# VADOSE Tutorial

# (Case History: Wilson Column)

## 1 Introduction

The example illustrates how VADOSE can be used to model actual evaporation from soil. Actual evaporation rates are calculated based on the relative humidity within the soil, which is controlled by temperature and matric suction, and the climate conditions as defined by the boundary condition. The simulated results are compared to measurements from a laboratory experiment (Wilson et al., 1993).

## 2 Feature highlights

GeoStudio feature highlights include:

- Verification of formulation by comparison with a case history
- The use of surface layers
- Water balance graphing

## 3 Numerical Model

Wilson (1990) carried out a laboratory experiment involving the evaporation of water from a column of sandy soil that was situated within a climate controlled environmental chamber (Figure 1). The soil column was weighed frequently to determine the actual evaporation rates and compared with the evaporative rates from a container of free water.

The numerical representation of the laboratory experiment comprises a single conventional region with an increased mesh density in the vertical direction (Figure 2). A surface region was drawn on top of the conventional region to facilitate the application of a climate boundary condition. The climate boundary condition represents the conditions within the environmental chamber.

The initial conditions for the temperatures and pore-water pressures were obtain by means of an activation temperature (in the Material Model definition) and by drawing an initial water table, respectively.

The climate data definition – which is associated with a climate boundary condition – uses the measured potential evaporation rates as the Energy Data Source. The remaining defined inputs include the temperature and relative humidity within the chamber.

The simulated duration of 40 days was completed in 40 linear steps of 1 day. Adaptive time stepping was also used to automatically alter the size of the increment; that is, generate sub-steps during when large changes in the primary variables were occurring.

