GeoStudio Example File
Leakage from a Pond with a Clay Liner

To see the latest GeoStudio learning content, visit Seequent Learning Centre and search the catalogue for “GeoStudio”.

Introduction

The objective of this example is to illustrate how to model the effect of leakage from a lined pond on a groundwater flow system. Two cases are considered: a long-term steady-state analysis and a transient analysis. The steady-state analysis is conducted to determine the maximum water table rise assuming the pond will exist in perpetuity. The latter case is used to model the transient response of the water table from the time of filling the pond to when the system approaches steady-state. A third case also considers the leakage from a crack in the liner in a long-term steady-state analysis.

Numerical Simulation

Figure 1 and Figure 2 present the geometry of the numerical model and the Analysis Tree for the GeoStudio Project, respectively. The containment facility is located on the top of a hill slope. The first analysis analyzes the long-term steady-state condition with the pond-in-place. The second analysis is used to establish the initial pore-water pressure conditions for the transient analysis. Analysis 2a models the transient rise in the water table, while Analysis 3 is used to model the effect of a crack in the liner.

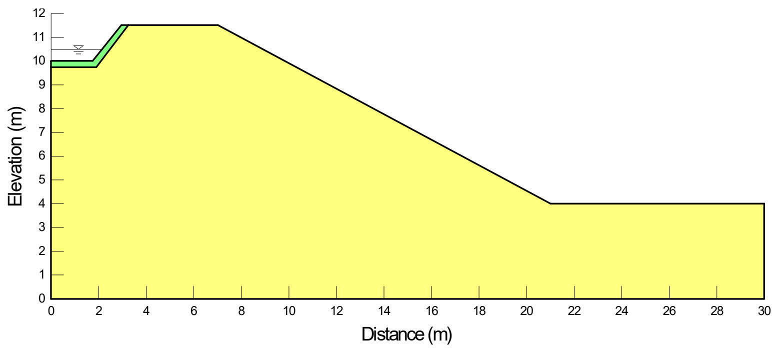

Figure 1. Problem configuration.

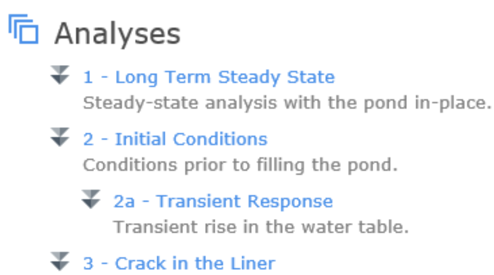

Figure 2. Analysis Tree for the Project.

The ground surface at the toe of the embankment is modeled using a pressure head = 0 m boundary condition for all analyses. This condition implies that the groundwater flow system is initially hydrostatic with a water table located at an elevation of 4 m. The pond is assumed to be filled and maintained at a depth of 0.5 m for analyses 1, 2a, and 3. As such, the total head is set to 10.5 m within the pond area. It is anticipated that a seepage face may develop along the slope face, so a potential seepage face boundary condition is applied.

There are several different approaches for modeling the effect of a crack in the liner, including the use of an opening in the mesh. A simpler approach, however, is to model the effect of the crack with a specified boundary condition. In this illustrative example, the total head at one point below the liner is assigned a value of 10.5 m (Figure 3), which is equal to the total head at the top of the liner. This implies that there is no total head loss across the liner within the crack.

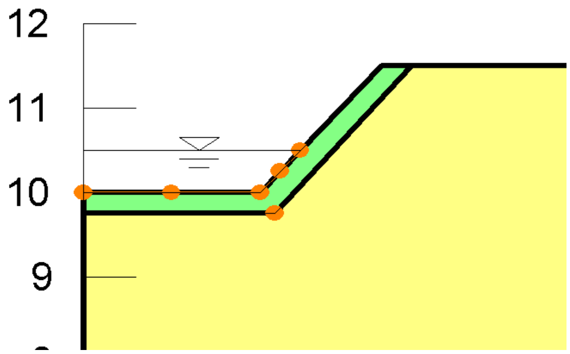

Figure 3. Hydraulic head boundary condition applied to simulate crack in clay liner.

The SEEP/W sample functions were used to define the hydraulic conductivity and volumetric water content functions (Figure 4 and Figure 5). The saturated hydraulic conductivity for the foundation material and clay liner was set to 0.1 m/day and 0.008 m/day, respectively.

