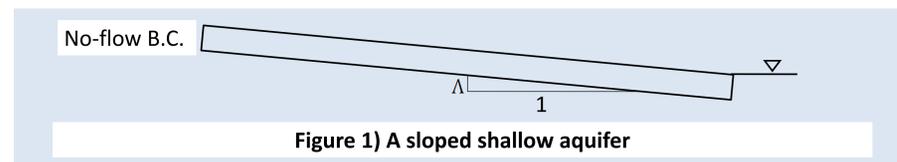


## INTRODUCTION

- Parameterization of soil water in linked atmosphere/land surface models must be simple and robust.
- A simple soil moisture parameterization scheme, WATDRAIN, was previously developed for shallow aquifers.
- A new scheme, based on more rigorous application of Richard's Equation, combines topography and soil parameters to develop a physical-based interflow scheme.
- The new scheme is evaluated by comparisons to numerical solutions of the Richards' equation
- The new scheme is proposed to address the deficiencies of WATDRAIN.

## METHODOLOGY

- A shallow aquifer with length  $L$  and slope  $\Delta$  is used to develop the solution (Figure 1). The seepage face is always saturated and the upper one has a no flow boundary condition (B.C.).



- The scheme uses a power expression as before, except the time surrogate,  $\epsilon(t)$ , is used in order to satisfy the boundary conditions.

$$\psi_g = \left( \frac{x}{x_s} \cdot \frac{t_c}{t} \right)^{\frac{-b}{2b+2}} \rightarrow \psi_g = \left( \frac{x + \epsilon}{x_s + \epsilon} \right)^{\frac{-b}{2b+2} \left( 1 - \frac{x}{x_s} \right)^2}$$

where  $\psi$  is the suction,  $x_s$  locates the saturated portion of the aquifer,  $\epsilon$  is a function of time, and  $b$  is a Clapp-Hornberger soil index.

- Flow from the aquifer is initially constant (blue zone – Figure 2) until a critical time  $t_c$  at which time capillary forces begin to have an effect. When this occurs,  $x_s$  equals  $L$  and  $t_c$  can be determined as:

$$t_c = \frac{\int_0^L \phi(1-s)}{k_s \Delta}$$

- The flow during the next stage after  $t_c$  (green zone – Figure 2) is initially driven by gravity forces. An increasing portion of the aquifer becomes inactive. Here the suction is sufficient to resist the elevation head. Thus, suction is given by:

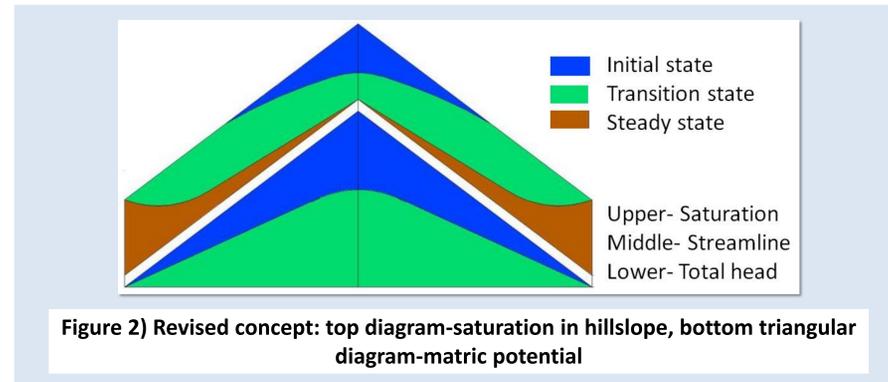
$$\psi_f = \psi_0 - \Delta(L - x)$$

- It can be argued that the hydraulic resistance is proportional to the square of suction. Therefore, using a parallel electric circuit analog :

$$\psi = - \left( \frac{w}{\psi_g^2} + \frac{1-w}{\psi_f^2} \right)^{-\frac{1}{2}}$$

$w$  is a weighting factor which has a simple quadratic relation with  $\epsilon$ .

## METHODOLOGY (Cont.)



- At a given time, the system is completely defined by  $\epsilon$  and  $w$ . These can be determined from the conditions at the  $x=0$  boundary. The no flow boundary condition gives:

$$\left. \frac{\partial \psi}{\partial x} \right|_{x=0} = \Delta$$

Applying the following mass balance at the  $x=0$  boundary

$$-\phi \frac{\partial s}{\partial \epsilon} \cdot \frac{\partial \epsilon}{\partial t} \Big|_{x=0} = k \frac{\partial^2 \psi}{\partial x^2} \Big|_{x=0}$$

yields both  $\epsilon(t)$  and  $w(t)$  and ultimately  $\Psi(x,t)$  and  $s(x,t)$ .

## TEST RESULTS

- Richards' equation is the governing equation for water flow in variably saturated soil, and here used as numerical "truth" to which the proposed solution is compared.

$$\eta \frac{\partial \psi}{\partial t} = \frac{\partial}{\partial z} \left( K \frac{\partial \psi}{\partial z} + K \right)$$

where  $\eta$  is the specific storage. The numerical implementation has been validated against published simulation results.