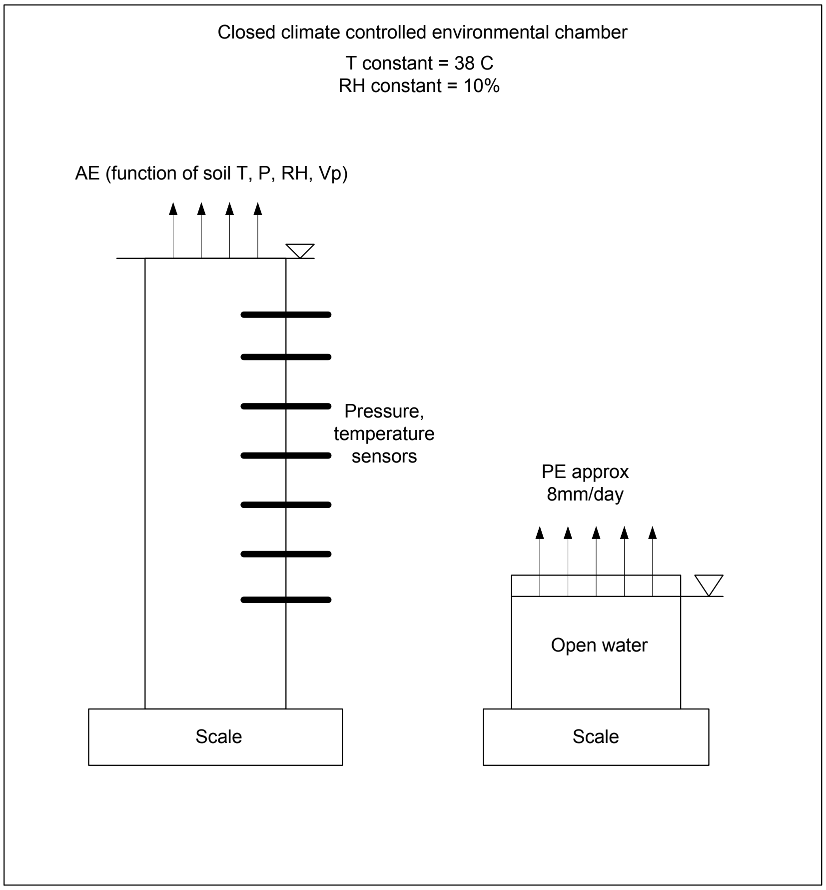

**Figure 1.  Schematic of the laboratory experiment.**

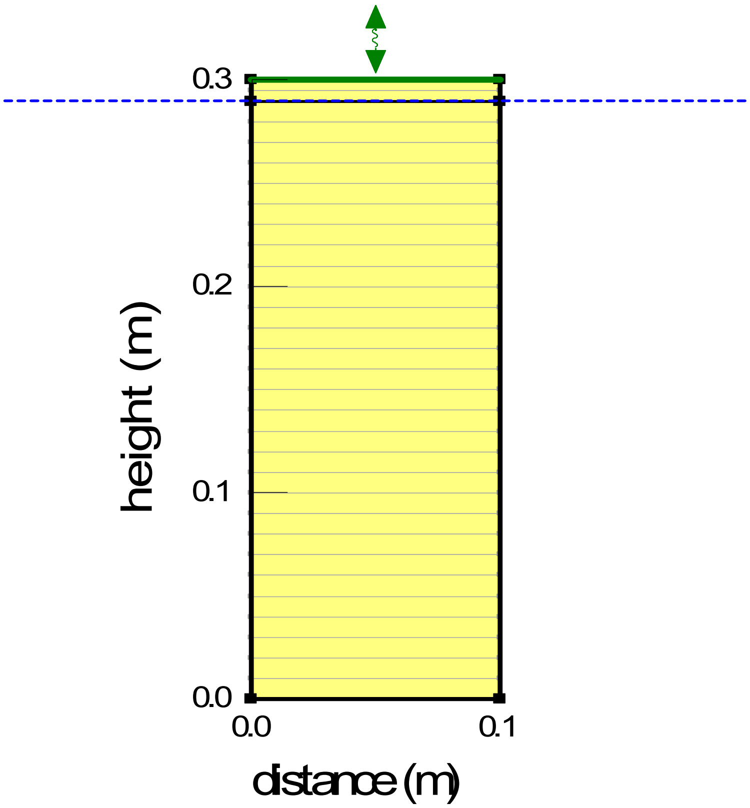

**Figure 2. Finite element domain and climate boundary condition.**

### *3.1 Material properties*

Both hydraulic and thermal material properties are required to solve the coupled heat and mass transfer equations. The material properties used in this example are based on laboratory measurements. Figure 3 shows the hydraulic and volumetric water content functions. The water content function has been curve fit using the Fredlund and Xing technique. A simplified thermal model was used to represent the sand because the temperature within the chamber was maintained at 38 degrees Celsius (KeyIn | Materials).

