Slope Stability

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Exercise 4b

LEM software application

EXERCISE AND TUTORIAL OF GEOSTUDIO SLOPE/W

Introduction

Similarly to Exercise 4a, the goal of this exercise is to perform slope stability analyses by using the commercial software GeoStudio 2018 (student version). Let $F(s_i)$ the safety factor computed for a specific surface s_i. By considering that the actual failure surface is unknown, a certain number of potential failure surfaces s_i needs to be considered. The actual safety factor is defined as $F = min_i \{F(s_i)\}$.

GeoStudio 2018 can be downloaded at the following website: https://www.geoslope.com/learning/downloads/alternate-downloads. A tutorial is presented in section 1.2 in order to guide the student through the basic steps of GeoStudio. The tutorial refers to the GeoStudio 2018 version (if you would like to download a newer version there might be some small differences compared to this tutorial but it should be quite easy to understand them).

1.1 Exercise description

In this exercise, the stability of a cut and fill is analyzed. The geometry and soil properties are recalled in Figure 1 and Table 1. The soil is considered dry. In the following tutorial, coordinates to define the slope geometry will be also given.

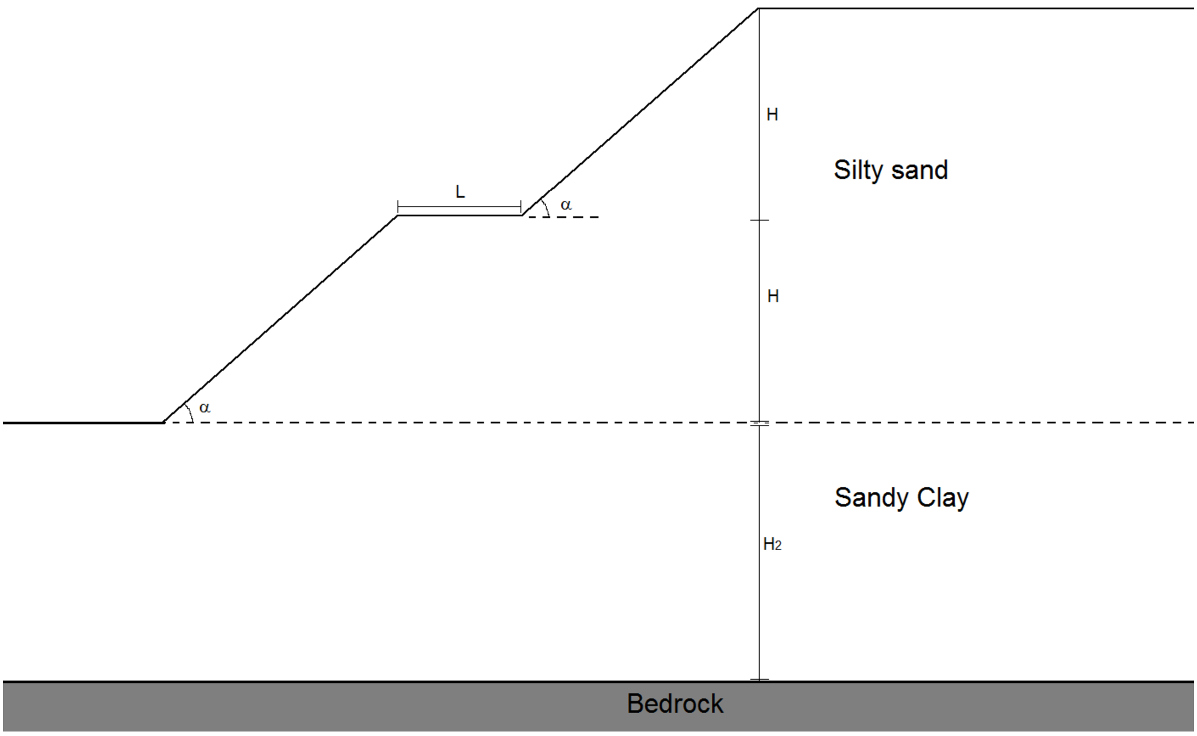

Figure 1: "Cut and fill" slope geometry.

Table 1: geometry and soil properties of the slope reported in Figure 1.

Material	γ_d (kN/m^3)	φ' (°)	c' (kPa)
Silty sand	18	32	6
Sandy clay	16	18	10

Slope geometry	α (°)	$H(m)$	$H_2(m)$	$L(m)$
	41.3	10	16	6

For the proposed slope configuration, evaluate the factor of safety $F = min_i \{ F(s_i) \}$ by adopting GeoStudio™ SLOPE/W. Subdivide the slope in a number of slices equal to 40 and perform the stability analyses by using the simplified Bishop's method and the Morgenstern-Price method. For identifying the circular slip surfaces it is suggested to use the *Grid and Radius* method.

Write in Table 2, for the dry conditions and for each applied method, the results of the analyses in terms of:

- safety factor F;
- characteristics of the failure surface (coordinate of the center C and radius r).

Make final comments on the obtained results. Can the slope be considered stable? Consider satisfactory a safety factor $F \geq 1.3$ to keep into account uncertainties due, for example, to the estimation of the geotechnical parameters. In discussing the results, distinguish between superficial and deep failure mechanisms.

Table 2: summary of results obtained by using GeoStudio SLOPE/W.

	BISHOP simplified	*MORGENSTERN-PRICE*
"Cut and fill"	F = (x_C ; y_C) = r =	F = (x_C ; y_C) = r =

1.2 GeoStudio™ SLOPE/W tutorial

In the following sections a step-by-step tutorial is presented to solve the proposed problem; three main steps will be accomplished:

1. a pre-processing phase, where all the input data are introduced (geometry, material properties, type of analysis...);
2. a processing step, in which the problem is solved with the Limit Equilibrium Method according to the selected approach (i.e. simplified Bishop's method or Morgenstern-Price method);
3. a post-processing step, in which the obtained results are displayed and analyzed.

