GeoStudio Example File
Infiltration into a multi-layered system

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Introduction

The objective of this example is to illustrate how SEEP/W can be used to simulate infiltration and drainage of multi-layered soil profiles. Such systems exist at large scales, such as in heap leach facilities, and at smaller scales, such as soil cover systems over mine wastes. Zettl et al. (2011) conducted multiple infiltration and drainage experiments on seven sites located north of Fort McMurray, AB. SEEP/W was used to simulate one of the experiments and explore the role of textural variations on the hydraulic response of the system. The results of the simulations are compared to the field measurements and numerical analyses completed by Huang et al. (2011).

Background

Zettl et al. (2011) conducted seven infiltration experiments on sites north of Fort McMurray, AB. A Diviner 2000 (D2k) portable capacitance probe and EnviroSCAN semi-permanent capacitance probes were used to measure *in situ* volumetric water content (VWC). A double-ring infiltrometer was placed over the instrumentation. The infiltrometer was filled rapidly with water and maintained at a constant head until the volumetric water content was at steady-state to a depth of about 100 cm. The ponded water was then allowed to drain from the infiltrometer while the spatial and temporal variations in volumetric water content were measured.

Once all of the ponded water infiltrated, Zettl et al. (2011) removed the rings and covered the area in plastic to prevent evaporation and precipitation from influencing the infiltration experiment. After approximately 20 hours, the field capacity conditions were reached and the last volumetric water content measurements were taken. The soil from one-half of the entire profile was excavated to a depth of approximately 1.1 m and disturbed samples were taken for laboratory analysis.

Huang et al. (2011) conducted numerical simulations using HYDRUS-1D to evaluate the potential influence of textural variability within the soil profile on the observed water content profiles. Three of the seven sites were simulated and resulting volumetric water content profiles were compared for both the infiltration and drainage experiments (Figure 1 and Figure 2, respectively). Huang et al. (2011) concluded that the multi-textured profile had an influence on the overall soil storage of the soil. Huang et al. (2011) included hysteresis effects in the drainage experiment simulations.

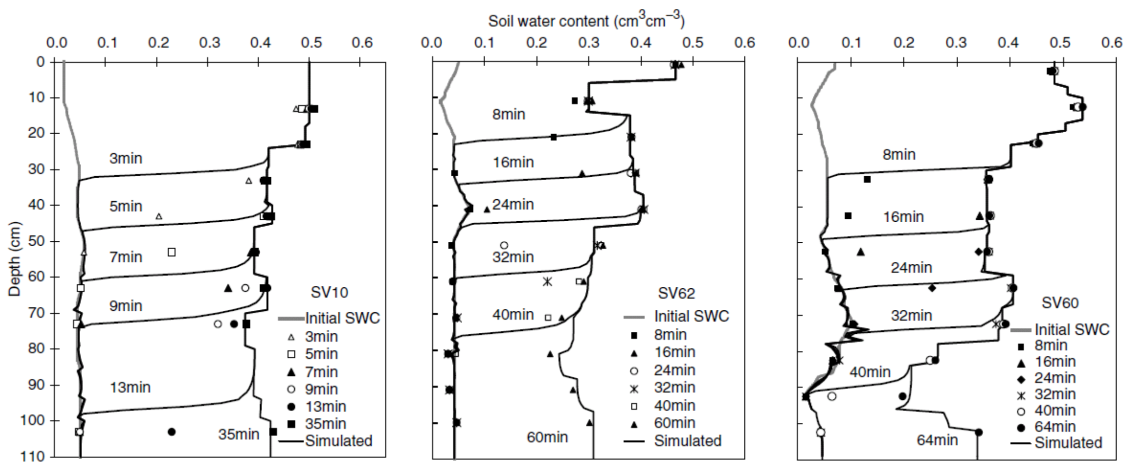

Figure 1. Comparison of simulated vs. measured soil water content profiles for three sites undergoing infiltration experiments (Huang et al. 2011).