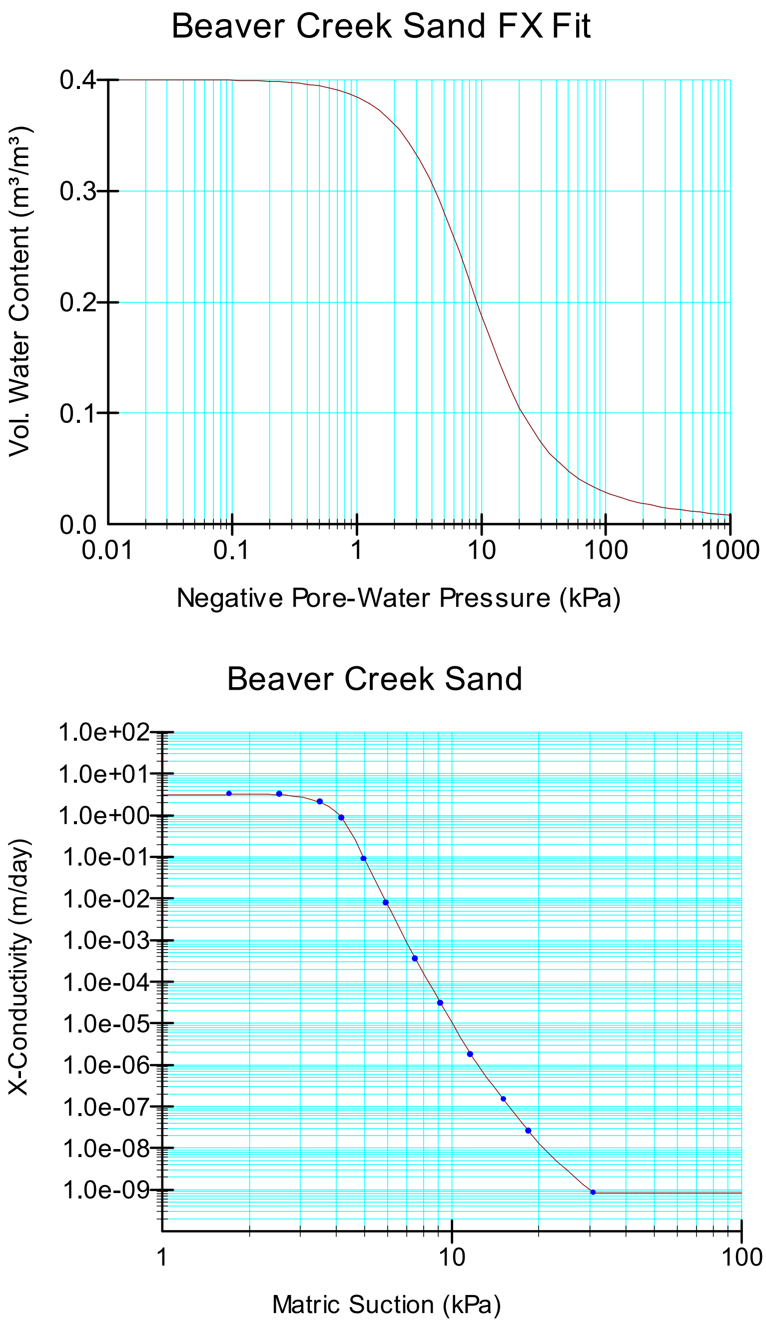

**Figure 3. Volumetric water content and hydraulic conductivity functions of the Beaver Creek Sand.**

## 4 Discussion of results

Figure 4 shows the measured potential and actual evaporation rates (Wilson et al., 1993). Figure 5 shows the simulated actual evaporation (AE) as compared to the input potential evaporation (PE), which compares well at all times to the measured values. Figure 6 shows the pore-water pressure at the top nodes as a function of time. The AE matches the PE at early time when water is freely available near the surface of the column. The matric suction at the ground surface starts to increase after day 4, which results in a rapid reduction in the evaporative flux. Wilson et al. (1993) describes the physical processes that are responsible for the decrease in the evaporative fluxes.

