GeoStudio Example File

Rapid Drawdown with Simple Effective Stresses

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Introduction

Embankment dams are large earth or rock dams that depend on the shear strength of the compacted material to withhold the water pressure of the upstream reservoir. An important consideration for embankment dam design is the dam stability during reservoir drawdown. Under operating conditions, the reservoir water pressure has a stabilizing affect on the upstream dam face. During rapid reservoir drawdown, the stabilizing effect of the water is lost but the pore-water pressures within the embankment may remain high. Consequently, the dam stability along the upstream face may decrease until the high pore water pressures within the embankment dissipate. Pore water pressure dissipation depends on the permeability and storage characteristics of the embankment materials. Highly permeable materials drain quickly during rapid drawdown, while low permeability materials take a long time to drain. This example demonstrates a simple method for modeling the effects of rapid drawdown on embankment dam stability.

Numerical Simulation

The embankment in this example comprises three materials: a clay core, chimney drain, and the general embankment fill (Figure 1). The Mohr-Coloumb material model is selected for these materials and the specified shear strength properties are provided in Figure 1. The clay core has the greatest cohesion but a relatively low friction angle, compared to the embankment fill and chimney drain. The embankment sits on impenetrable bedrock, defined by the Bedrock material model.

The crest of the dam is at an elevation of 20 m. The initial reservoir level is 18 m, as defined by the piezometric line illustrated in Figure 1 – this is the case considered in Analysis 1. The pore water pressures within the embankment (also defined by the piezometric line) are assumed to be in a steady state. The reservoir water results in both vertical and horizontal hydrostatic forces acting along the upstream embankment face. These forces are distributed as line loads acting normal to the embankment face, indicated by the blue arrows (Figure 1). The coordinates defining the piezometric line are provided in the first two columns of Table 1.

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Color	Name	Unit Weight (kN/m³)	Cohesion' (kPa)	Phi' (°)
	Bedrock			
	Chimney Drain	19	0	35
	Clay Core	18	15	15
	Embankment Material	18	8	30

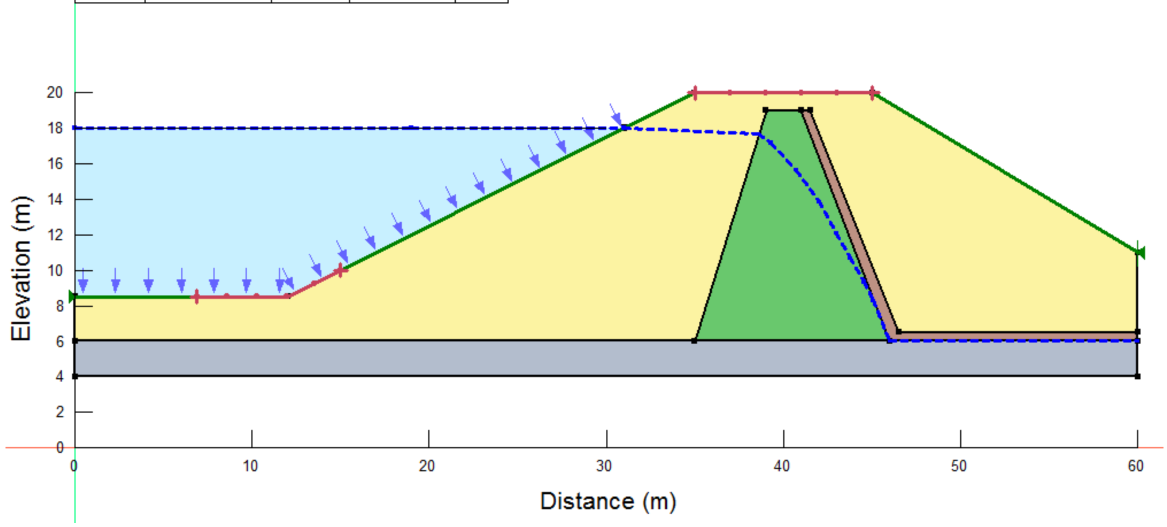

Figure 1. Problem configuration and piezometric line before drawdown, simulated in Analysis 1.

Table 1: Coordinates defining the piezometric lines in each SLOPE/W analyses.

Analysis 1		Analysis 2	
X (m)	Y (m)	X (m)	Y (m)
0	18	0	12
19	18	19	12
31	18	31	18
38.57	17.65	38.57	17.65
39.28	17.15	39.28	17.15
40.71	15.65	40.71	15.65
41.98	13.85	41.98	13.85
43.01	12.07	43.01	12.07
43.78	10.67	43.78	10.67
44.54	9.32	44.54	9.32
45.09	8.28	45.09	8.28
46	6	46	6
60	6	60	6

The second analysis in the project file investigates the reduced factor of safety when the reservoir is instantaneously lowered to an elevation of 12 m. The modified piezometric line represents the rapid drawdown conditions (Figure 2). The pore water pressures within the embankment remain the same as in Analysis 1; however, upstream of the embankment, the piezometric line is at the new pond level. Thus, the embankment face remains saturated but is now exposed. The coordinates defining the piezometric line in Analysis 2 are also provided in Table 1.