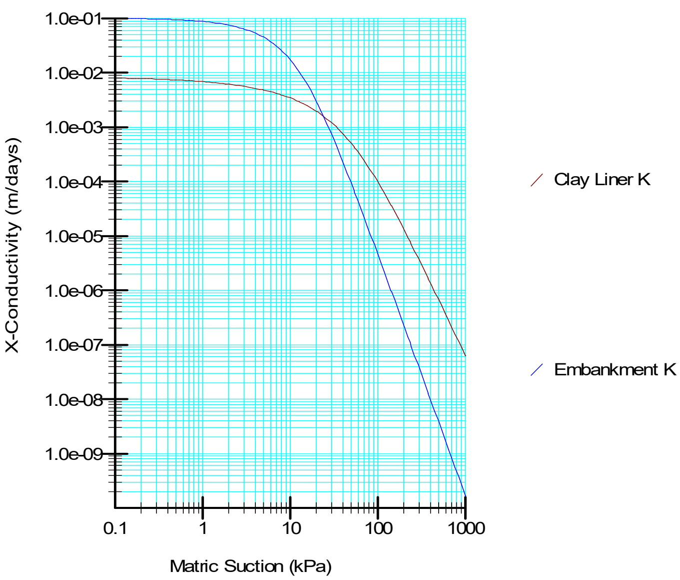

Figure 4. Hydraulic conductivity functions for the native soil and clay liner.

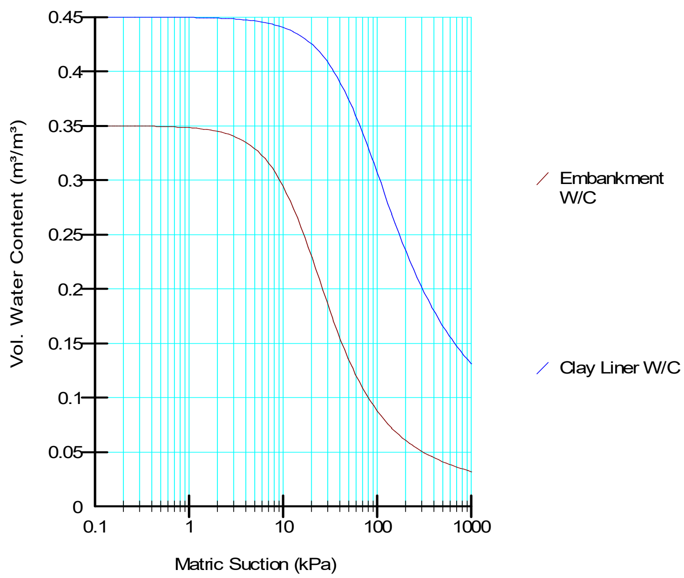

Figure 5. Volumetric water content functions for the native soil and clay liner.

The global element size was set to 0.5 m. In order to simulate the influence of the clay liner on the movement of water accurately, the mesh within the clay liner region was refined to an element size of approximately 0.125m (Figure 6). The transient analysis has a total duration of 240 days over 30 time steps that increase exponentially with an initial time step size of 1 day.

