rocscience

Spatial Variability Multi Material

1. Introduction

Spatial variability analysis is a sub-option of the probabilistic analysis in Slide2, which allows you to simulate the variability of soil properties such as strength and unit weight, with location within a soil mass.

For an overview of spatial variability analysis in Slide2, using a simple one material slope, see Tutorial 33 Spatial Variability.

This tutorial example will demonstrate the spatial variability option using a multi-material rock-faced tailings dam model (Ref.1).

2. Note on Number of Samples

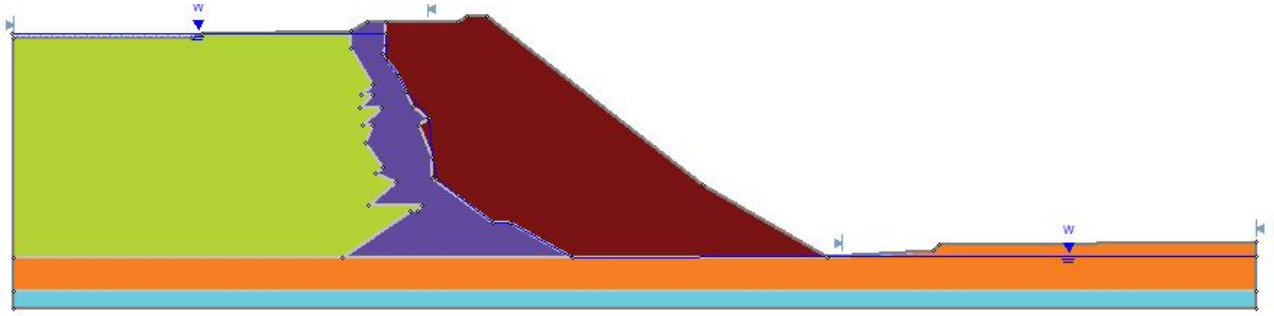
For the purpose of decreasing the compute time required to view results for this tutorial, the Number of Samples was set to the relatively low value of 500 in Project Settings.

It is important to note that for Spatial Variability Analysis, higher values are recommended.

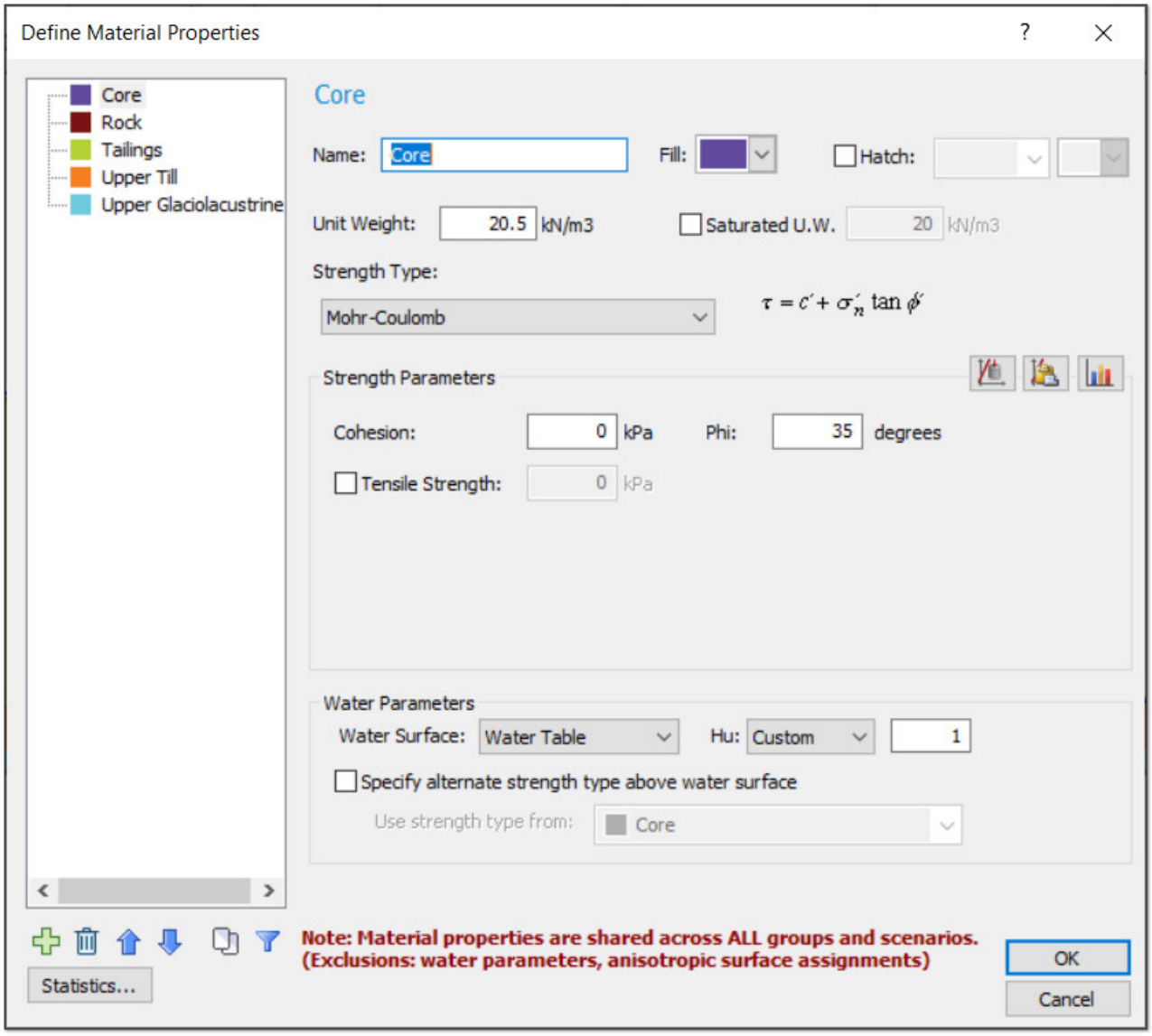
Number of Samples – a minimum of 1000 samples is recommended for probabilistic analysis using Latin Hypercube sampling. With spatial variability analysis, even higher numbers are sometimes required (e.g. 2000 to 10,000 or higher, depending on the level of confidence required).