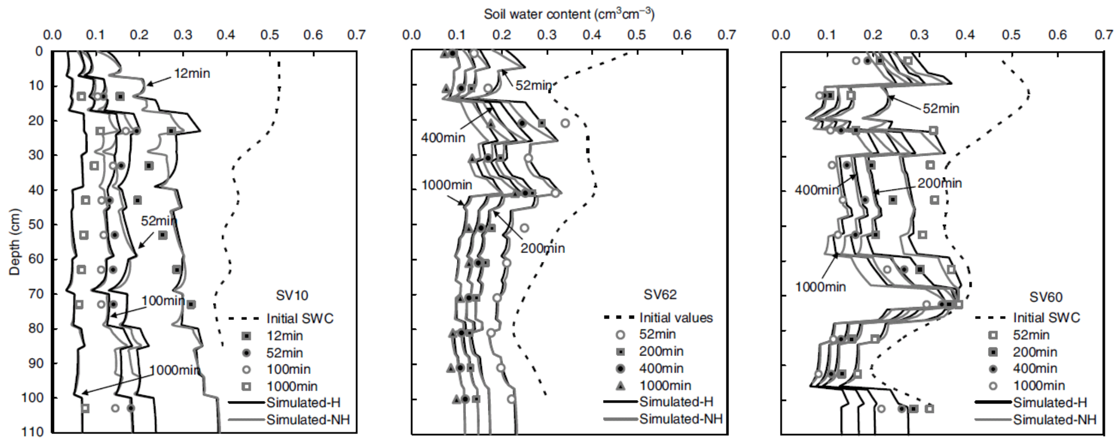

Figure 2. Comparison of simulated vs. measured soil water content profiles for the same three sites during the drainage experiments (Huang et al. 2011).

Numerical Simulation

The model domain comprises a 1.1 m one-dimensional column with a global element size of 5 mm (Figure 3). There are two analyses in the Project file to simulate the infiltration and drainage portion of the test. The initial pore-water pressure profile was defined using a spatial function created using the initial pore-water pressure conditions presented in Huang et al. (2011). The infiltration experiment was simulated using a 0.1 m constant pressure head boundary condition at the surface for a constant “pond” of 10 cm. The lower boundary condition was defined as a unit gradient (free drainage) boundary condition. The upper boundary condition was removed for the drainage simulation. These boundary conditions were selected in accordance with those used by Huang et al. (2011).

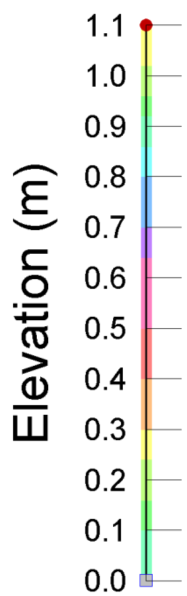

Figure 3. Problem configuration.

The saturated-unsaturated material model was used for all 14 layers used in the analyses. The simulation was developed based on the simulations conducted by Huang et al. (2011) on site SV10. Table 1 summarizes the parameters used by Huang et al. (2011) to estimate the volumetric water content and hydraulic conductivity functions.

Table 1. Input parameters for the volumetric water content and hydraulic conductivity functions.

Layer	Elevation to	Residual Water Content	Saturated Water Content	α^d	n	Hydraulic conductivity	
	(m)			/cm		cm/min	m/sec
1	1.02	0.017	0.5	0.114	3.235	2.378	3.96E-04
2	0.96	0.016	0.5	0.086	3.195	1.985	3.31E-04
3	0.92	0.019	0.5	0.071	3.511	2.093	3.49E-04
4	0.86	0.025	0.492	0.062	2.993	1.71	2.85E-04
5	0.8	0.028	0.42	0.067	2.684	1.693	2.82E-04
6	0.7	0.007	0.417	0.064	2.63	1.663	2.77E-04
7	0.64	0.001	0.427	0.049	3.602	1.761	2.94E-04
8	0.5	0	0.392	0.048	3.605	1.616	2.69E-04
9	0.4	0	0.418	0.053	3.653	1.855	3.09E-04
10	0.3	0	0.374	0.042	3.608	1.546	2.58E-04
11	0.24	0	0.393	0.038	3.641	1.67	2.78E-04
12	0.16	0	0.393	0.042	3.638	1.566	2.61E-04
13	0.1	0	0.411	0.043	3.644	1.63	2.72E-04
14	0	0	0.43	0.039	3.551	1.535	2.56E-04

The volumetric water content functions were calculated according to the van Genuchten (1980) equation:

$$\theta(h) = \theta_r + \frac{\theta_s - \theta_r}{[1 + |\alpha h|^n]^m}$$ Equation 1

where θ, θ_s, and θ_r are the calculated, saturated, and residual volumetric water contents, respectively, α, n, and m are van Genuchten parameters and h is the pressure head. The resulting volumetric water content curves are shown in Figure 4.