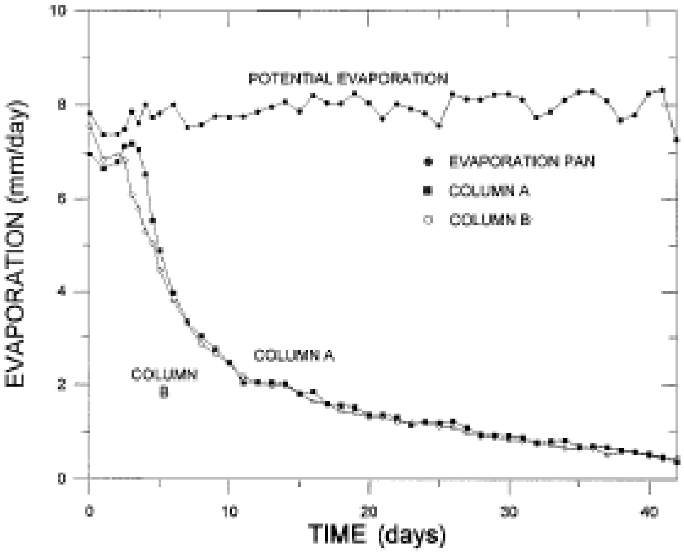

**Figure 4. Measured potential and actual evaporation rates (Wilson et al., 1993).**

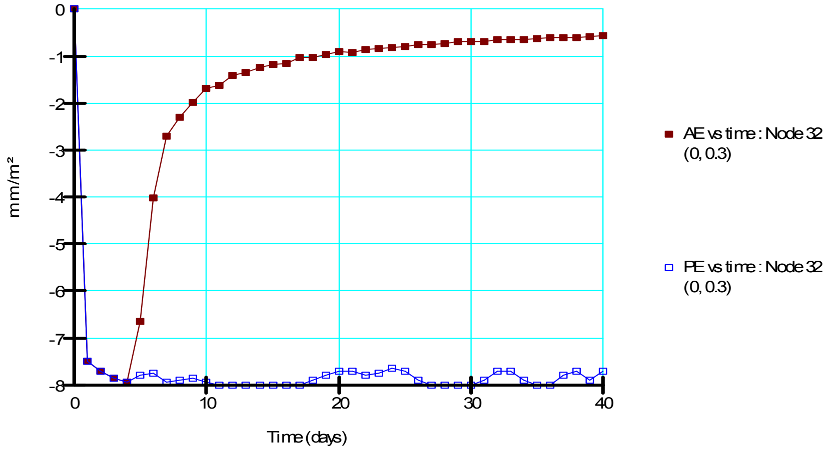

**Figure 5. Simulated actual evaporation compared with input potential evaporation.**

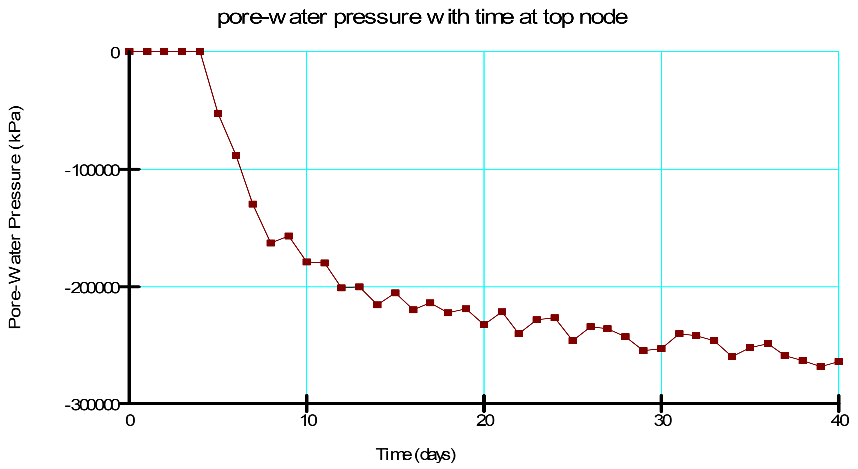

**Figure 6. Pore-water pressure versus time at the top nodes.**

Figure 7 shows the key water balance data. The cumulative surface evaporation volume is essentially equal to the cumulative change in water storage within the entire domain, resulting in a negligible water balance error.

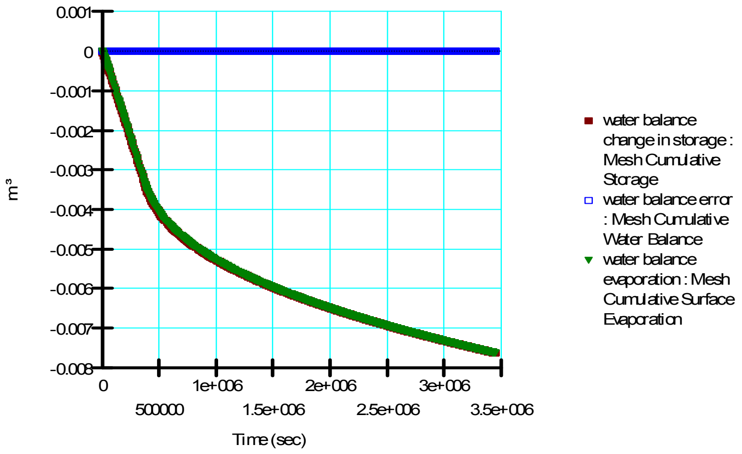

**Figure 7. Water balance data.**

VADOSE allows graphs to be generated for Surface Region nodes and Surface Region Base Layers. This graphing functionality permits determination of flow volumes across a certain depth beneath the ground surface (as defined by the Surface Region Base Layers). Figure 8 shows the cumulative volume of water that moved upwards (positive values) past the base of the surface region. The cumulative volume past the Base of Layer 1 is slightly less than that past the ground surface, indicating that the surface region dried out more than the rest of the column. Graphs of this type could, for example, be used to determine net percolation volumes past the base of individual layers within a store and release cover.

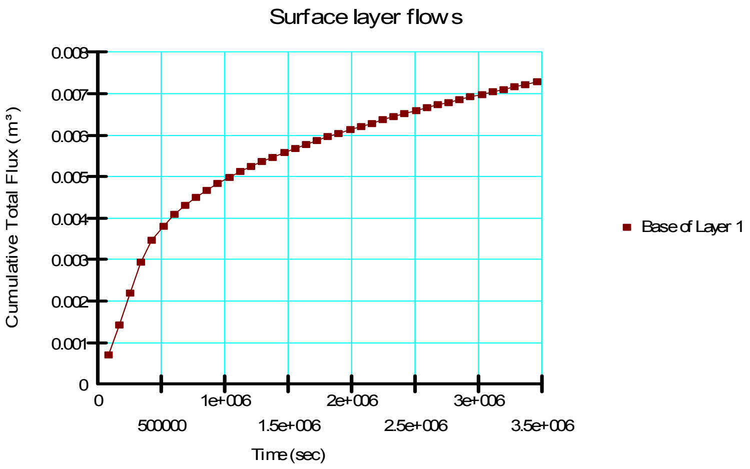

**Figure 8. Cumulative volume passing the base of the surface region.**

## 5 Summary

VADOSE/W calculates actual evaporation rates at the ground surface based on both the soil and climate conditions. The column was placed in a constant climatic condition; consequently, the decrease in the evaporative rate was controlled entirely by the reduced availability of water at the ground surface. Wilson et al. (1993) provides a detailed description of the physical processes that are operating within the column and summarize the physics by which these processes are described.

## 6 References

Wilson, G.W. 1990. Soil evaporative fluxes for geotechnical engineering problems. Ph.D. dissertation. University of Saskatchewan, Saskatoon, Canada.

Wilson, G.W., Fredlund, D.G., and Barbour, S.L. 1993. Coupled soil-atmosphere modeling for soil evaporation. Canadian Geotechnical Journal. Volume 31, pg. 151 – 161.