3. Model

1. Select **File > Recent > Tutorials** and open the file *Tutorial 34 Spatial Variability – starting file.slmd.*

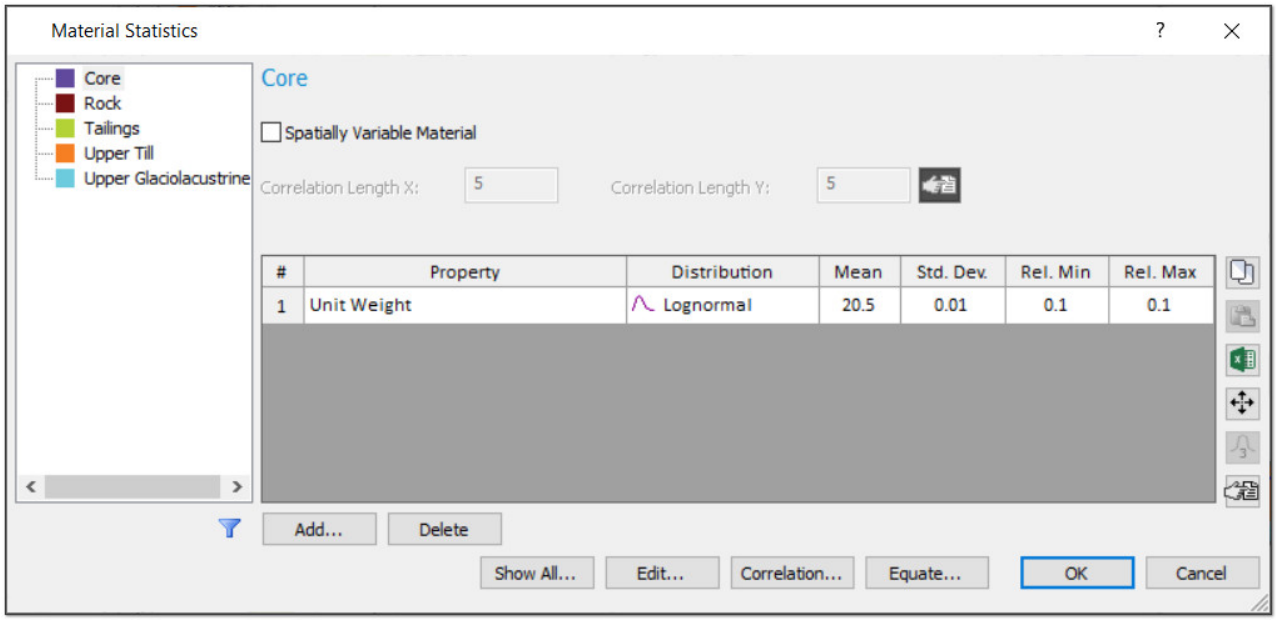


2. This model has five different materials. Select **Properties > Define Materials**.



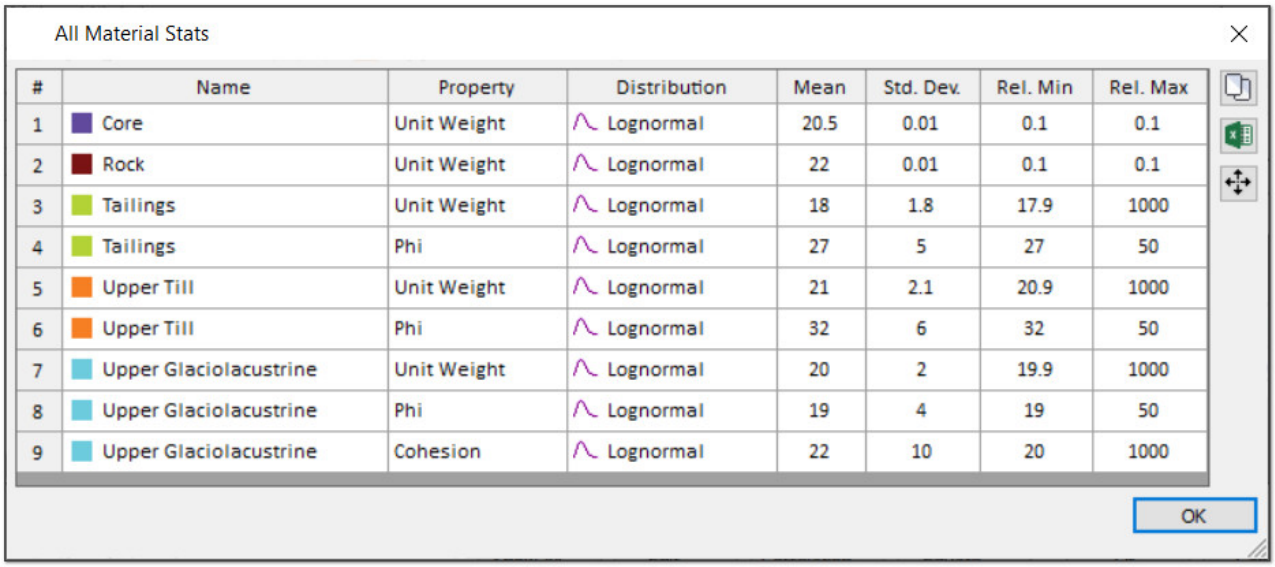
3. All five materials have statistical distributions defined for some of the material parameters. Select the **Statistics** button at the bottom of the **Define Materials** dialog

4. In the **Material Statistics** dialog, select the **Show All** button to see all the random variables which have been defined for material properties.



Note

- Unit Weight is a random variable for all materials
- Friction angle is a random variable for 3 materials
- Cohesion is a random variable for 1 material



5. Click **OK** and then **Cancel** in all dialogs.

We will first run the model WITHOUT spatial variability, using:

- the Overall Slope probabilistic analysis type with 500 samples
- non-circular slip surfaces with surface altering optimization
- GLE limit equilibrium method