To indicate a command, the notation 'Menu→Submenu→Command' is used.
Launch GeoStudio™ 2018 ('Démarrer→Programmes→ Programmes GC→GeoStudio 2018').

For creating a new project select SLOPE/W project as show in Figure 2.

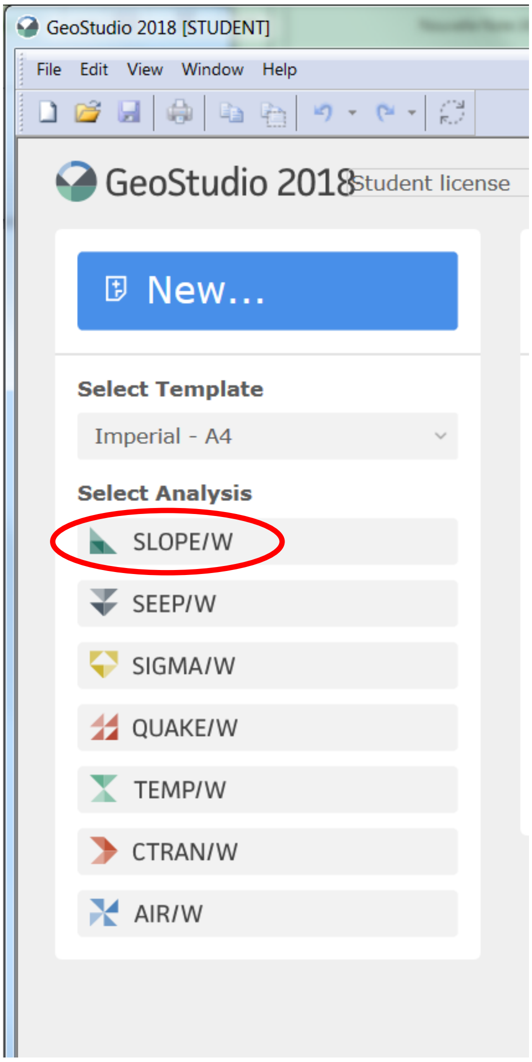

Figure 2: GeoStudio™ 2018 starting interface.

It is suggested to choose the basic units of measurements: 'View→ Units' (Figure 3).

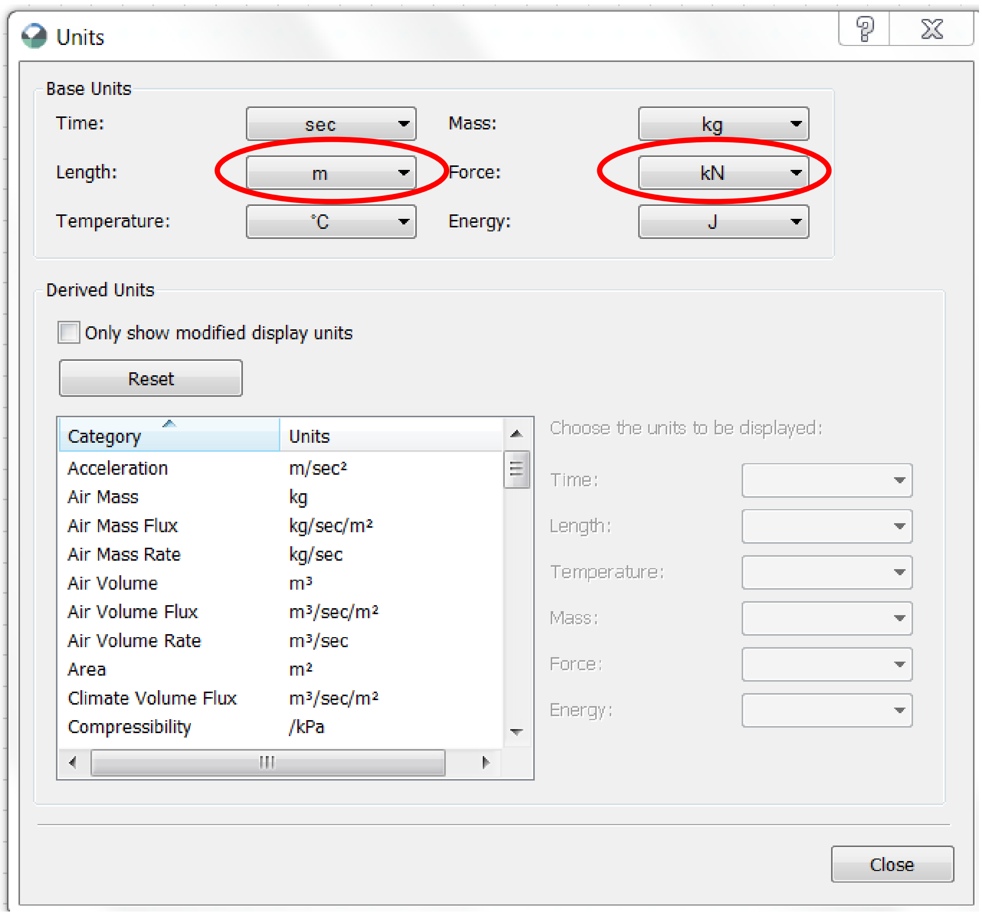

Figure 3: Units window.

The Grid spacing can be changed by using the command 'View→ Grid' (Figure 4).

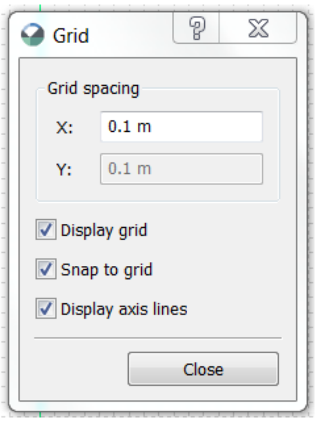

Figure 4: Grid window.

Afterwards, save the project in your working folder: *namefile*.gsz, as a GeoStudio file (*.gsz). Remember to save regularly your project (File→Save).

