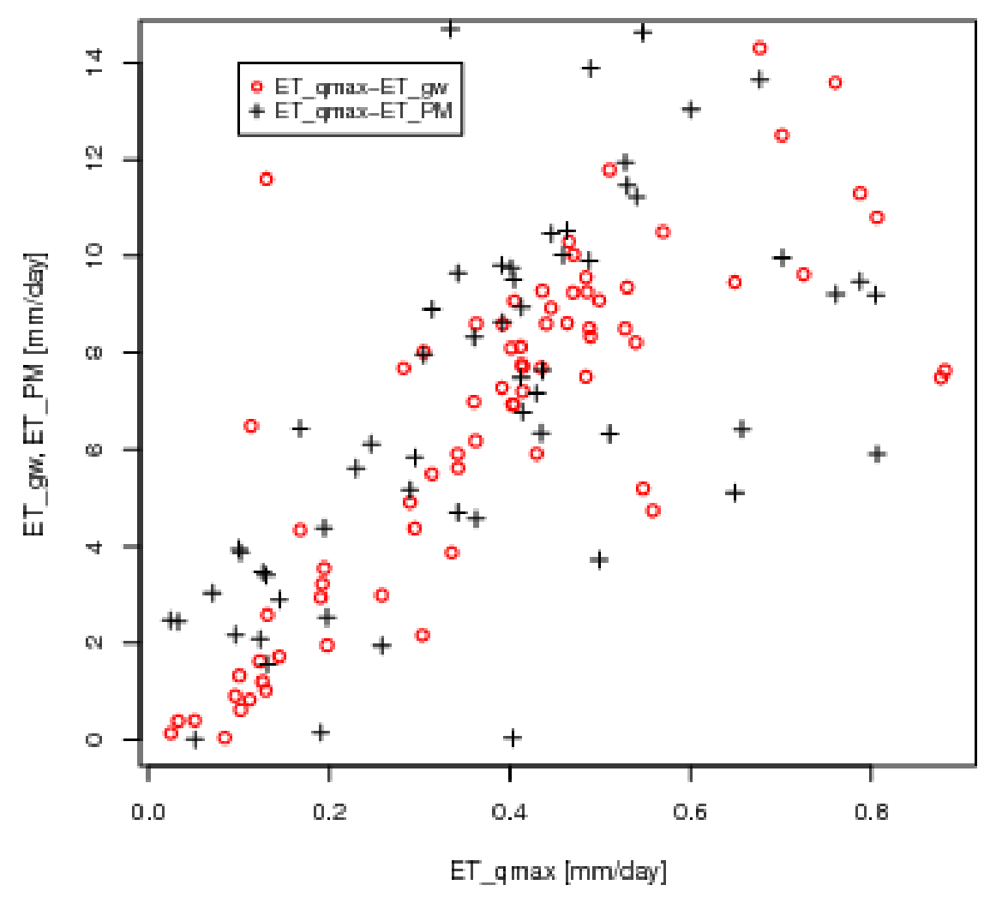


Figure 9. Comparison of daily ET rates of the rainless periods by the different methods

Validation by a Numerical Model (FEM)

Governing equation

$$\frac{\partial}{\partial x}\left(K(\Psi)\cdot\frac{\partial h}{\partial x}\right) + \frac{\partial}{\partial y}\left(K(\Psi)\cdot\frac{\partial h}{\partial y}\right) + s = m\cdot\chi\cdot\frac{\partial h}{\partial t}$$

where *K* [LT-1] is the hydraulic conductivity (a function of the pressure head, *Ψ*); *h* [L] is the hydraulic head; *m* is the slope of the water retention curve which becomes the coefficient of volume change in the saturated zone; *s* is the source/sink term which represent ET in this model; *γ* is the unit weight of water; and *x*, *y* [L] and *t* [T] represent the horizontal, vertical and temporal coordinates.