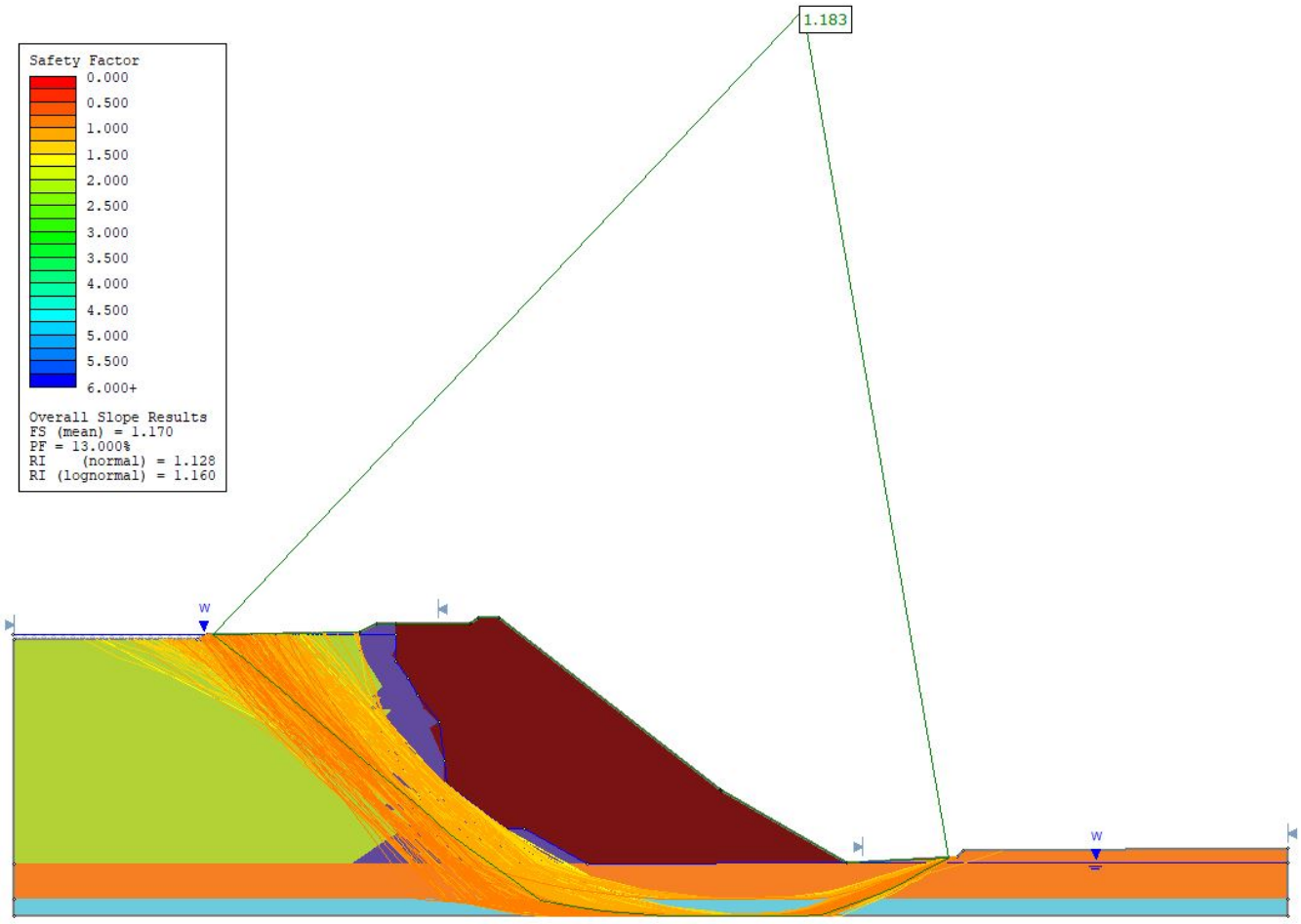
4. Compute

1. Select **Compute** to run the analysis.

Because we are using the Overall Slope probabilistic analysis with non-circular surface search optimization, the analysis will take some time, around 1 hour, depending on the speed of your computer.

5. Interpret

1. Select **Interpret** and you should see the following:

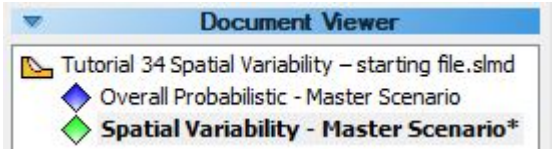



```