Pre-processing step, geometry and material

Define analysis: settings

For defining the options of the analysis to be performed, use the "Define Analyses" interface by following the path: 'Define→ Analyses'.

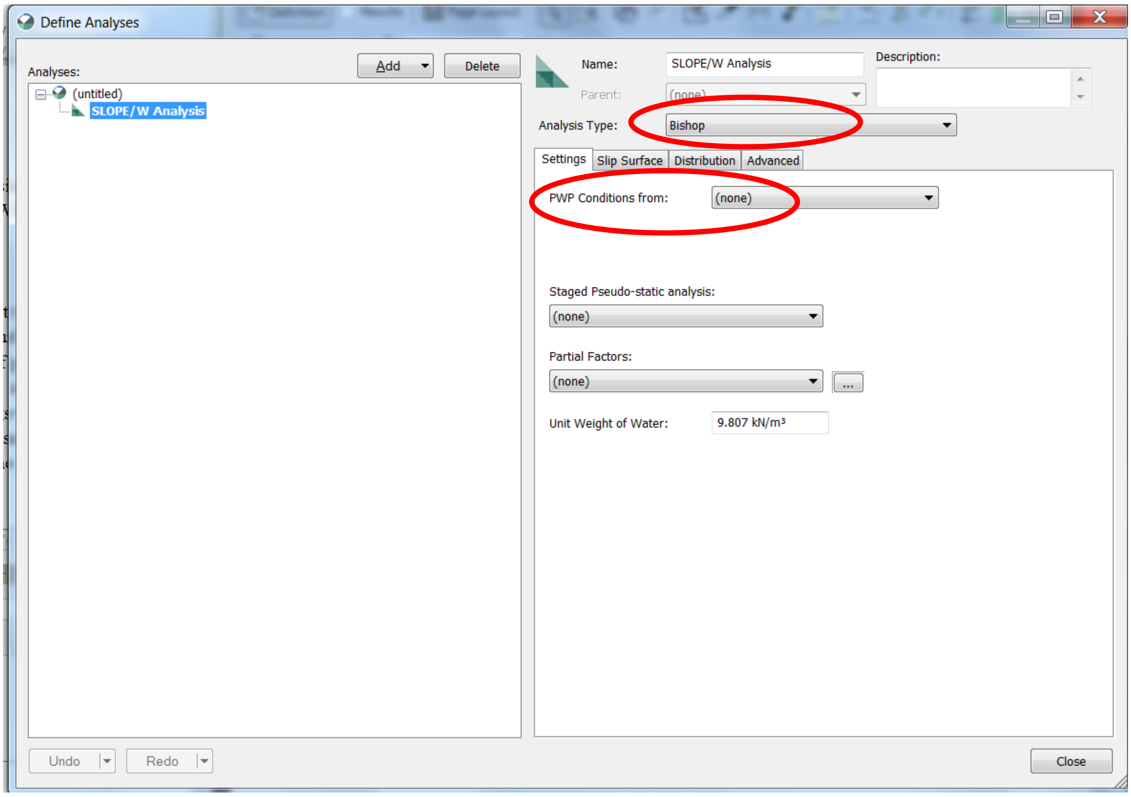

Figure 5: *Define Analyses* interface.

The method for performing the analysis can be chosen: 'Define→ Analyses → Analysis Type→Bishop'. For the current study, the pore water pressure conditions are not kept into account: 'PWP conditions from→(none)' (Figure 5).

Define analysis: Slip surface

'Define→ Analyses → Slip surface'

The direction of movement has to be defined, according to Figure 1, going from '<u>right to the left</u>'. A <u>'Grid and Radius'</u> slip surface option is set (Figure 6). It means the potential slip surfaces will be defined during computation with a grid of possible centers of rotation and a series of parallel lines tangential to slip surfaces.

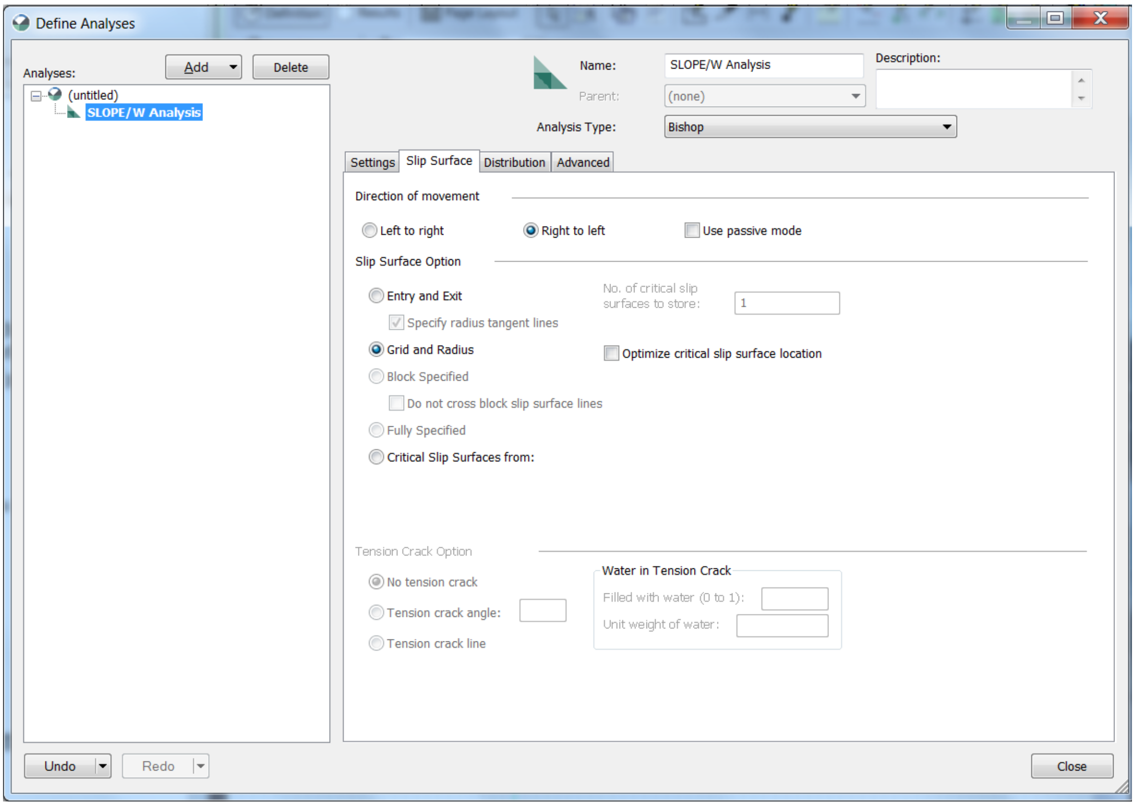

Figure 6: *Slip surface* window.

