VADOSE/W Basic Edition

Introduction

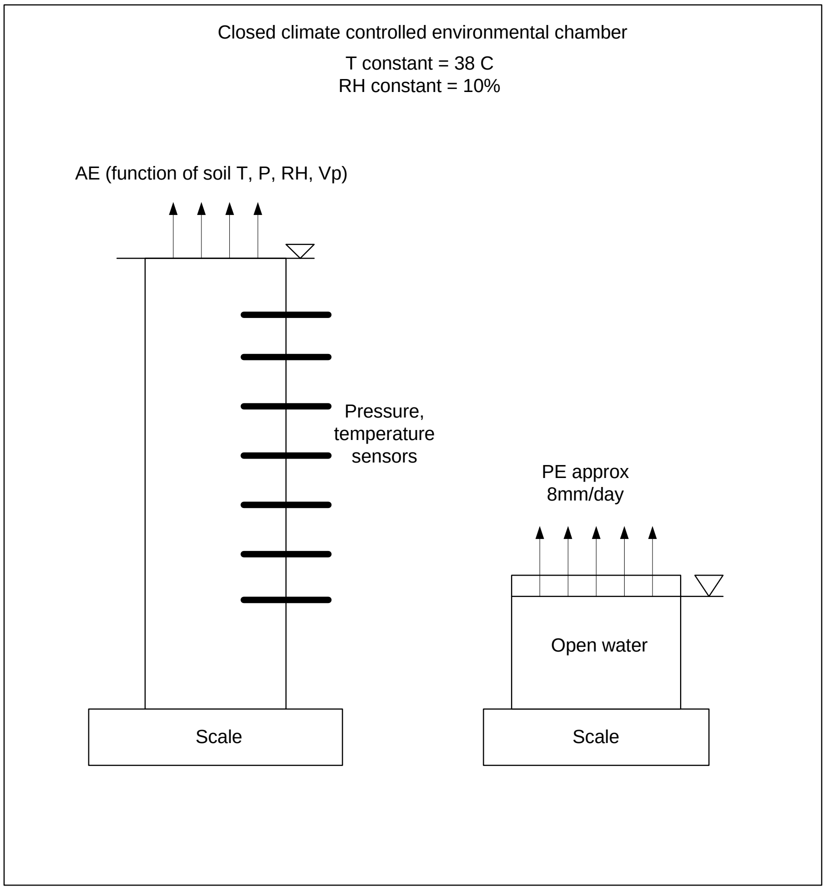
Landfill and mine waste cap design has typically been based on regulated design criteria, simple water balance modeling (e.g., HELP model), or semi-rigorous finite element or finite difference modeling (e.g., UNSAT-H, HYDRUS). These latter two models are rigorous from a seepage solution standpoint but are limited in their ability to accurately predict the climate-ground interactions. VADOSE/W has been commercially available for seven years in a two-dimensional (2D) formulation but is now available in a one-dimensional (1D) "Basic Edition" formulation at a significantly reduced cost. VADOSE/W is unique in its formulation in that actual evaporation from a ground surface is based on the stress state in the soil; in particular the temperature, relative humidity and matric suction at the soil–climate interface. This example discusses some of the functionality of VADOSE/W Basic edition as well as how the unique formulation was verified. For more information about VADOSE/W, please contact sales@geo-slope.com.

Geometry and boundary conditions

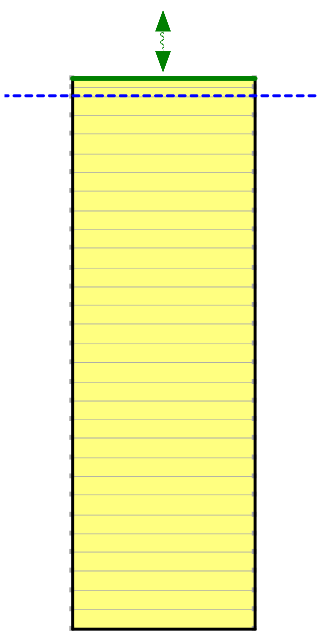
As part of his PhD study, Dr. Ward Wilson carried out a laboratory experiment in which he evaporated water from a sandy soil surface and an open container inside an environmental chamber where climate conditions were controlled. The water from the open container was weighed each day so that the change in weight could be used to calculate the potential evaporation rate in the chamber. A column of sandy soil at saturated conditions was place beside the open container and it was weighed as well, in order to know the rate of actual evaporation from the soil. The experimental configuration is shown below.