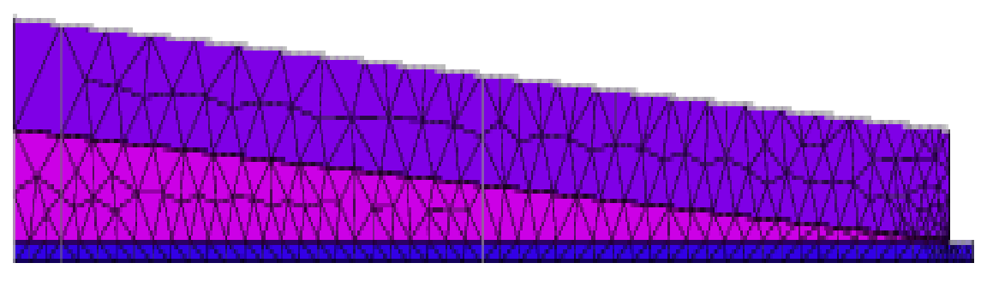


Figure 10. The model domain

Parametrisation
- Site specific characterisation of hydraulic parameters.
- 6 mm/day ET as a sin^2 (t) shape diel water uptake.
- Boundary conditions: constant heads at stream (0.05 m) and at background (1.0 m).
- 10 days long modelling period.