Define analysis: distribution

'Define→ Analyses → Distribution→ Constant'

GeoStudio 2018 with Student license allows only a constant *F* distribution calculation (Figure 7).

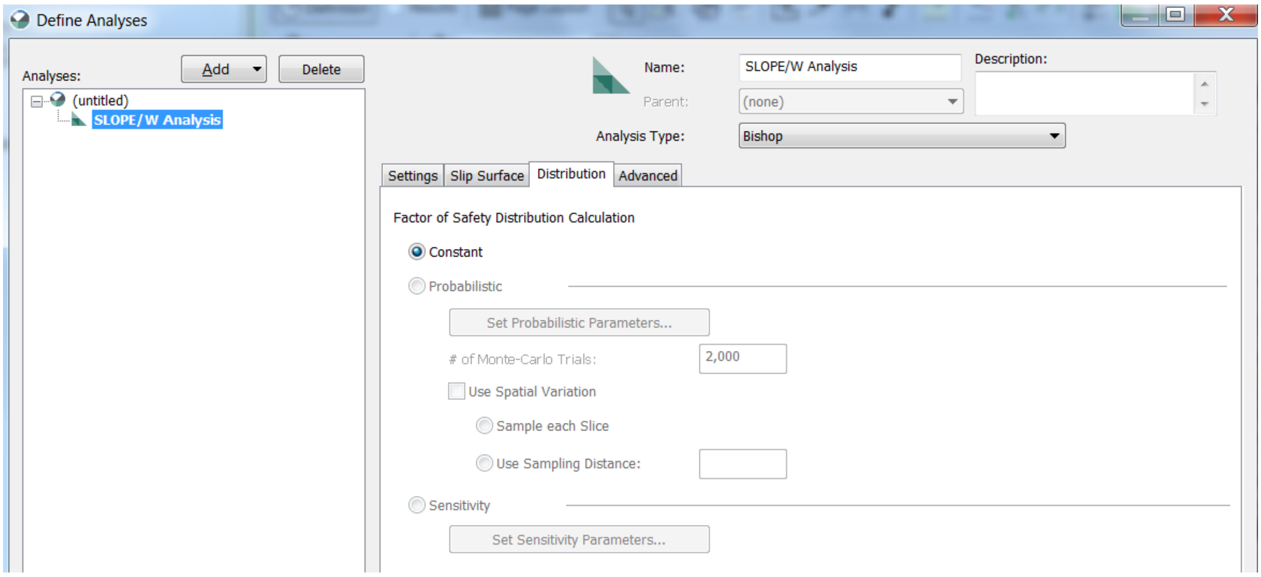

Figure 7: *Distribution* window.

Define analysis: Advanced
'Define→ Analyses → Advanced→ Number of slices→40' (Figure 8).

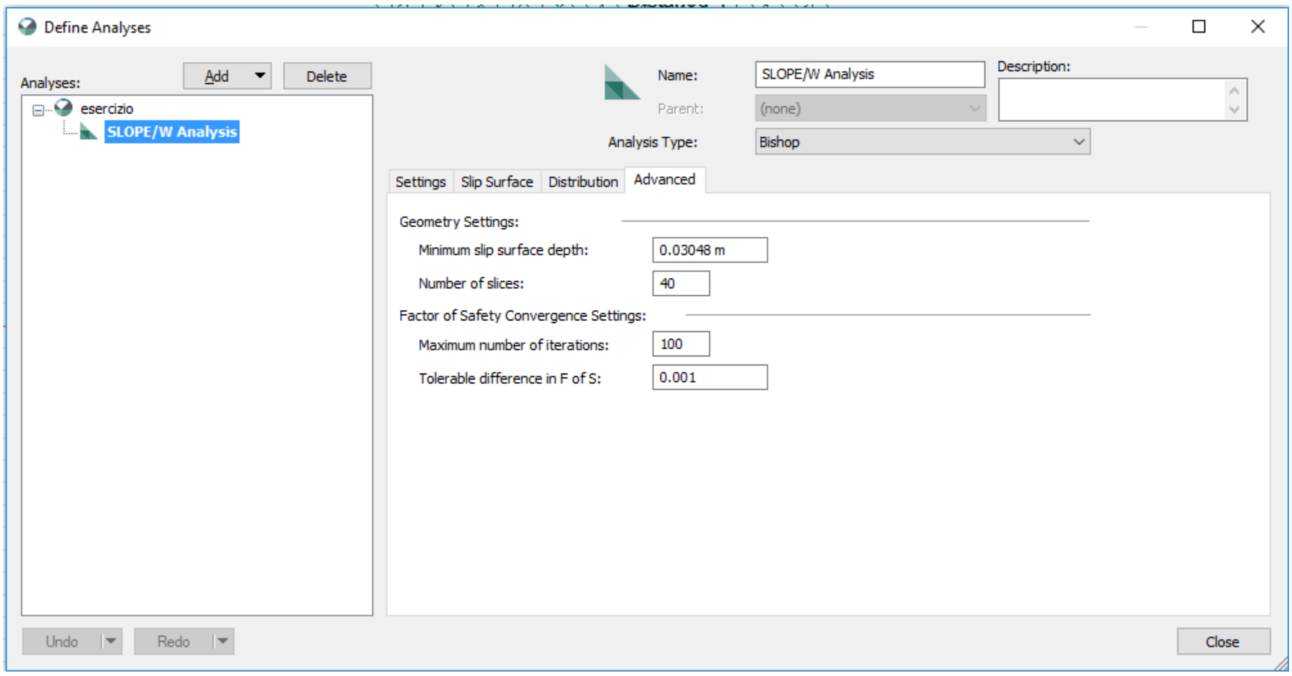

Figure 8: *Advanced* window.