The hydraulic conductivity functions were calculated using:

$$K(h) = K_s {S_e}^{1/2}\left[1 - \left(1 - {S_e}^{1/m}\right)^m\right]^2$$ Equation 2

where K and K_s are the calculated and saturated hydraulic conductivities and S_e is the effective water content, which can be calculated using:

$$S_e = \frac{(\theta - \theta_r)}{(\theta_s - \theta_r)}$$ Equation 3

The hydraulic conductivity functions for each layer are shown in Figure 5.

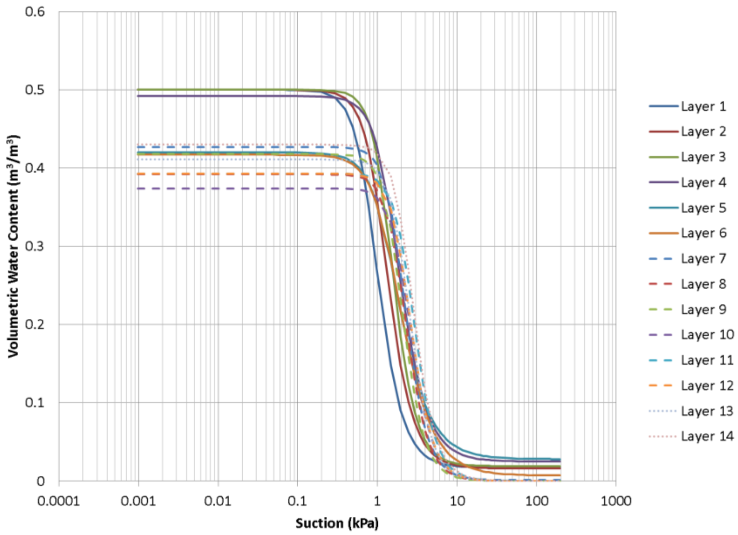

Figure 4. Volumetric water content functions for the 14 layers used in the analyses.

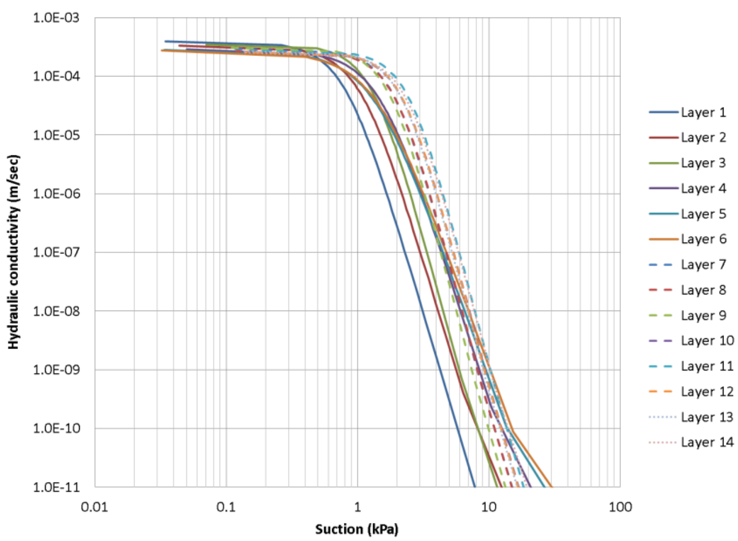

Figure 5. Hydraulic conductivity functions for the 14 layers used in the analysis.

The infiltration analysis has a total duration of 1 hour with 30 second time intervals that are saved every 5 steps to decrease the file size. The drainage experiment uses the final pore-water pressure conditions from the Parent infiltration experiment as the initial conditions. The drainage analysis has a total duration of 20 hours with 30 second time intervals saved every 5 steps.

Results and Discussion

Figure 6 compares the simulated volumetric water content profiles with the measured results and those presented by Huang et al. (2001). The simulated profiles compare well with the measured data. A reasonable match was also obtained to the simulation of Huang et al. (2011) despite the fact that hysteresis effects were not considered. The profile is completely saturated by 35 minutes, which is in keeping with the actual infiltration experiment. The variation in porosity are clearly evident in the near steady-state profiles.