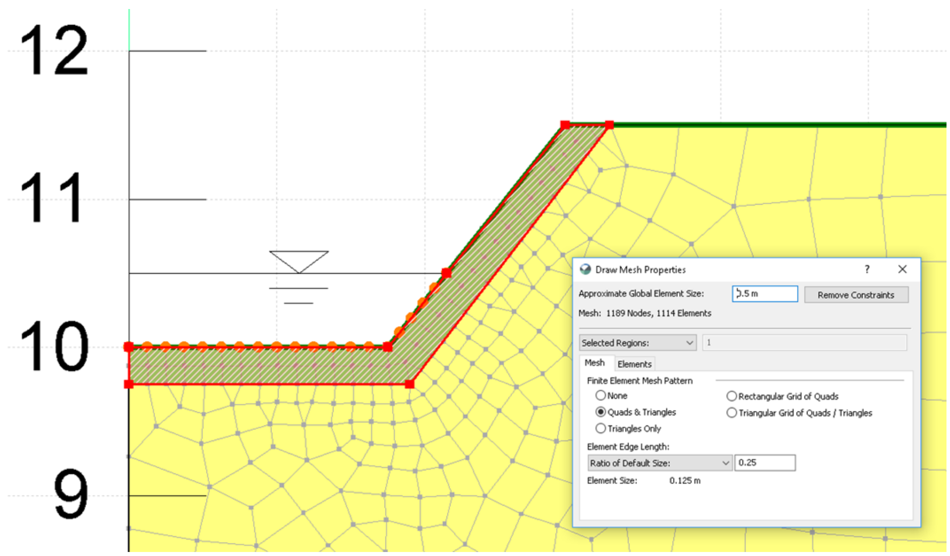

Figure 6. Mesh refinement of the clay liner.

Results and Discussion

Figure 7 shows the long term, steady-state conditions simulated in Analysis 1. Note that the water table has mounded and a seepage face has developed on the slope face just above the toe. Most importantly, however, is the leakage from the pond through the unsaturated zone. The leakage is sufficient to cause the water table to rise, but not sufficient to completely saturate the ground beneath the pond.

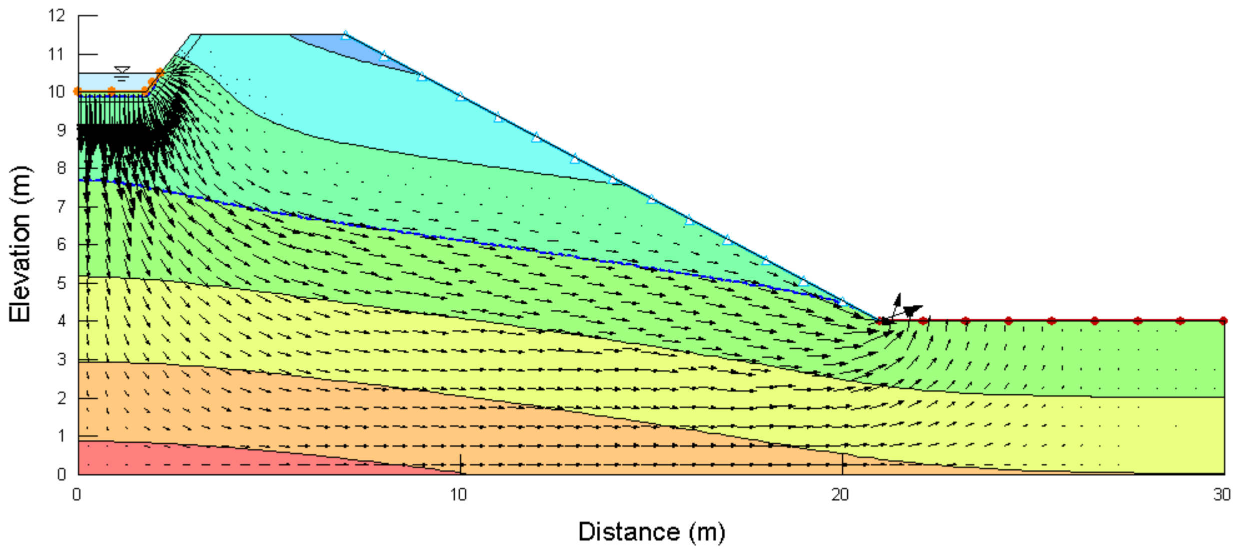

Figure 7. Long term steady-state conditions of Analysis 2.

Figure 8 presents the pore-water pressure contours for the steady-state initial condition analysis (2). The water table is located an elevation of 4 m and the system is hydrostatic (i.e. no flow). Figure 9 shows the location of the water table at various time steps in the transient analysis (2a). The water table is approaching the long-term steady condition by Day 240.