Overall Slope Results
FS (mean) = 1.170
PF = 13.000%
RI    (normal) = 1.128
RI (lognormal) = 1.160
```

The probability of failure for this model is about 13 percent, without considering spatial variability of material properties. Now we will re-run the analysis and include spatial variability.

6. Model (with Spatial Variability)

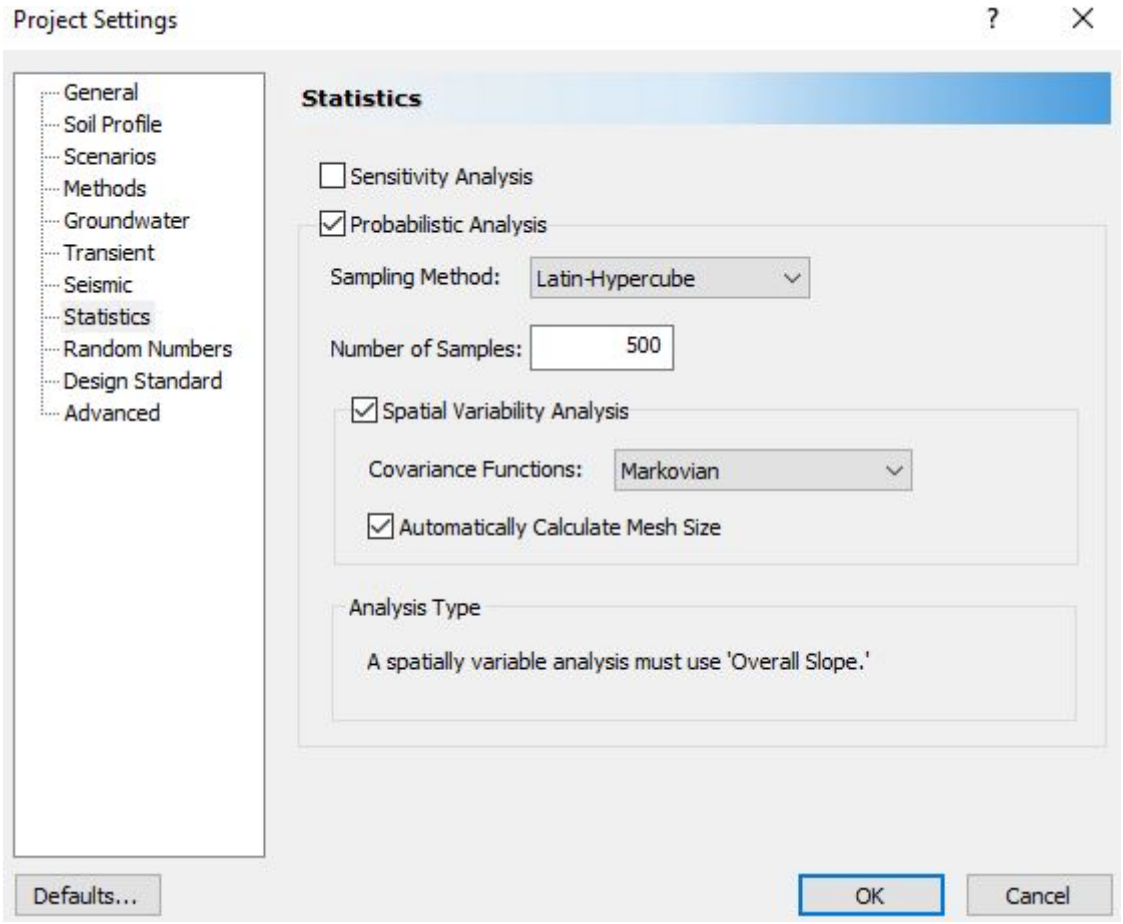
1. Duplicate the group and rename the two groups as shown.