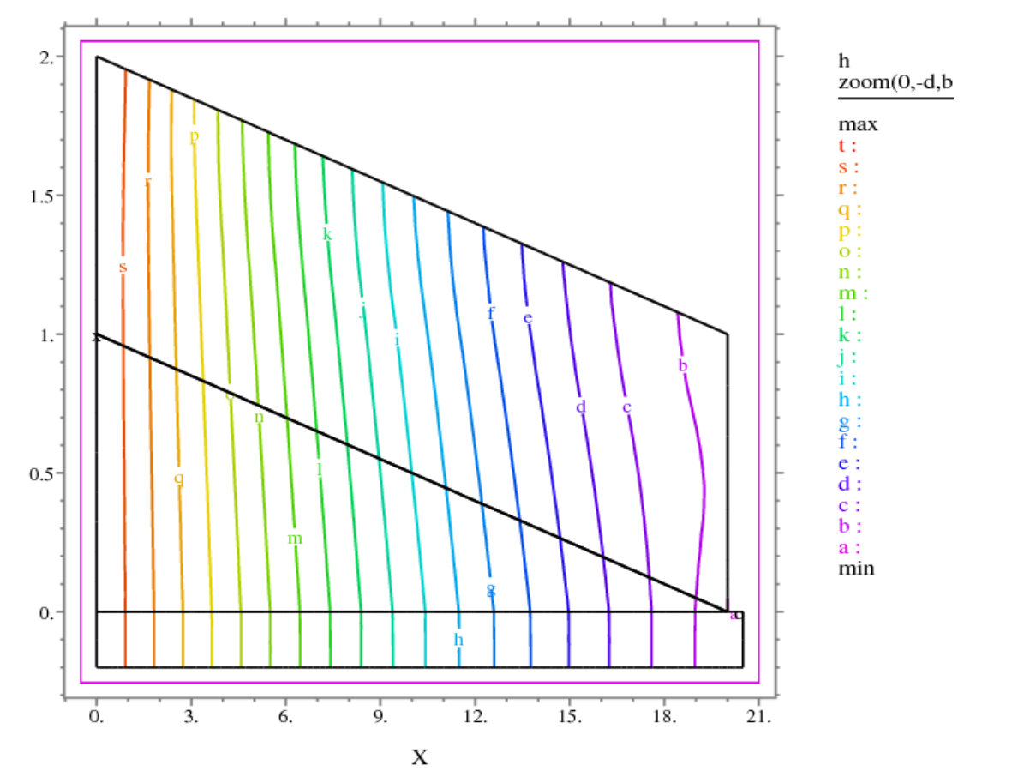


Figure 11. The calculated hydrauilc head distribution

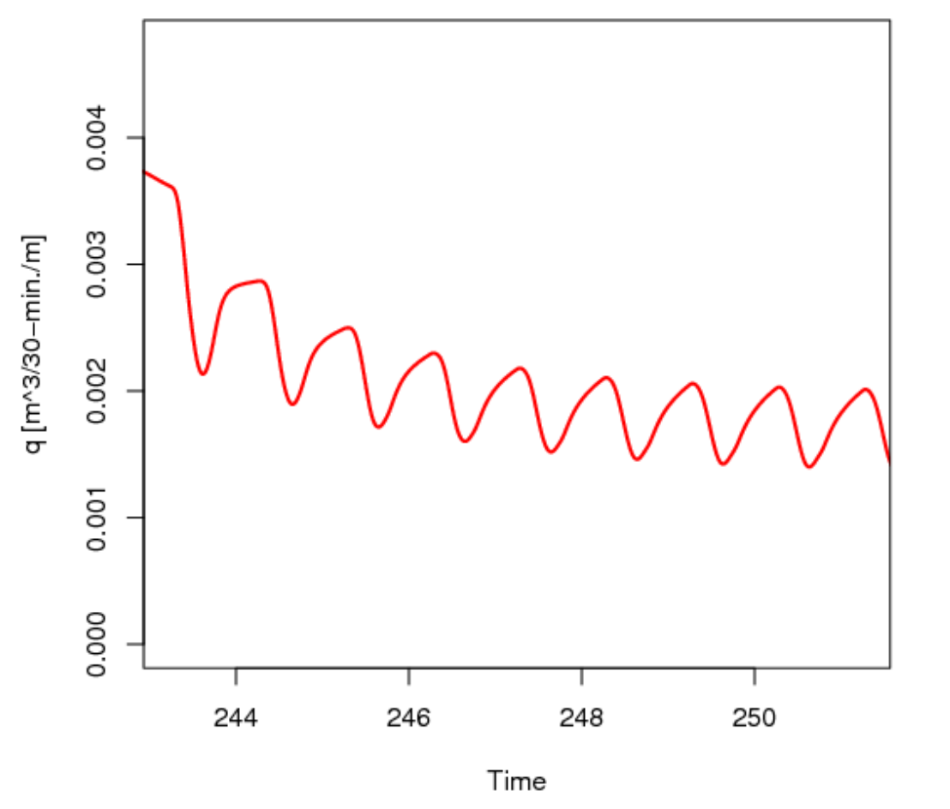


Figure 12. The synthetic diel baseflow signal calculated by the model

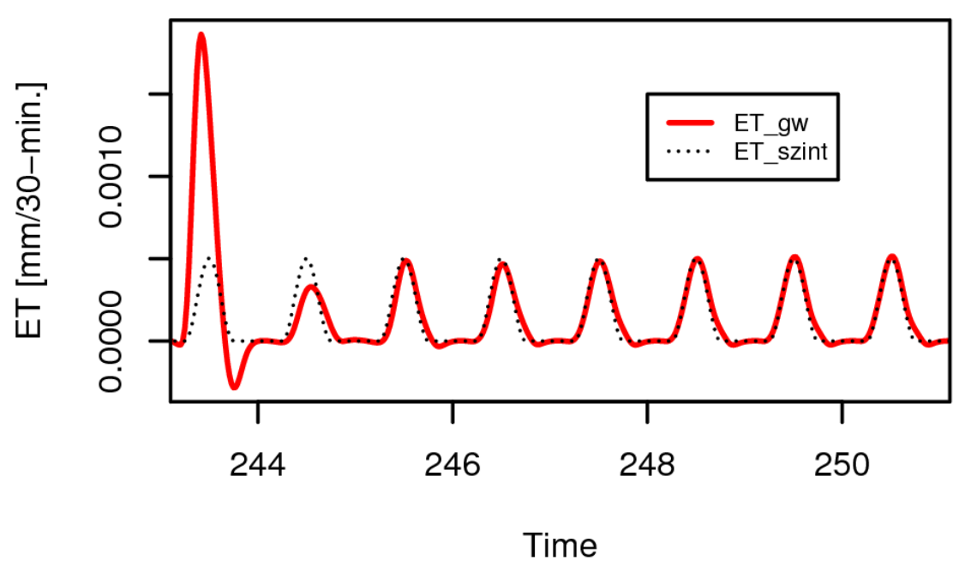


Figure 13. Comparison of ET calculated from synthetic dataset by the new method and ET used in the model as input.

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