Afterwards, save the project in your working folder: *namefile*.gsz, as a GeoStudio Compressed file (*.gsz). Remember to save regularly your project (File→Save).

Define geometry
The command 'Draw→Regions→Polygonal' allows the geometry to be defined manually (Figure 9). Then, the 'Enter coordinate' cell in the bottom left can be used for this purpose. Starting from the origin *O*, referring to the given geometry (Figure 1), the following points must be added: (0;0), (11.4;10), (17.4;10), (28.8; 20), (50;20), (50;0) and reconnect the last point to the origin (0;0). Subsequently draw the second region as follows: (50;0), (50;-16), (-30;-16), (-30;0), (50;0). Finally draw the bottom layer corresponding to the rigid bedrock. Would you expect that the thickness of such last layer would influence the problem?

Afterwards, the axes of the reference system can be displayed by setting their minimum and maximum values of interest: 'Sketch→Axes'.

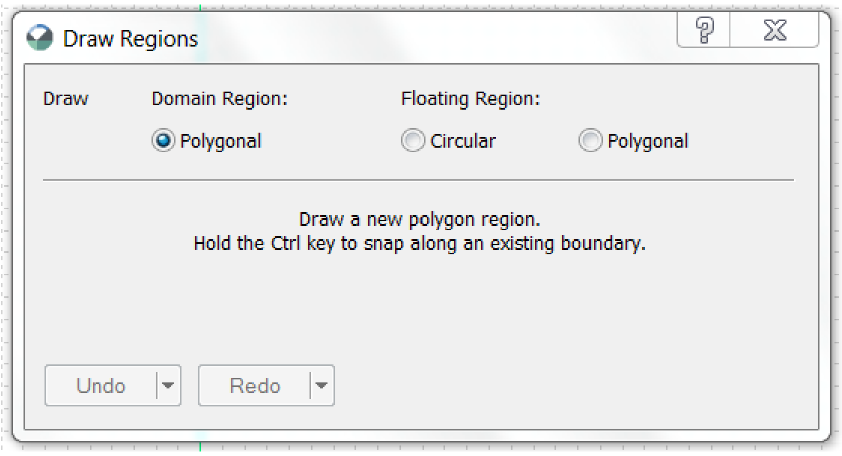

Figure 9: *Draw regions* window.

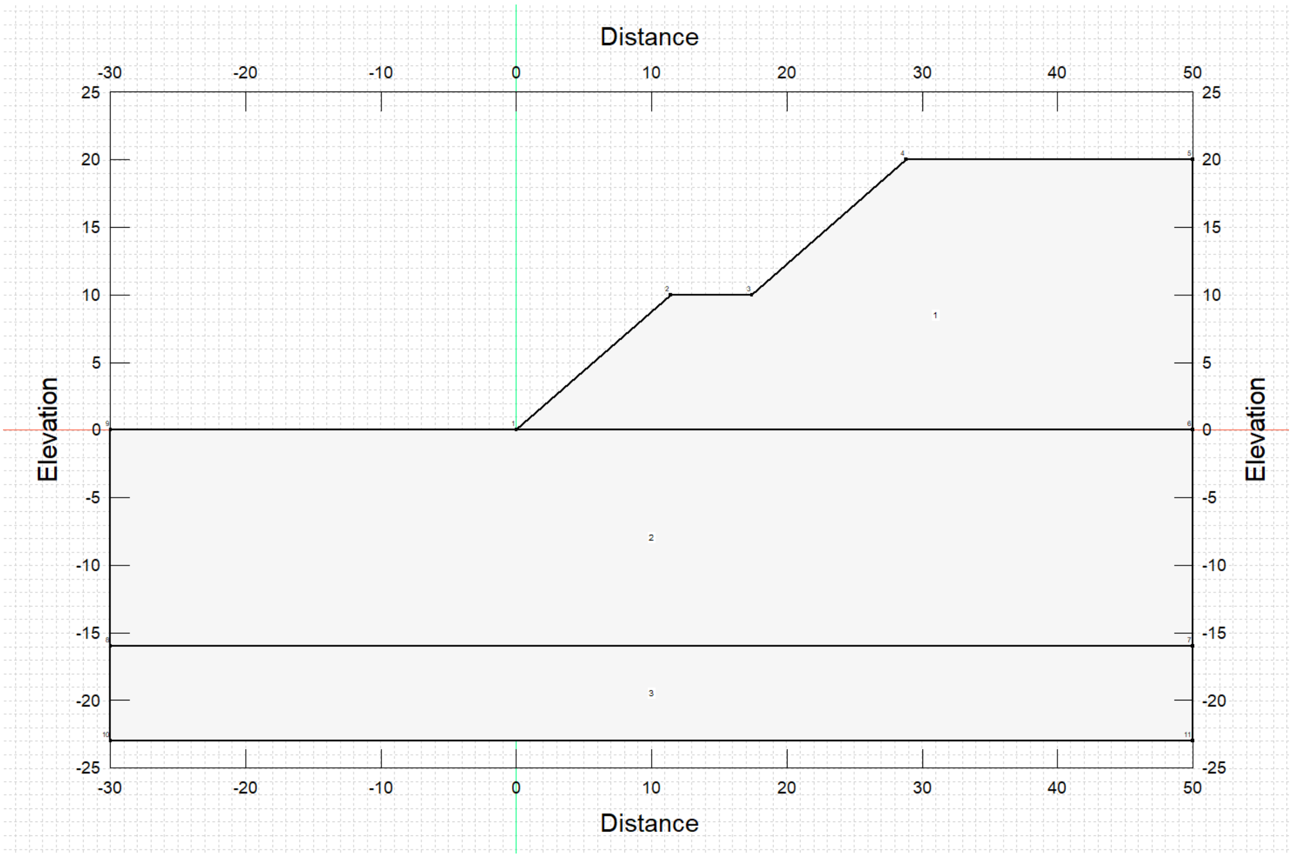

Figure 10: Geometry according to Figure 1 and Table 1.