2. Click on the **Spatial Variability** group.

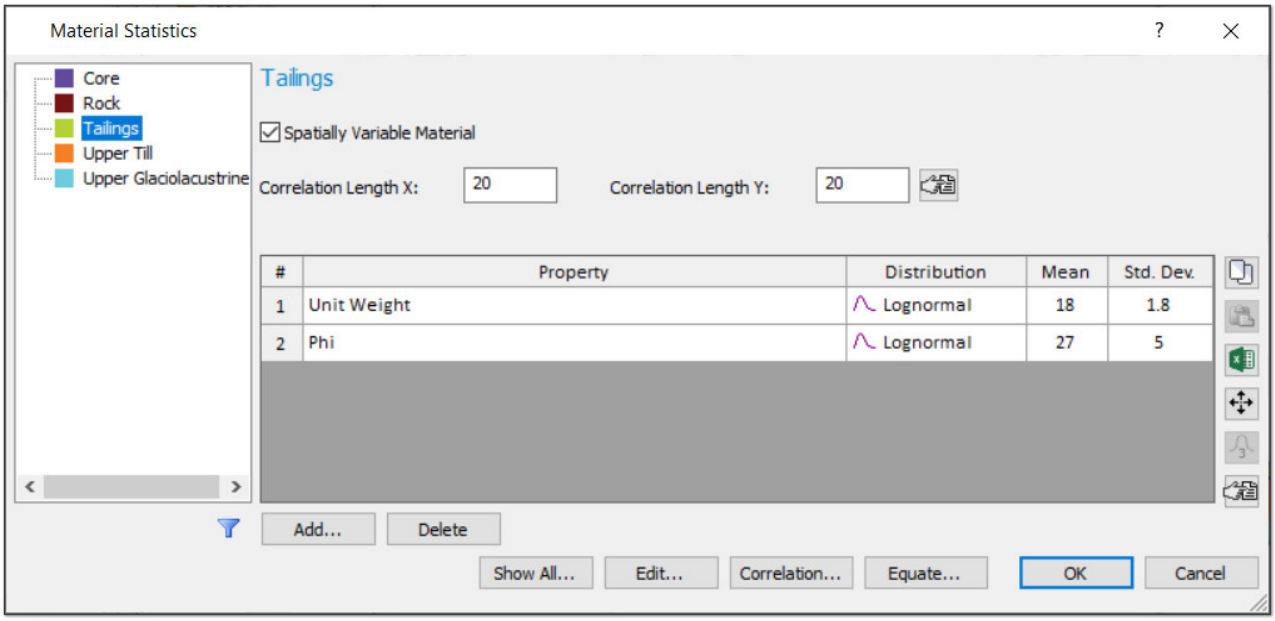
3. Select **Project Settings > Statistics** and turn on the **Spatial Variability Analysis** checkbox.