The numerical model to simulate this experiment is quite simple and consists of a column of 30 elements with a total height of 30 cm as shown below. The top of the column has a climate boundary condition applied. The initial temperature of the soil was specified as a material activation property, and a water table was drawn to specify initial pressures in the sample. The model was solved for 40 days of climate data, where the climate data represented the potential evaporation, temperature and relative humidity in the controlled chamber.

The time stepping sequence in a VADOSE/W model is important because there can be very steep drying fronts with high gradients. The model was set up to solve 40 one day steps; however, an adaptive time stepping scheme was enabled to insert additional steps as necessary, so that the model converged to a reasonable solution. In this case, the adaptive steps were allowed to vary between 0.001 and 1 day in length. Control of the adaptive time stepping was set to allow a maximum change in Head of 5% between any two time steps. For more important information on time stepping, please refer to various discussions in the VADOSE/W Engineering Methodology Book.



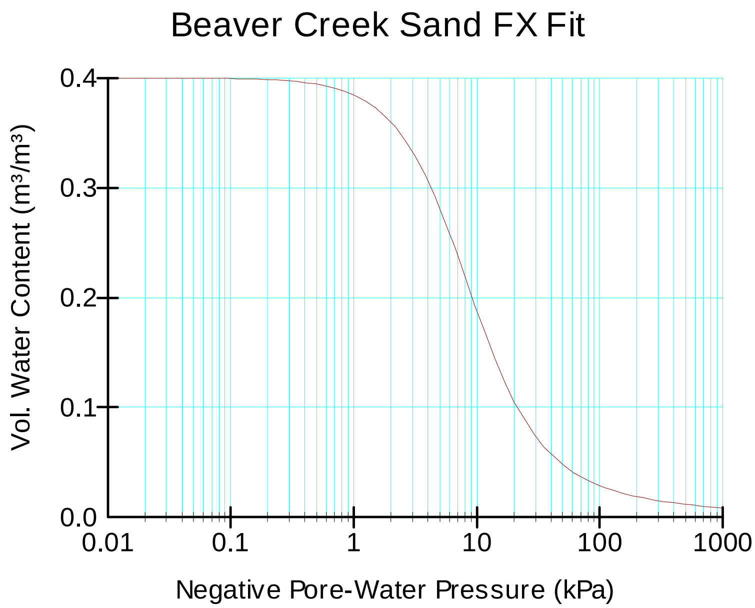
1 Soil column and open water pan set up inside environmental chamber



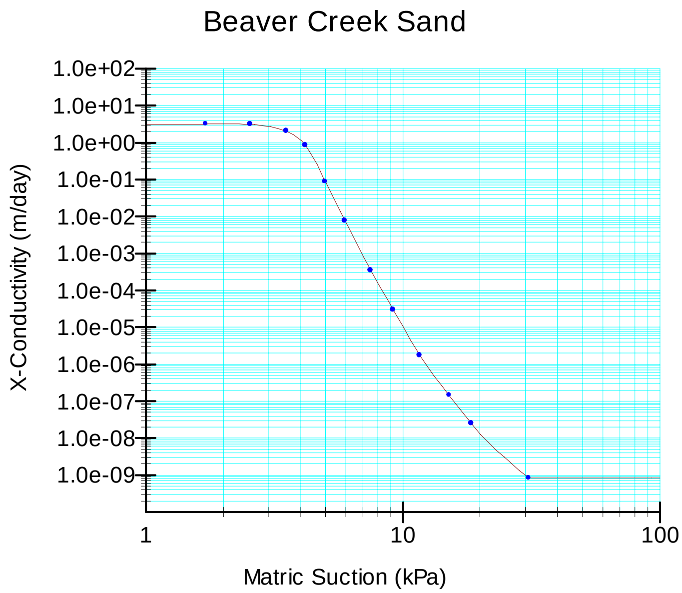
2 30cm one dimensional VADOSE/W Basic model

Material properties

The material properties used in this example are based on those measured by Dr. Wilson. Both hydraulic and thermal properties are required in a VADOSE/W analysis because the model solves for coupled heat and mass transfer. Since the temperature in the chamber was fixed at 38 degrees, a simplified thermal model was used in the analysis. A summary of the properties for the Beaver Creek sand are shown below. The water content function has been fit with Fredlund and Xing parameters in this case.