Define and assign materials

The command 'Define→Materials' allows defining the properties of the materials. For the case under study, select Mohr-Coulomb material model and write the basic information of the soils according to the given data (Table 1).

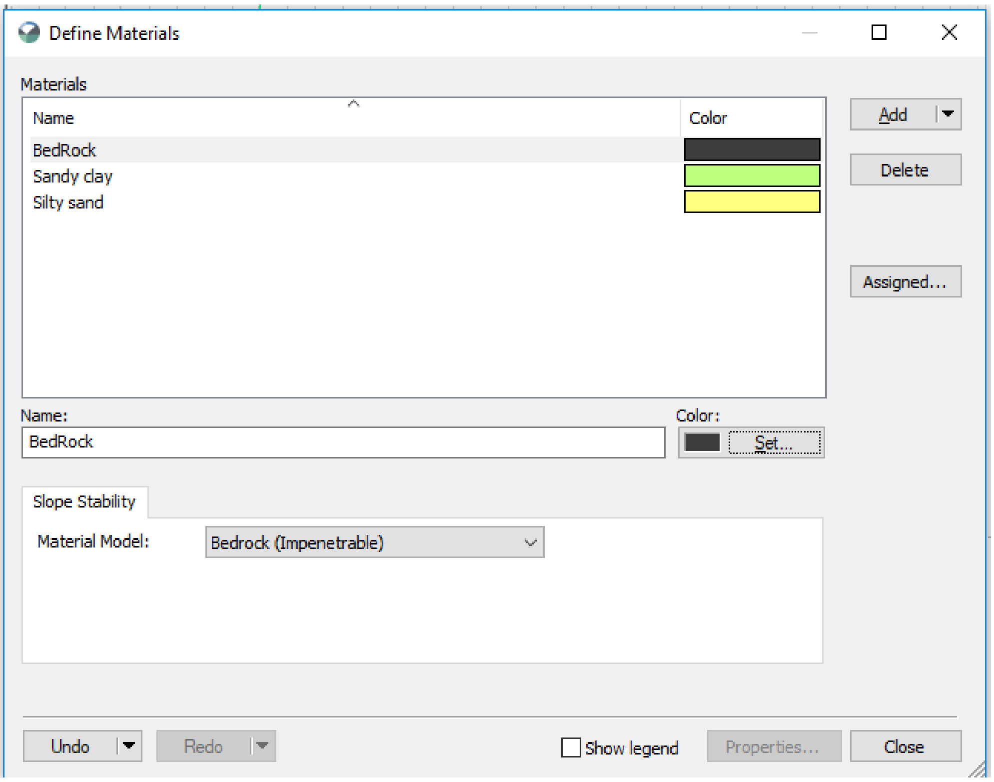

Figure 11: *Define materials* window.

The defined material can be assigned to the specific region of interest. For the case under study, the defined material has to be assigned to the corresponding domain. In order to assign the material do 'Draw → Materials → Assign' and select the respective domain. If the assignment is successful, the region is colored with the color corresponding to the chosen material (Figure 12).

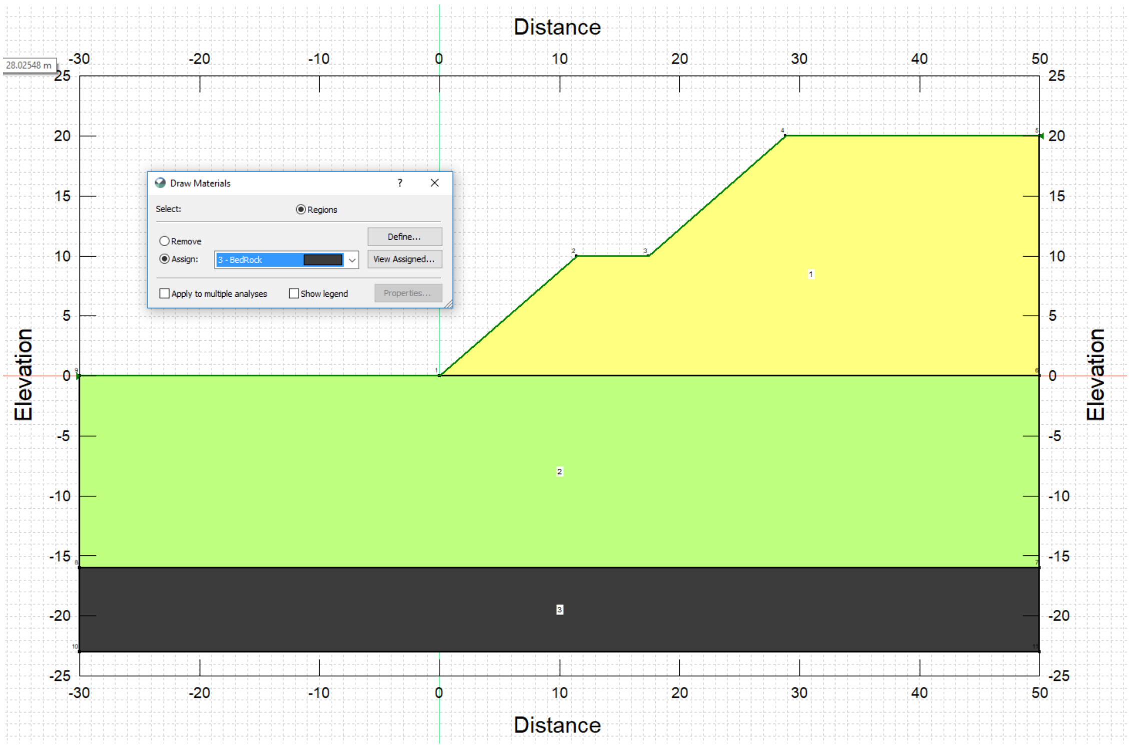

Figure 12: material assignment.