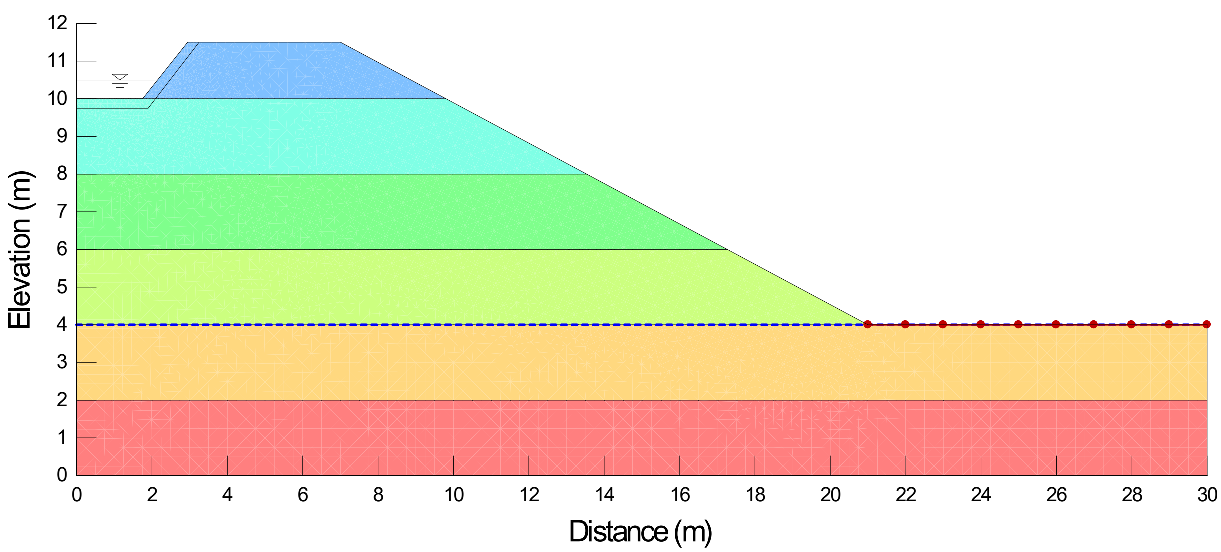

Figure 8. Initial hydrostatic conditions.

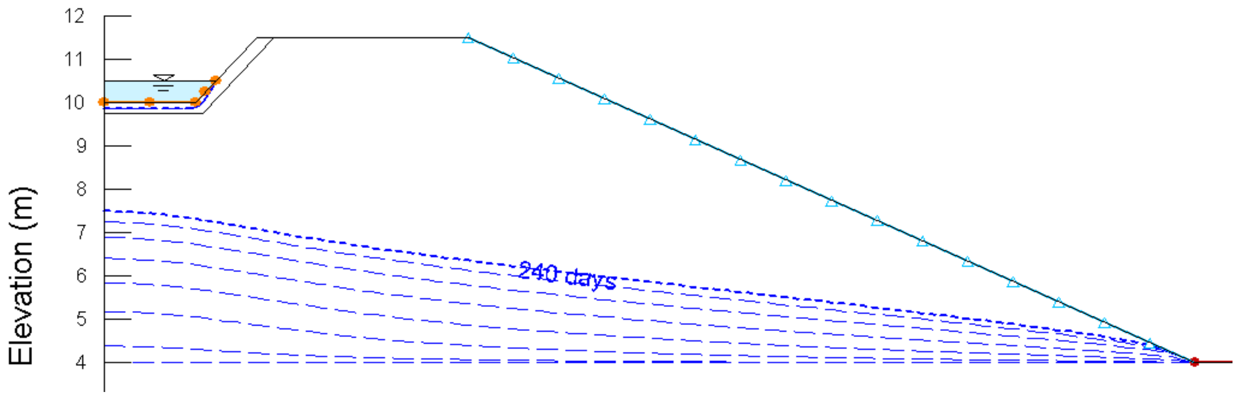

Figure 9. Mounding of the water table with time.

Figure 10 shows the total head contours and water flux vectors after about 15 days. Leakage from the pond causes a wetting front to propagate downward toward the water table. The rate at which the wetting front moves is controlled by both the hydraulic conductivity and volumetric water content functions of the soil. Soil storage must be filled to the point at which the pore-water pressure, and therefore hydraulic conductivity of the soil, is commensurate with the infiltration rate.