Color	Name	Unit Weight (kN/m³)	Cohesion' (kPa)	Phi' (°)
	Bedrock			
	Chimney Drain	19	0	35
	Clay Core	18	15	15
	Embankment Material	18	8	30

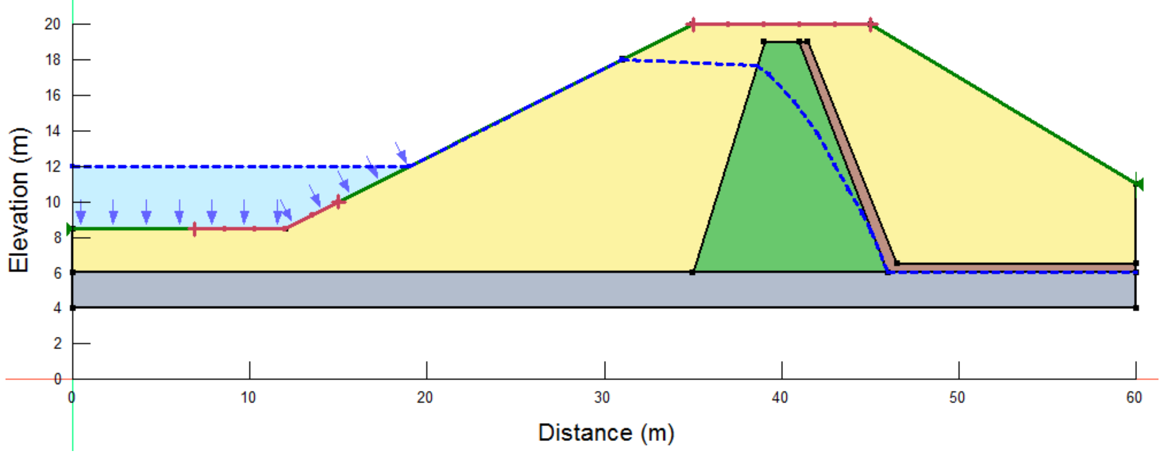

Figure 2. Piezometric line after rapid drawdown as simulated in Analysis 2.

Results and Discussion

The critical factor of safety determined in Analysis 1 is 1.985 (Figure 3). In Analysis 2, the critical factor of safety decreased to 1.096 (Figure 4). These results confirm the stabilizing effect of the reservoir water on the upstream face of the embankment. Rapid drawdown of the reservoir from 18 m to 12 m causes the factor of safety to fall by approximately 45% due to the high pore water pressures remaining in the embankment after drawdown. Over time, the pore water pressures should dissipate, causing a gradual increase in the embankment factor of safety.