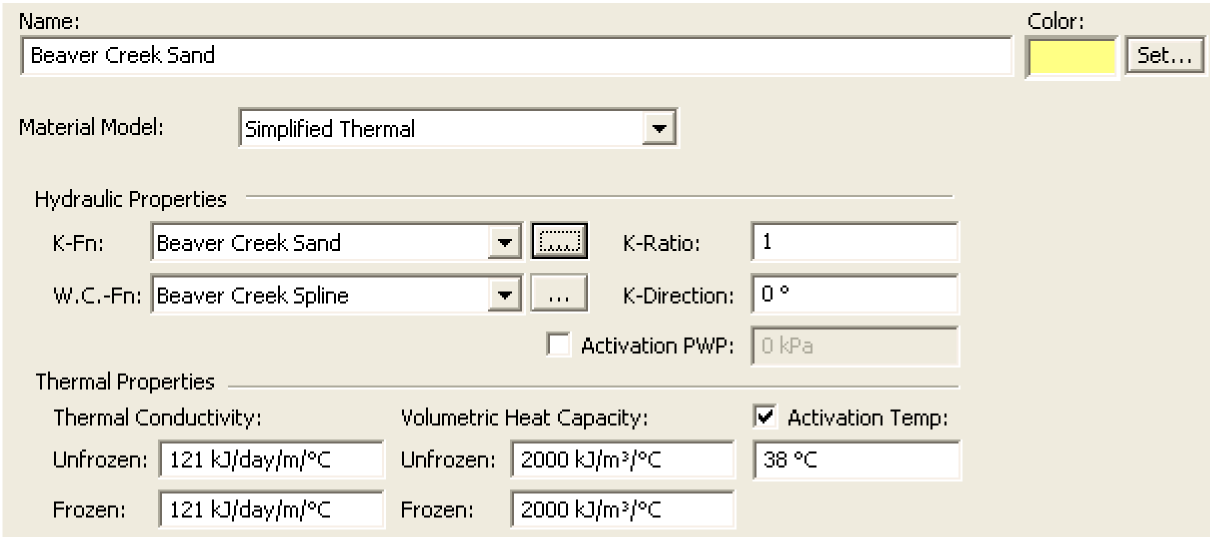


3 Volumetric water content function



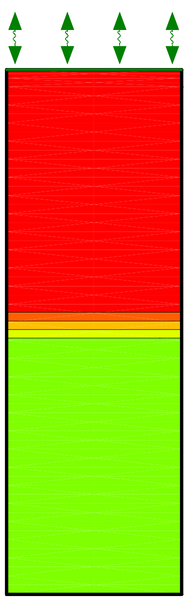
4 Hydraulic conductivity function

A summary of model properties as well as thermal input is given below.



Discussion of results

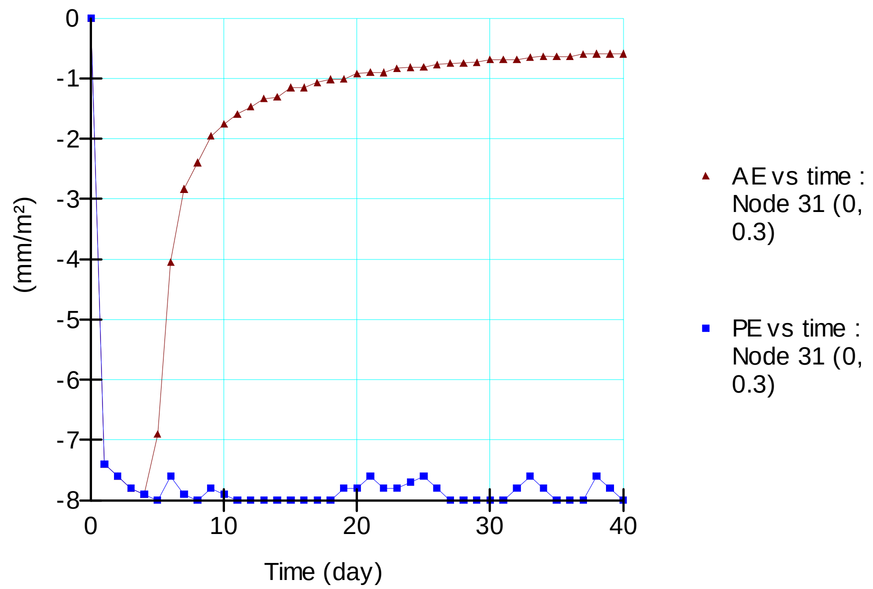
VADOSE/W Basic edition has all the contouring and post-processing capability of the full edition. The following is a contour of water content at the end of the model.