Definition of the possible failure surfaces

The centers of rotation of the circular surfaces and the lines that control the slip surface radii can be selected by using the command 'Draw slip surface grid' and 'Draw slip surface radius' from the command bar (Figure 13 and 14).

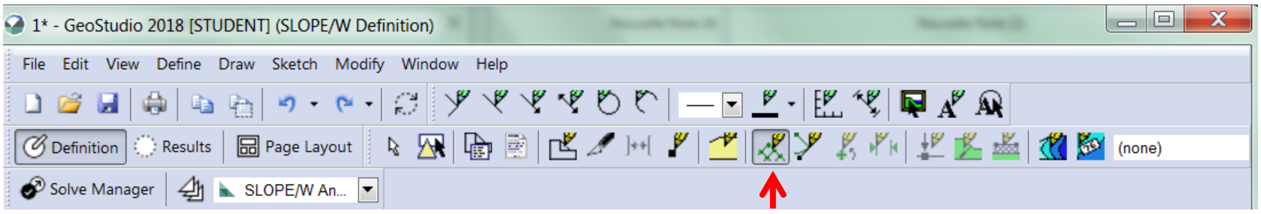

Figure 13: Draw slip surface grid.

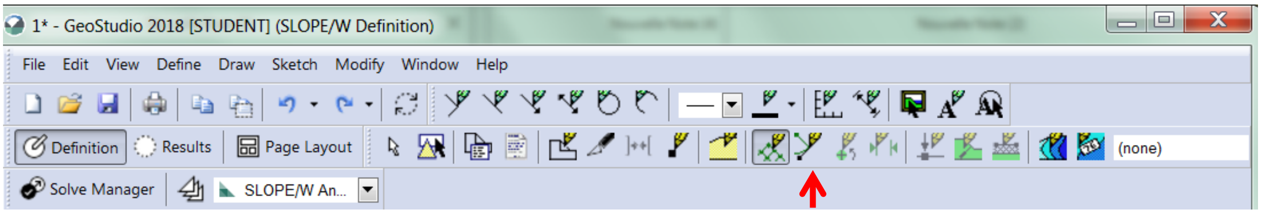

Figure 14: Draw slip surface radius.

Note that the grid must be defined by first clicking on the Upper-Left corner, then the Lower-Left corner and finally the Lower-Right corner.

A possible configuration of the grid and of the tangent lines is given in Figure 15.

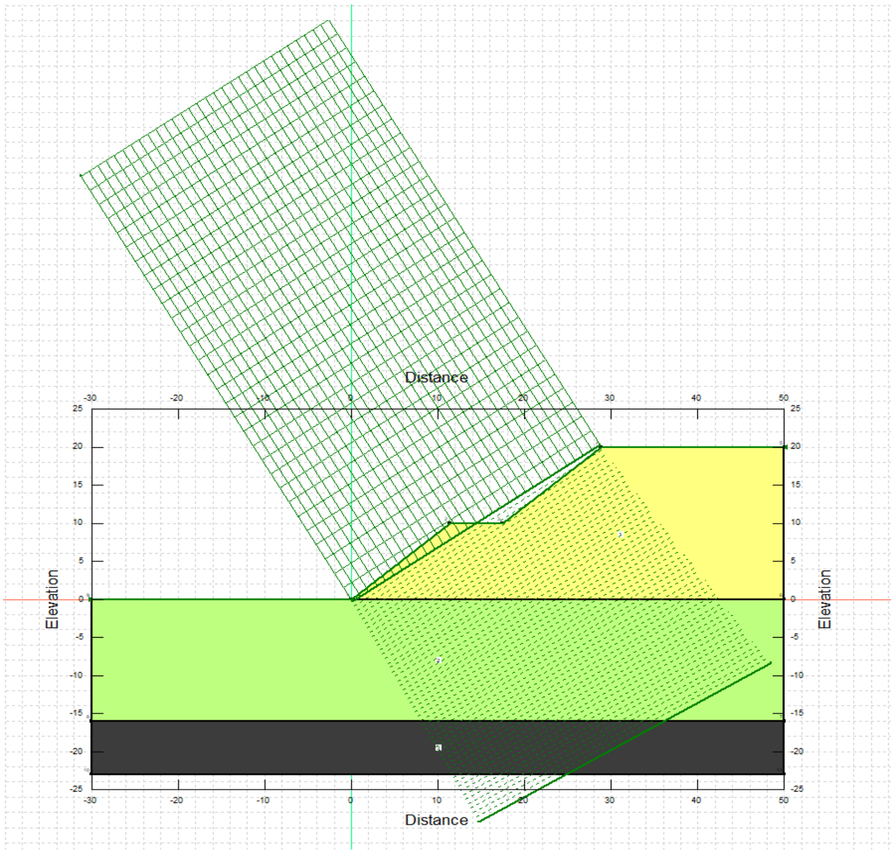

Figure 15: grid and radius definition.

Processing step

The processing step can be performed by launching the Solve Manager.

Post-processing step

At the end of the computation step, the interface automatically turns in the ‘Results’ mode: the ‘Definition’ button is de-selected. This is the post-processing interface of SLOPE/W which allows displaying and analyzing the results. For identifying the critical slip surface and analyzing the safety factors values follow the path: ‘Window → Slip Surfaces’. For setting the options of the Color Map (change colors, show the legend…), select the bottom ‘Draw slip surface color map’ on the command bar (Figure 16).