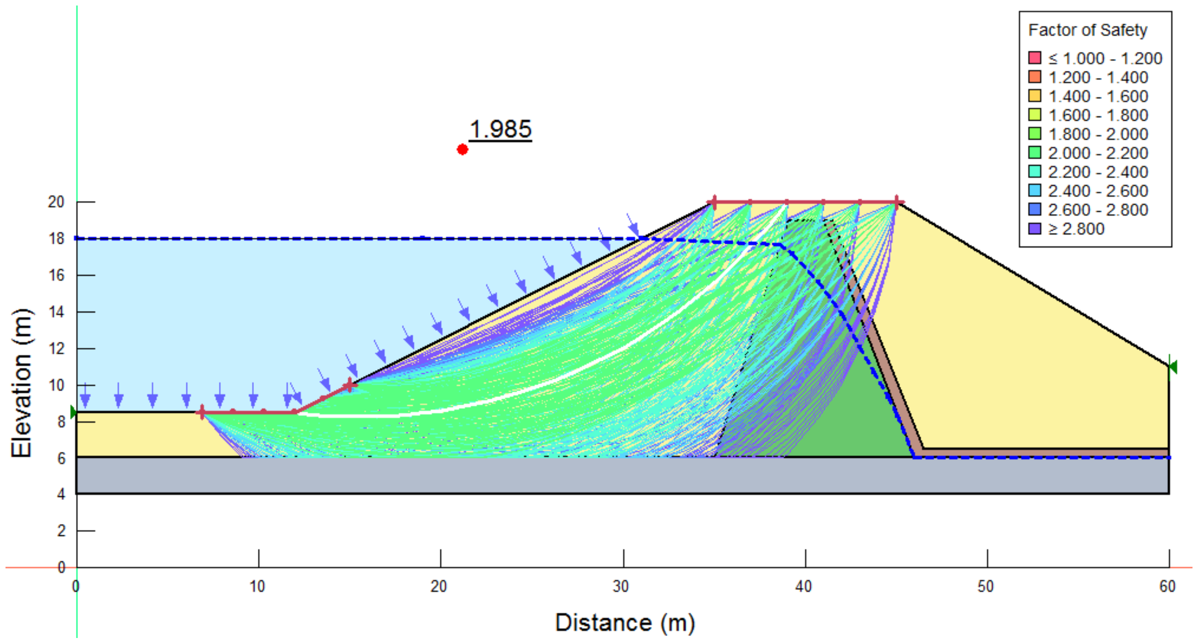

Figure 3. Critical slip surface and factor of safety colour map for Analysis 1, before drawdown.

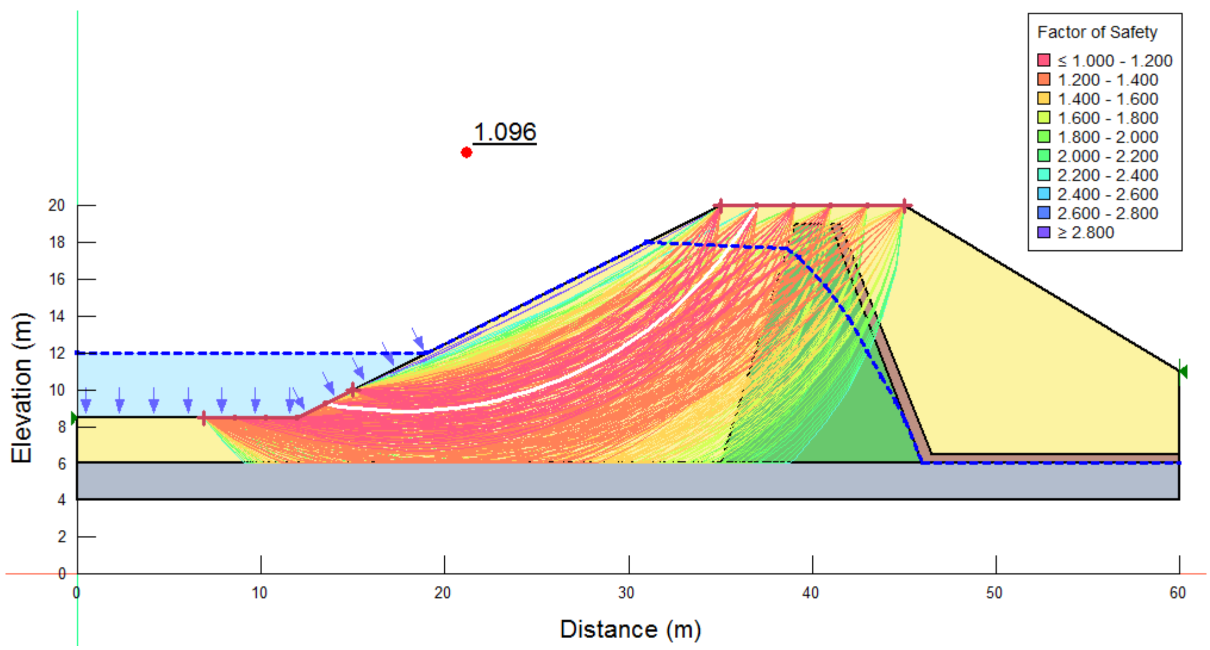

Figure 4. Critical slip surface and factor of safety colour map for Analysis 2, after rapid drawdown.

The approach outlined in this example assumes that the reservoir is instantaneously lowered, which in reality is impossible. Draw down of a reservoir will likely take some time. Excess pore water pressure within the embankment may dissipate during drawdown. Thus, the results represent a worst-case scenario as pressure dissipation was not incorporated in Analysis 2.

Summary

In this example, the critical factor of safety dropped significantly when the reservoir level decreased by 6 m. The described method assumes that negligible pore water pressure dissipation has occurred within the embankment. Thus, the results represent a preliminary estimate for embankment stability. If this initial assessment suggests that rapid drawdown could be a serious issue, more sophisticated analyses may be required. A more realistic representation of reservoir drawdown over time and subsequent changes to pore water pressures within the embankment, should be considered in further simulations. A SEEP/W analysis (coupled to the slope stability analysis) is required to simulate changing pore water pressures over time, as demonstrated in the example *Rapid Drawdown with Effective Stress*. Nonetheless, this example demonstrates a simple method for obtaining the factor of safety of an embankment during drawdown.