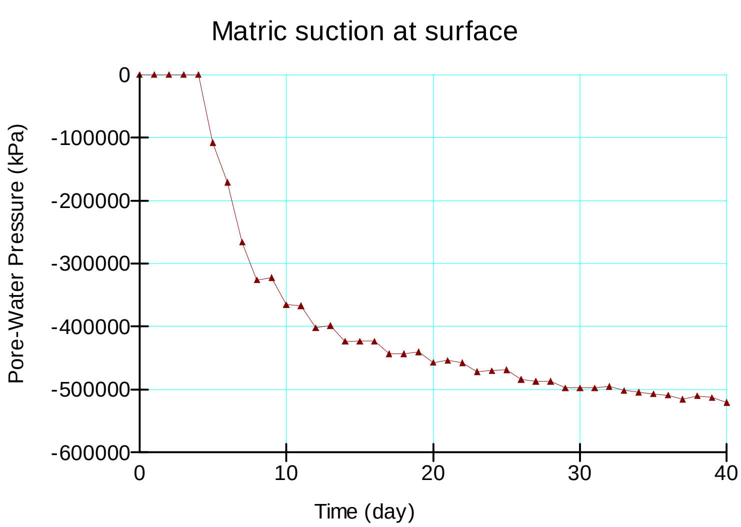
5 Water content profiles showing sharp wet/dry contact

Graphing in VADOSE/W Basic edition is very important as it can help to verify the climate input, and to consider the results, both the numerical reliability and engineering interpretation.

The first image below shows the applied potential evaporation as well as the computed actual evaporation from the surface of the soil. The potential evaporation matches that measured in the laboratory, while the actual evaporation is a function of climate data and soil conditions. You can see, for the first four days, the PE (blue) and AE (brown) match. This is because the soil surface is near saturation so the ability of the soil to give up water to the climate is not restricted. However, after about day 4, the matric suction at the ground surface starts to increase, and this results in the climate not being able to pull out water to its full potential rate. The actual evaporation shuts down relative to the potential rate.