4. Click **OK**.

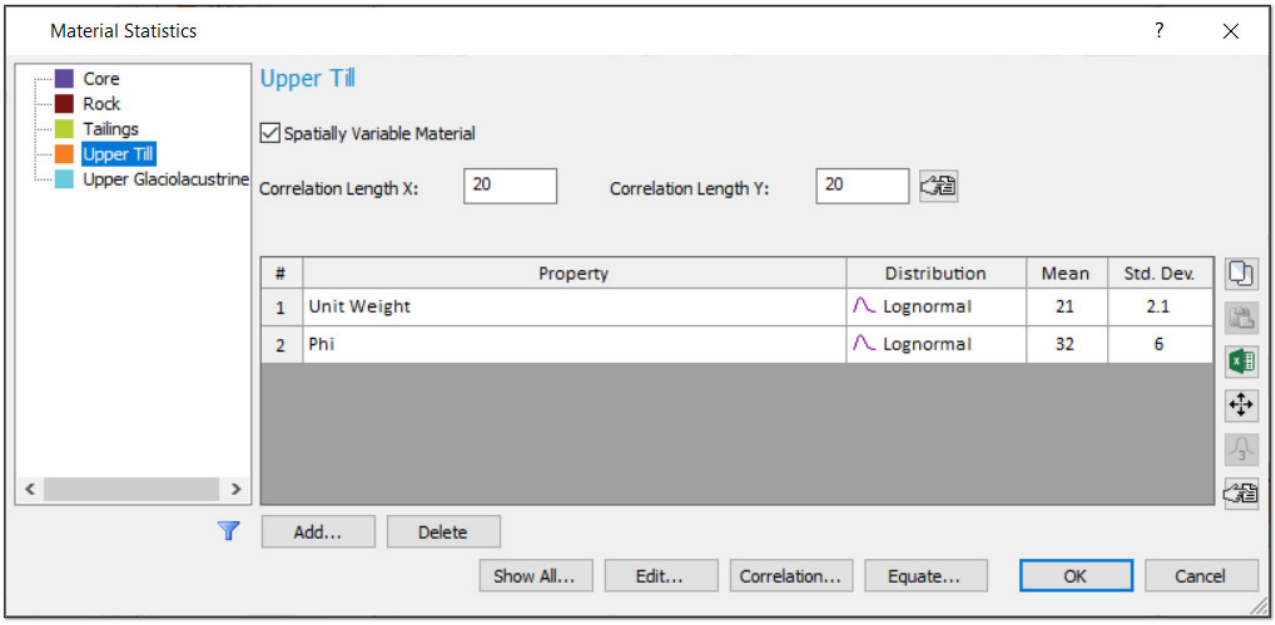


5. Select **Statistics > Materials**.

6. Select the **Tailings** material, turn on the **Spatially Variable Material** checkbox, and enter **Correlation Length = 20 meters** for both X and Y directions.



7. Repeat this for the **Upper Till** material and the **Upper Glaciolacustrine** material.



> **Note**
>
> The Core and Rock materials are NOT assigned spatial variability.

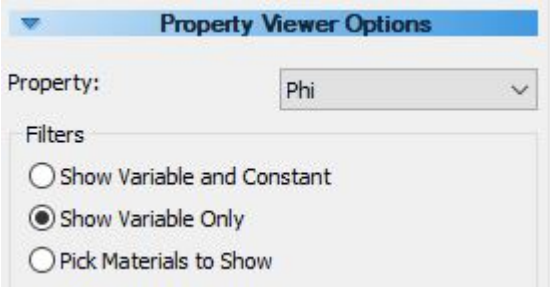
8. Select **OK** to save your input and close the **Material Statistics** dialog.