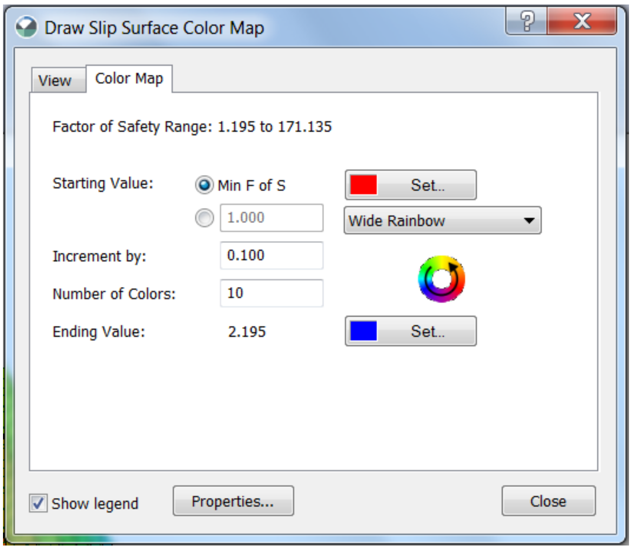

Figure 16: *Draw slip surface color map* window.

Several failure surfaces need to be analyzed iteratively in order to identifying the one which correspond to the minimum safety factor value (the corresponding failure mechanism should also be shown to be significant in terms of involved volume of soil).

In Figure 17 the expected critical failure surface according to the simplified Bishop method is shown. As last prescriptions for the current tutorial, remember to change the analysis mode for the Morgenstern-Price method through the interface reported in Figure 5 keeping the *half-sine function* as default settings (‘KeyIn Analysis→Analysis type→ Morgenstern-Price’ and ‘KeyIn Analysis→Settings→Side function→Half-sine function’).

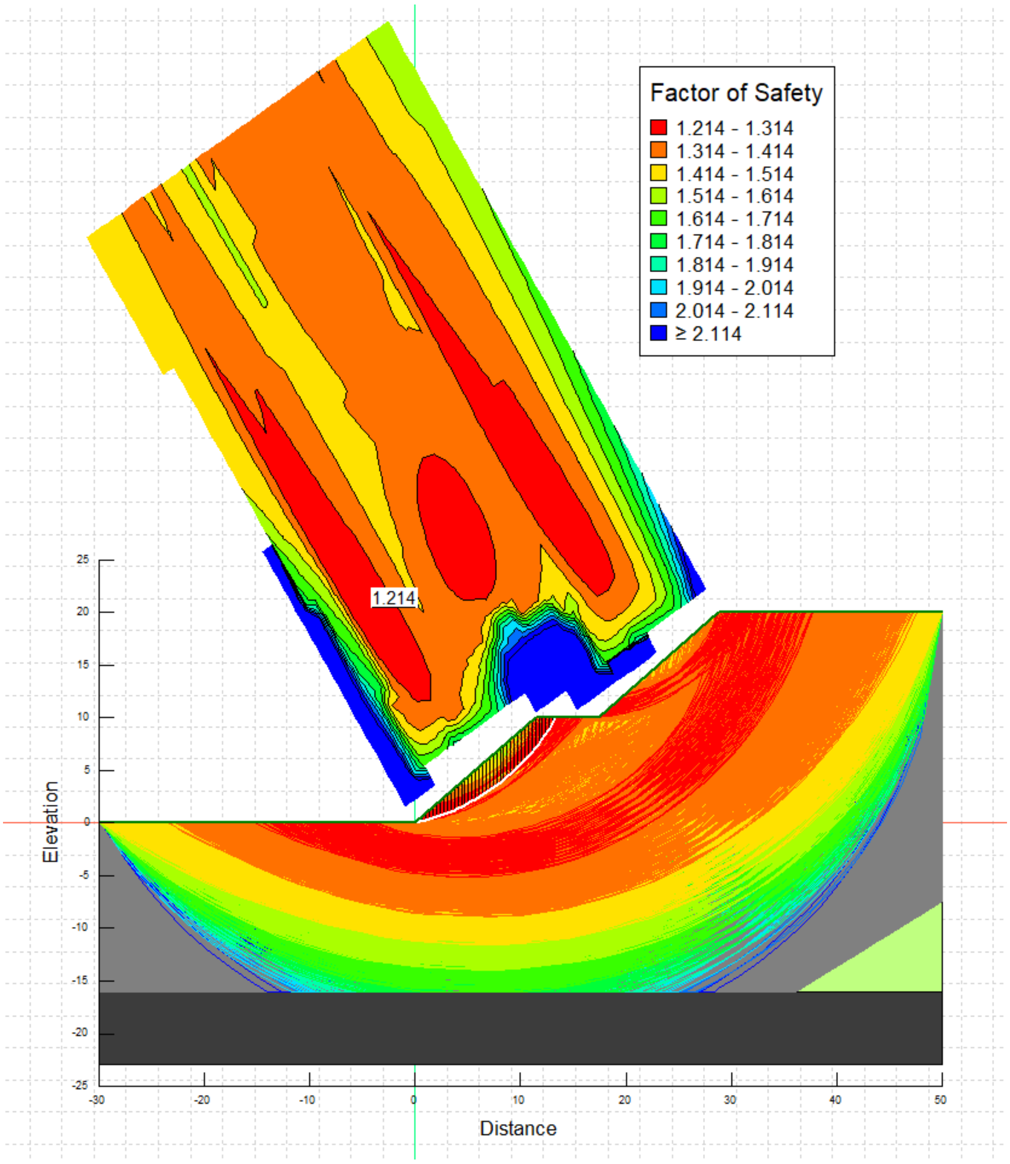

Figure 17: iso-*F* contour map and slip surface map according to the Bishop simplified method.

Conclude the Exercise by filling in Table 2 with the calculated factors of safety and the geometrical characteristics of the corresponding critical slip surfaces. Then, answer the questions given on page 2.

References:

1. Krahn, John. Stability Modeling with SLOPE/W - An Engineering Methodology. 2004.

2. Stability Modeling with GeoStudio (http://downloads.geoslope.com/geostudioresources/books/9/0/SLOPE%20Modeling-20180124.pdf