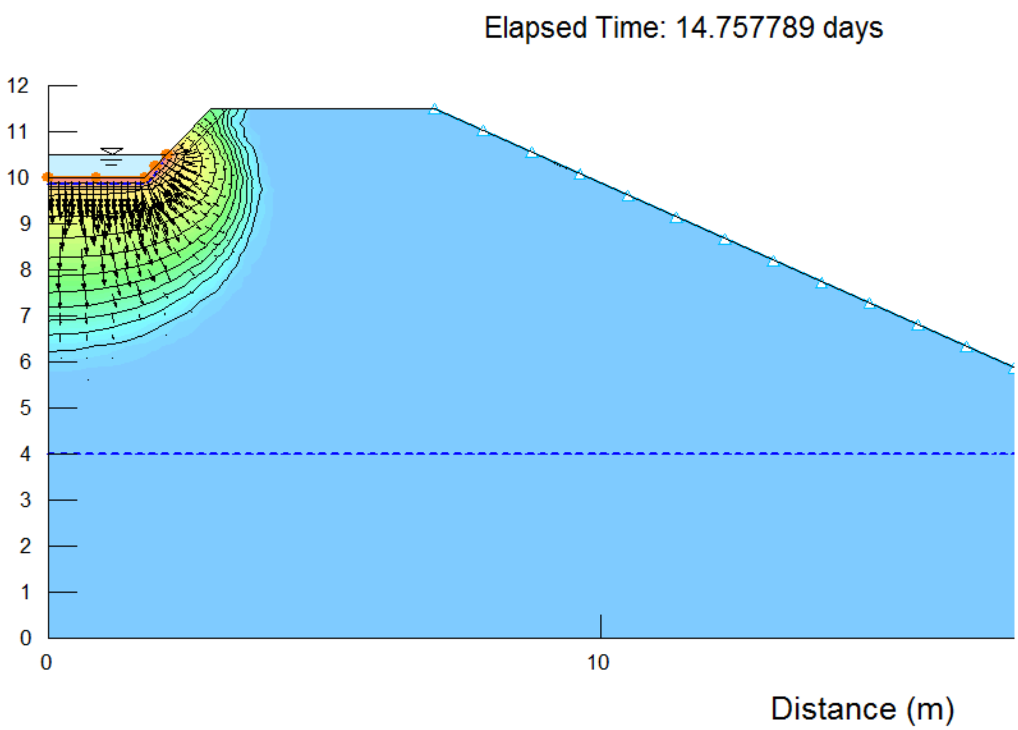

Figure 10. Conditions at the end of Day 15.

The water table never rises to the bottom of the pond because the foundation soil can transmit the leakage while remaining unsaturated. The infiltration rate beneath the pond after 240 days is approximately 4e-7 m/s or 3.5e-2 m/day (Figure 11). According to Darcy's Law, the flux at any given hydraulic conductivity depends on the sum of the gravitational potential energy gradient per unit weight of water (dy/dy = 1.0) and the gradient in pore-water pressure. The pore-water pressure gradient in the vertical direction will trend towards zero when the flux rate is less that the saturated conductivity of the soil such that q = K. In this case, the flux beneath the liner is about 4e-7 m/s, which corresponds to a pore-water pressure of about – 7 kPa on the foundation soil K-function (Figure 4). The pore-water pressure profile beneath the pond after 240 days is therefore around – 7 kPa.

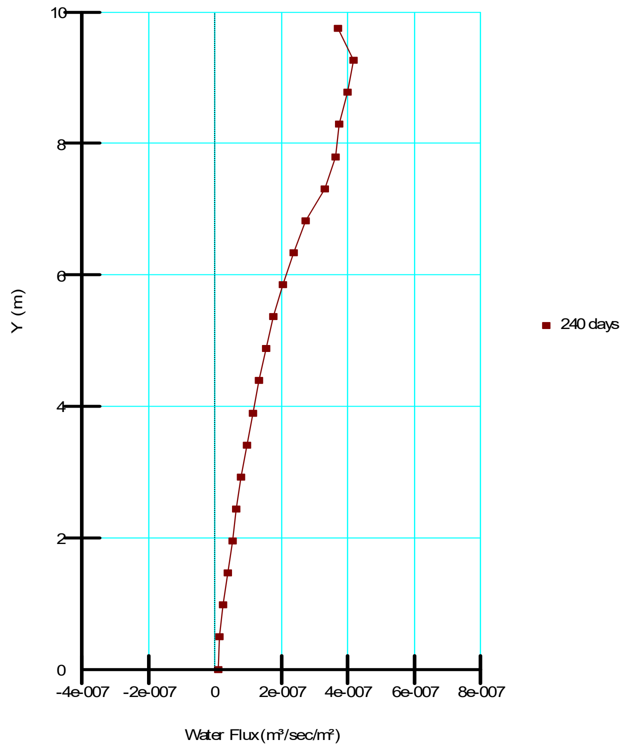

Figure 11. Water flux profile beneath the pond.