The increase in soil water storage within the column was calculated by numerically integrating the volumetric water content over the depth, yielding a volume of water per unit cross-sectional area, which can be interpreted as a height of water in a non-porous column with a unit cross-sectional area. It can be seen from Figure 7 that SEEP/W was able to capture the overall time-based storage change, with the maximum soil water storage of 470 mm of water being stored in the 1.1 m column at around 15 minutes.

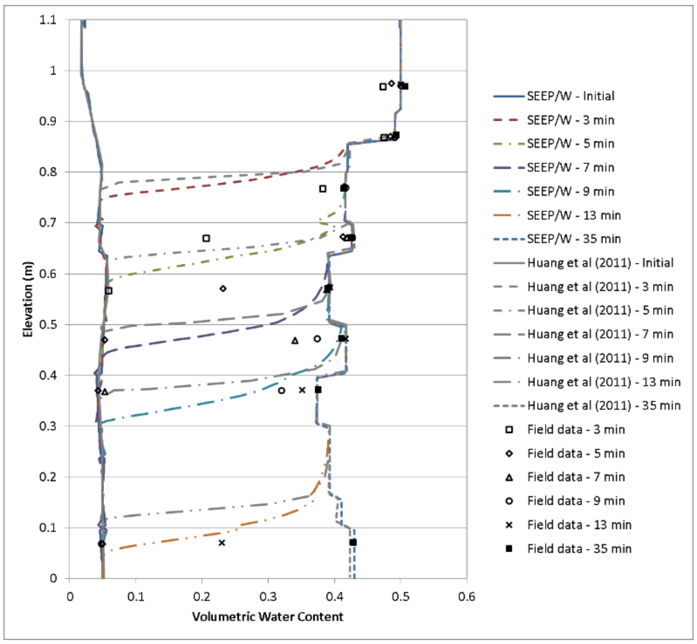

Figure 6. Volumetric water content profile with time for the infiltration simulation.

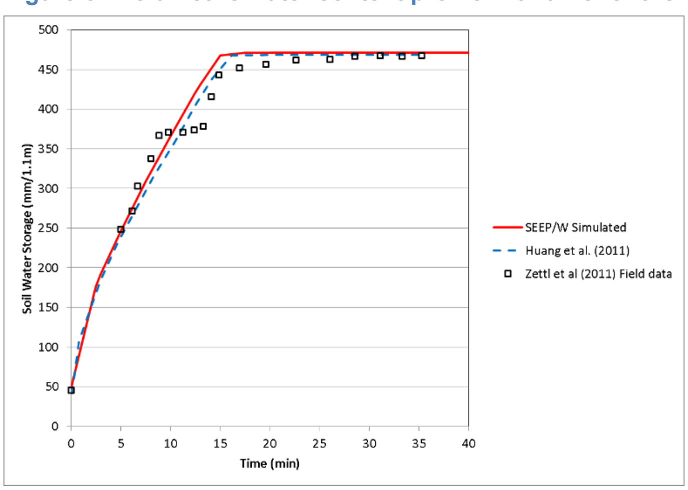

Figure 7. Increase in soil water storage in the column with time during the infiltration experiment.

During the drainage analysis, the upper portion of the soil column dries at a faster rate as the water moves down the column, keeping the lower portion of the column at a higher saturation level (Figure 8). As the water content in the upper portion of the column nears the field capacity, the saturation levels near the bottom of the column are able to reach similar saturation. After approximately 17 hours of draining time, all layers within the column have reached what is expected to be the field capacity water content of the sand materials. The simulated volumetric water content profiles in SEEP/W are very similar to those simulated by Huang et al. (2011) despite the exclusion of hysteresis.