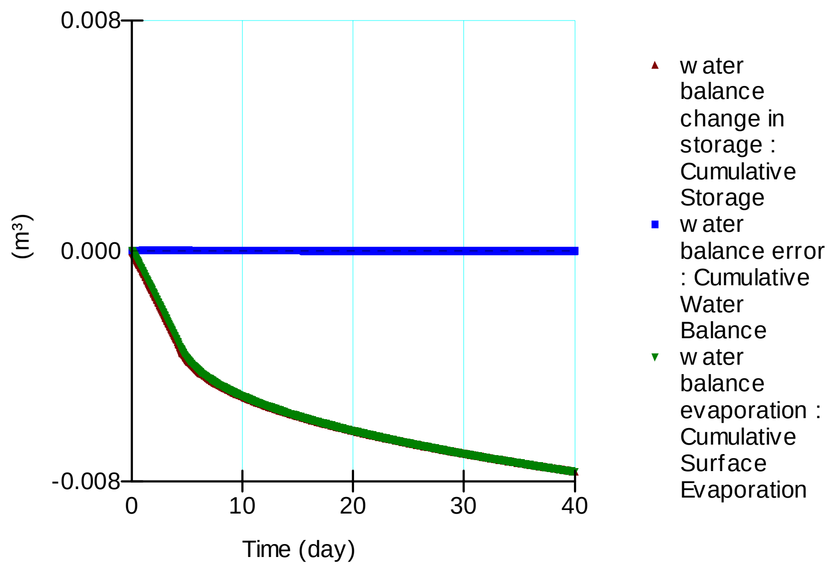


6 AE and PE at soil surface



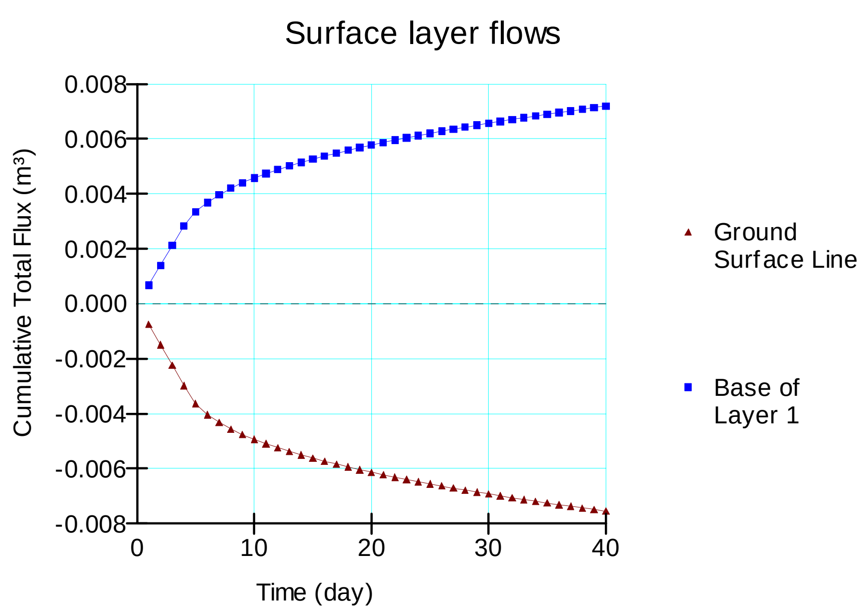
7 Soil water stress state at surface

How do we know this is a good solution? It is important in all VADOSE/W modeling to consider the water balance over the analysis. If the water balance error is minimal, it is a strong indication that the model has solved well. You can use the graphing tool to plot various water balance categories simultaneously, as shown below, in which all boundary flows and the internal change in storage of water are compared. If the sum of flow and change in storage is zero, it is perfectly balanced. In this case, the error is 1.1e-5, which is small relative to the change in storage of 0.008.



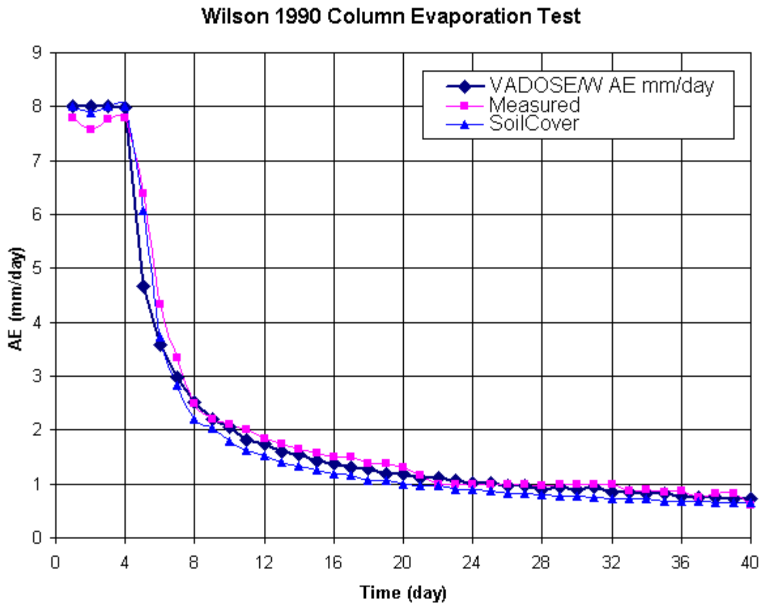
8 Water balance graphing to check solution

Suppose you were interested in knowing the amount of flow across a certain depth beneath the surface. If you had set up the model with the Draw Surface Layers command, then the base of any of these layers is a location where all flow data is automatically tracked. You can use the Draw Graph command to show flow across one or more of these layers, as shown below.



9 Checking the flow across soil cap layers

Finally, part of this example was to show how the formulation is correct. The chart below compares VADOSE/W with SoilCover and the laboratory data. SoilCover was the research code developed as part or Dr. Wilson's research group to put the theoretical formulation for actual evaporation into a numerical solution. There is excellent agreement of all cases.



10 Verification of the numerical solution