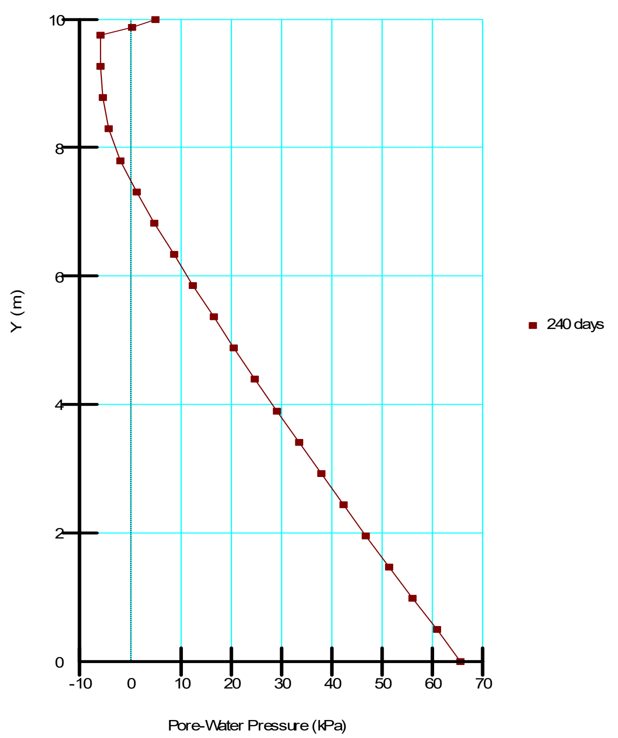

Figure 12. Pore-water pressure profile beneath the pond at Day 240.

The resulting water table is drastically altered when the crack in the liner is introduced (Figure 13). It is important to remember that the analysis is two-dimensional. As such, the crack extends in the out-of-plane dimension along the length of the structure. This is unlikely to occur in reality and needs to be considered in the interpretation of the results. Regardless, the analysis demonstrates that significant leakage will cause the water table to rise to the base of the pond in the long-term.

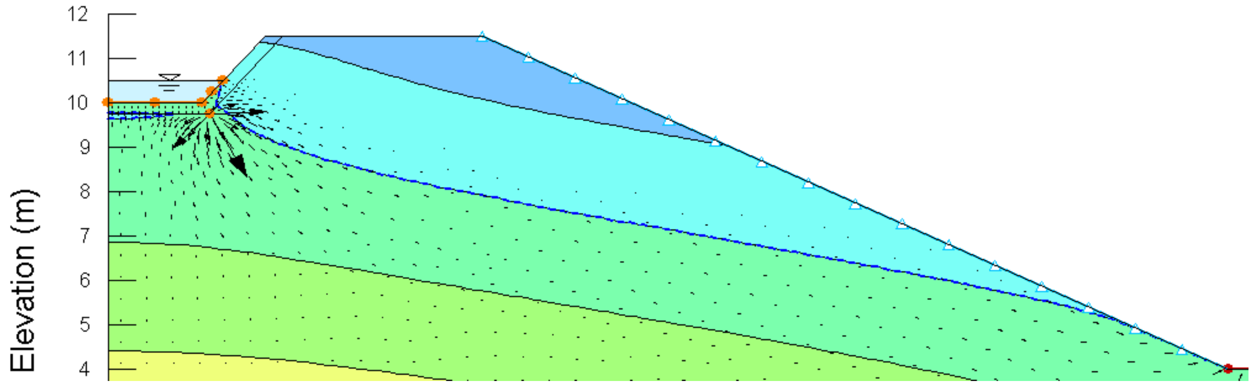

Figure 13. Effect of a crack in the liner.

Summary and Conclusions

The objective of this example was to illustrate the use of SEEP/W to simulate leakage from a pond with a clay liner. Both the long-term, steady-state and transient conditions have been discussed and compared. This example indicated that the long-term, steady-state condition was reached within 240 days, indicating that the steady-state solution is obtainable in real world situations.