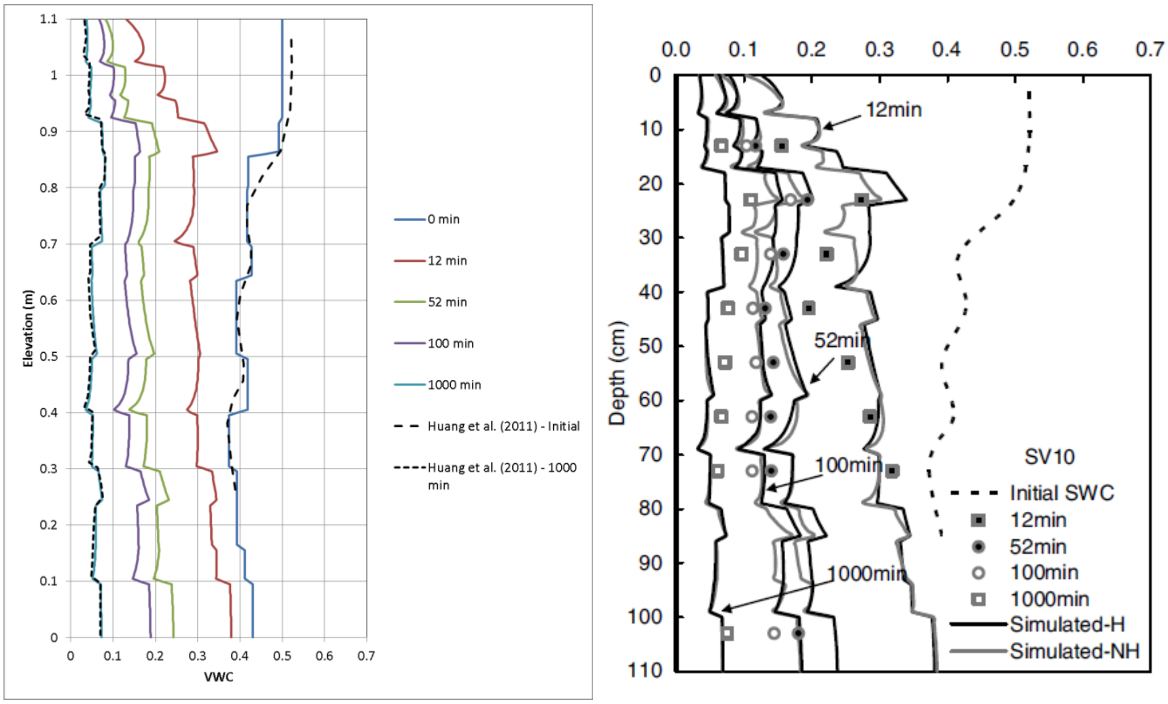

Figure 8. Volumetric water content profile with time during the drainage analysis in SEEP/W (left) and Huang et al. (2011 – right).

During the drainage of the column, the soil water storage continuously decreases until it nears the field capacity conditions of approximately 85 mm of soil water storage, where the drainage plateaus (Figure 9). Again, this value is similar to that reached in the simulations by Huang et al. (2011) and the field conditions.

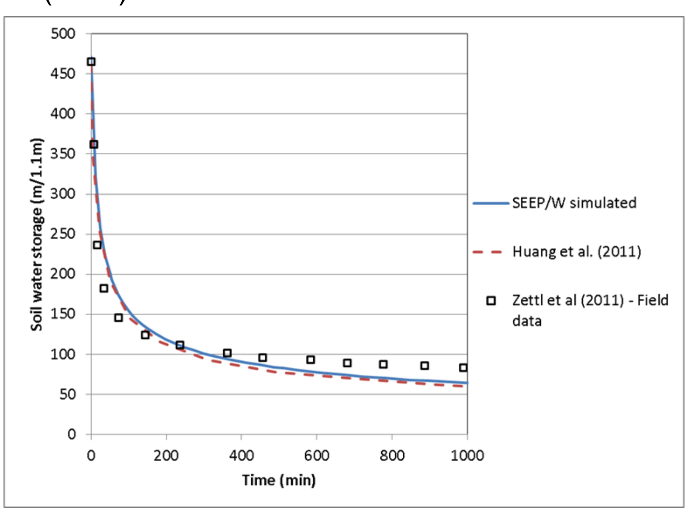

Figure 9. Decrease in soil water storage during the drainage analysis.

Summary and Conclusions

The objective of this example is to illustrate how SEEP/W can be used to simulate field conditions during infiltration and drainage experiments on multi-layered profiles using a one-dimensional column. The influence of varying texture is shown in the results of the volumetric water content profiles versus time. Even without hysteresis effects included in the drainage analysis, similar drying volumetric water content profiles were reached in the SEEP/W simulation as the Huang et al. (2011) simulation.

References

Huang, M., Barbour, S.L., Elshorbagy, A., Zettl, J.D. and Si, B.C. 2011. Infiltration and drainage processes in multi-layered coarse soils. Canadian Journal of Soil Science 91: 169-183.

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