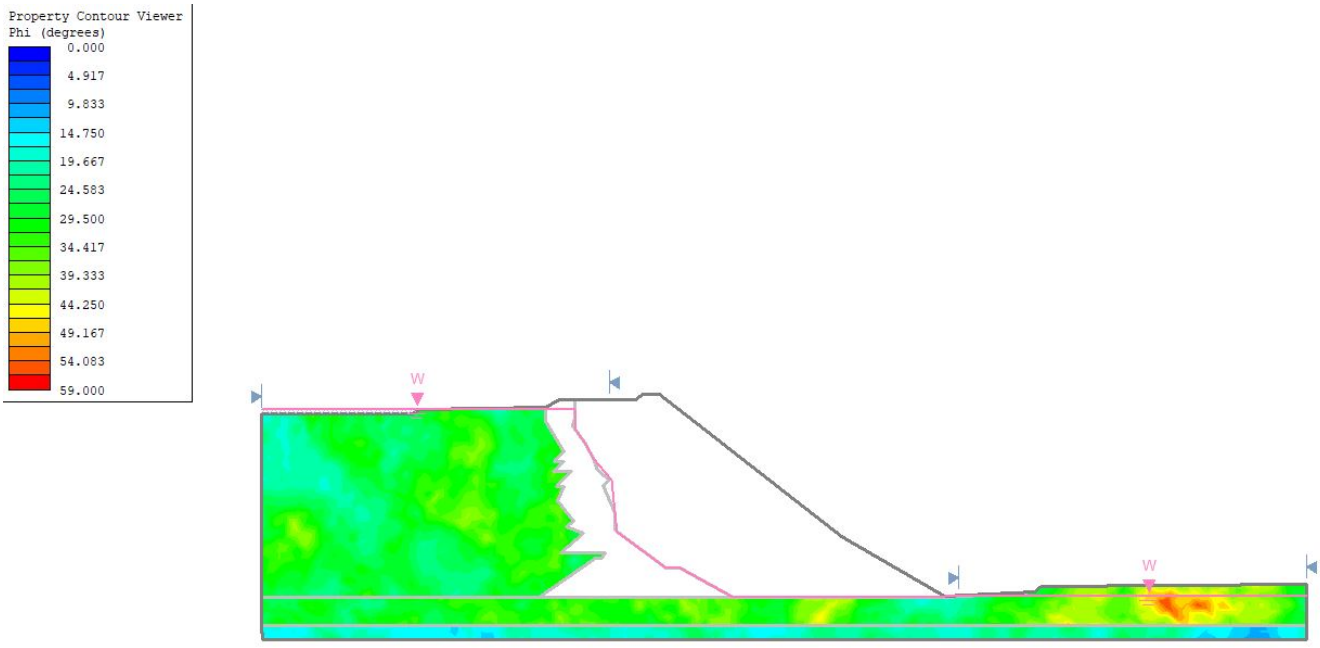
6.1 PROPERTY VIEWER

The **Property Viewer** option can be used to view contours of spatially variable data, and other types of data, directly on the model.

1. Select **Property Viewer** from the toolbar or the **Analysis** menu.

The data displayed by the Property Viewer is selected from the Property Viewer Options in the sidebar. For example, select **Property = Phi** and **Filter = Show Variable Only**. You should see the following contours of friction angle for the three spatially variable material regions.





If you scroll through the sample numbers, you will see contours of the random field generated for each random sampling. This is the actual data used for each run of the probabilistic analysis.

Select different property types (e.g. Cohesion, Unit Weight) to view the results. If a parameter does not have variable properties, it will be displayed using a white color on the model.

Experiment with the different Property Viewer Options.

Close Property Viewer

To close the Property Viewer and return to the model view, select:

- the **Close** button in the toolbar, OR
- the Return to Modeler option in the right-click menu.

This will close the Property Viewer and return you to the main model view.