- The analytical solution is tested by using a 400 m long aquifer, with slope of 0.01. The soil properties are defined by Clapp-Hornberger parameters for sand and for silt at opposite corners of the SCS soil triangle

- The differences between the analytical and numerical solutions are minor. The bulk saturation differences are less than 0.005 percent absolute.

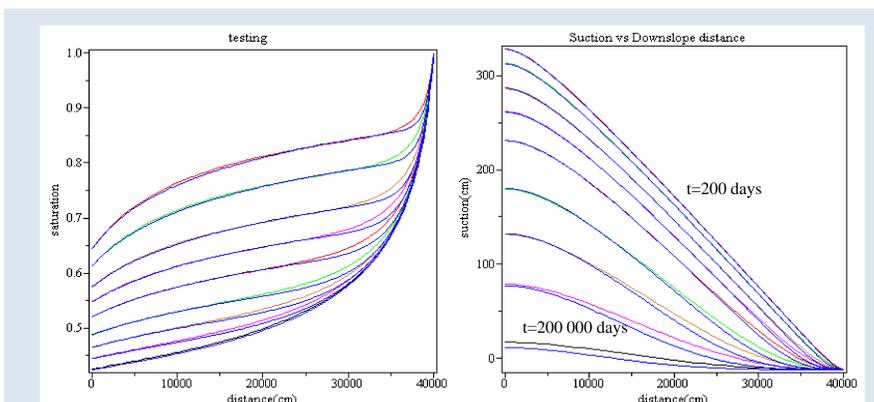


Figure 3) Soil profiles for sand at variable time (Left: saturation; Right: total potential) Blue- numerical solution; Color-analytical solution

## TESTING RESULTS (Cont.)

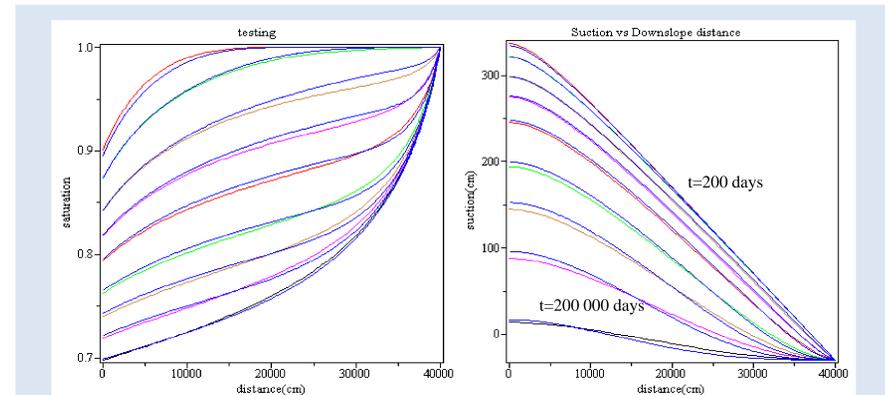


Figure 4) Soil profiles for silt at variable time (Left: saturation; Right: total potential) Blue- numerical solution; Color-analytical solution

## BULK SATURATION

Bulk saturation for the old and new methods is compared in Figure 5. The new method is expected to generate much shallower and prolonged recession curves than MESH currently produces. The blue line represents both the analytical and numerical solutions.

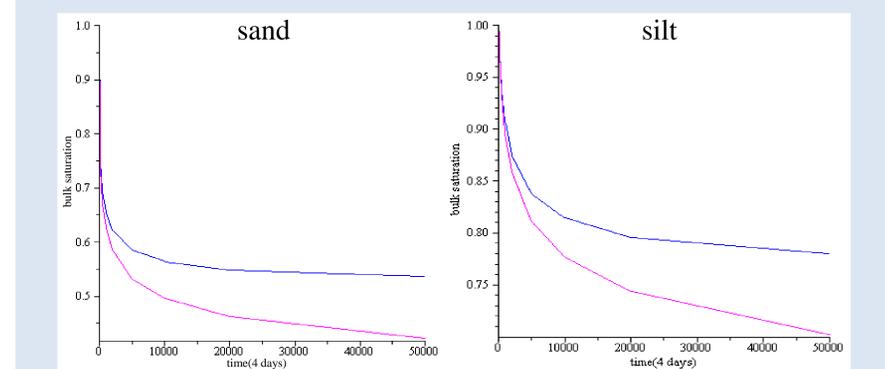


Figure 5) Bulk saturation without suction (pink), with suction (blue).

## CONCLUSION

- The new analytical scheme was evaluated against the numerical solution of the RE and is shown capable of reproducing the saturation and suction distributions for widely different soil types.
- The solution uses only Clapp-Hornberger parameters, slope and slope length all of which are available in MESH. Furthermore, the implementation algorithm will be the same as WATDRAIN.
- The solution is for a streamline which can be differential element for any soil layer with either constant or variable properties.
- The procedures are general, therefore suitable for CRHM or other distributed hydrological models as well as land surface schemes.

## REFERENCES

- Dingman, S.L., Physical Hydrology, Prentice-Hall, Inc., Upper Saddle River, New Jersey 07458, 2002.
- R. B. Clapp and G. M. Hornberger. Empirical equations for some soil hydraulic properties. Water Resources Research, 14:601–604, 1978.