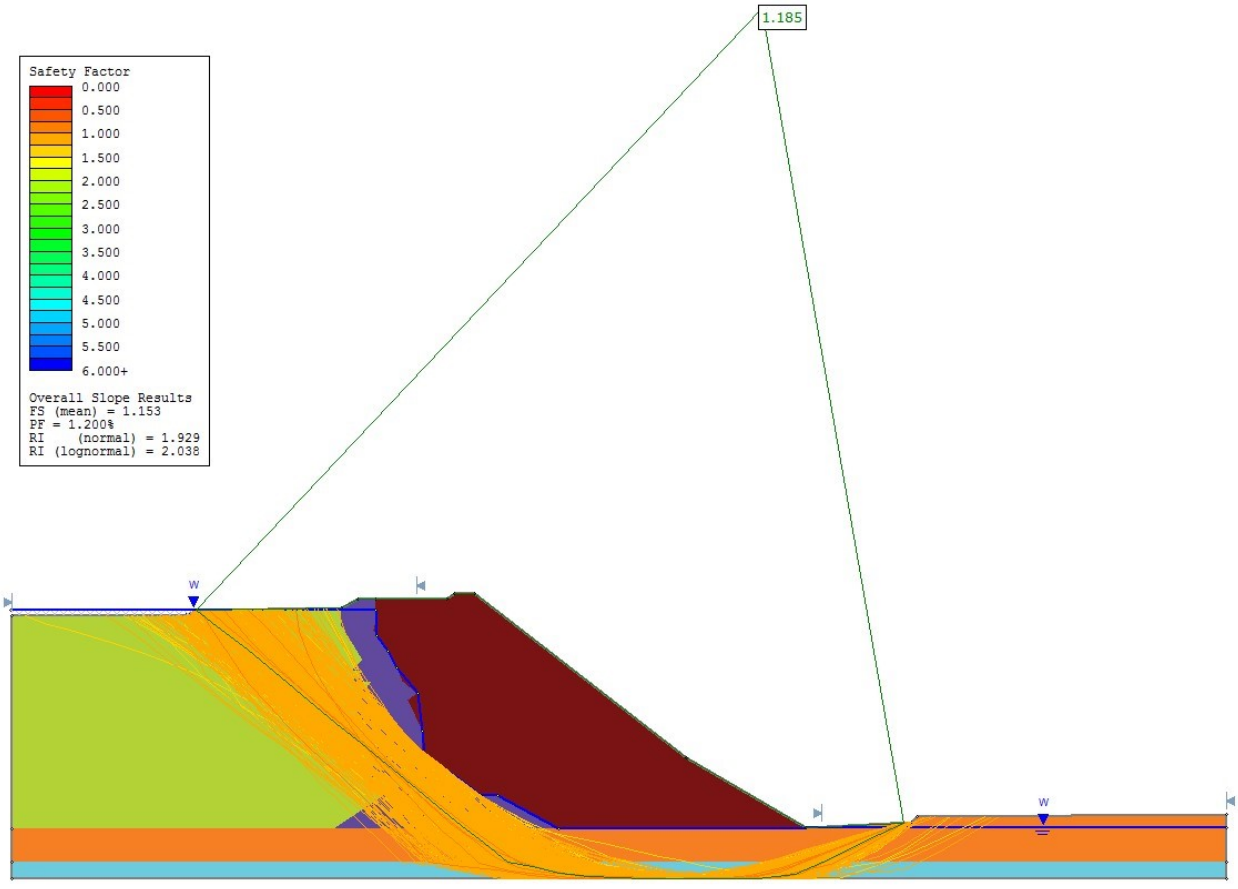
7. Compute

1. Select **Compute**  . Only the new scenario will be automatically selected.
2. Click **OK**. Depending on the speed of your computer, this may take around an hour.

8. Interpret

1. Select **Interpret** 

With spatial variability included, the **Probability of Failure** has dropped to approximately 1.0 percent.



This is the primary result of interest. With spatial variability included, the Probability of Failure has dropped from 13 percent to 1 percent.

Let's compare the distribution of safety factor from the two files.

1. For each scenario, select **Statistics > Histogram Plot**, and generate a safety factor distribution with FS < 1 highlighted.
2. For each of the histogram plots, select **Edit Properties**, and enter the same min and max values for the horizontal axis: Min = 0.5 and Max = 2.0.
3. Tile the graph views and minimize the model views.

You should see the following. The histogram on the right shows the safety factor distribution with NO spatial variability, and the plot on the left shows results WITH spatial variability.

This comparison highlights the effect of using spatial analysis.

- With spatial variability included (left plot) the distribution of safety factors from the Overall Slope probabilistic analysis is much narrower than the plot on the right (no spatial variability).
- Considering spatial variability reduces the level of uncertainty of the problem.
- Fewer analyses had safety factor < 1, resulting in a lower Probability of Failure for the file with spatial variability.

Maximize the model view for the spatial analysis file.

8.1 PROPERTY VIEWER

The Property Viewer is available in both the **Model** and **Interpret** programs. In Interpret, the Property Viewer has the additional capability of showing results for slip surfaces corresponding to random samples of the spatial probabilistic analysis.

1. Select **Property Viewer** from the toolbar or the **Analysis** menu.
2. In the Property Viewer Options in the sidebar, select:
    - Property = Phi

- Filter = Show Variable Only
- Normalize Spatial Contours to StdDev (checkbox ON)

3. Scroll through the sample numbers.

You will notice that the global minimum slip surface corresponding to the current sample is displayed.

The **Normalize Spatial Contours to StdDev** option normalizes the contours for all spatial materials, relative to the standard deviation for each material so that you can quickly see the relative min and max values of the random fields, for all materials. If you wish to plot the actual (absolute) values then simply turn this checkbox off.

While in the Property Viewer, notice the options in the toolbar:

- Synchronize Property Viewers
- Open New Property Viewer
- Contour Options
- Display Options

The first two options are helpful when there is correlation between parameters. They would allow you to view the random field for cohesion and friction angle at once, for example, by tiling the Property Viewer views. By synchronizing the property viewers, you would be able to scroll the samples at the same time.

Notice the options to the right of the **Sample Number** field.

- Filter Samples

- Show the sample that gives the minimum factor of safety

4. Select the **Filter Samples** option.
5. In the **Filter Samples** dialog, select the option of **samples with the lowest factors of safety** and enter **10**.
6. Select **Done**

If you now scroll through the sample numbers in the sidebar, you will see that only the 10 lowest safety factor samples and slip surfaces are displayed.

> **Note**
>
> The sample numbers shown in the Sample Number edit box, are the actual sample numbers generated during the analysis.

7. Now click on the **minimum factor of safety** button next to it.

You will see sample 359 which has a factor of safety of 0.942 as shown.

That concludes this tutorial.

You are encouraged to experiment with the **Property Viewer Options** and the **Contour Options** to become familiar with the many different display possibilities.

To read more about this example please see Ref. 1.

9. References

Cami, B., Javankhoshdel, S., Lam, J., Bathurst, R.J. and Yacoub, T. 2017. Probabilistic analysis of a tailings dam using 2D composite circular and non-circular deterministic analysis, SRV approach, and RLEM. 70th Canadian Geotechnical Conference, Ottawa, Ontario, 7 p.