Example Application 19

Swelling of a Fully Wetted Slope

Soil Properties for Slope

Soil	3	4	5
mass density (kg/m^3)	1728.3	1575.4	1978.5
bulk modulus (Pa)	1.54×10^7	3.27×10^7	2.93×10^7
shear modulus (Pa)	7.12×10^6	1.5×10^7	2.2×10^7
cohesion (Pa)	4,800	4,800	1,440
friction angle (degrees)	30	30	40
tension limit (Pa)	0.0	0.0	0.0
swelling properties			
a_1	1.533	0.694	0.0004
a_3	0.436	0.468	0.00047
c_1	-0.0187	-0.0211	0
c_3	-0.0215	-0.023	0.001
angle	0	0	0
m_1	0.023	0.028	0
m_3	0.036	0.036	0
modnum	1	1	2
ninc	50,000	50,000	50,000
pressure	1.0133×10^5	1.0133×10^5	1.0133×10^5

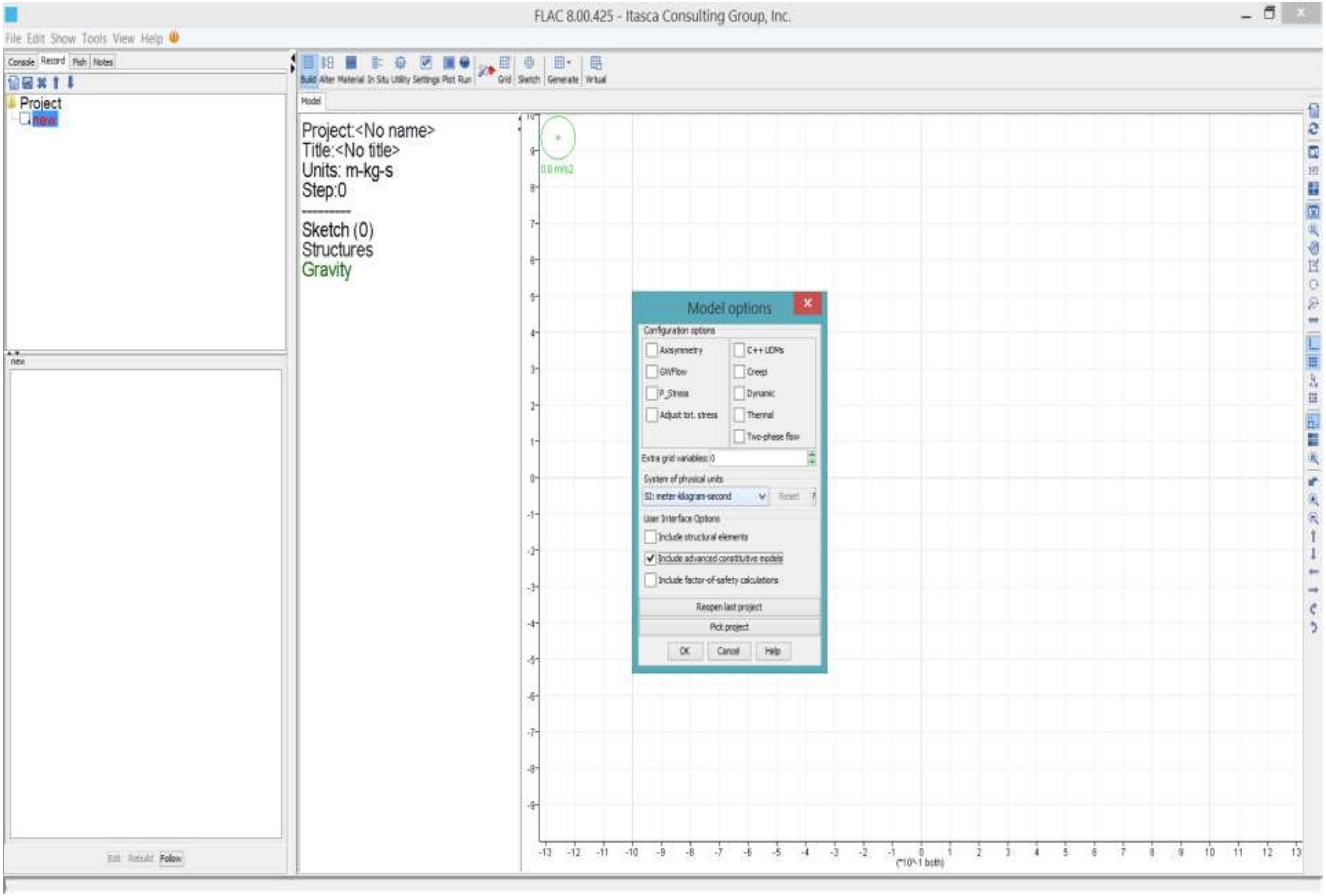
Modeling Procedure

Step 1 Create the fill slope model grid, set boundary conditions, assign the swell material model and specify properties for the three layers of fill. Do not input swelling properties, and the soil will behave as un-wetted Mohr-Coulomb material.

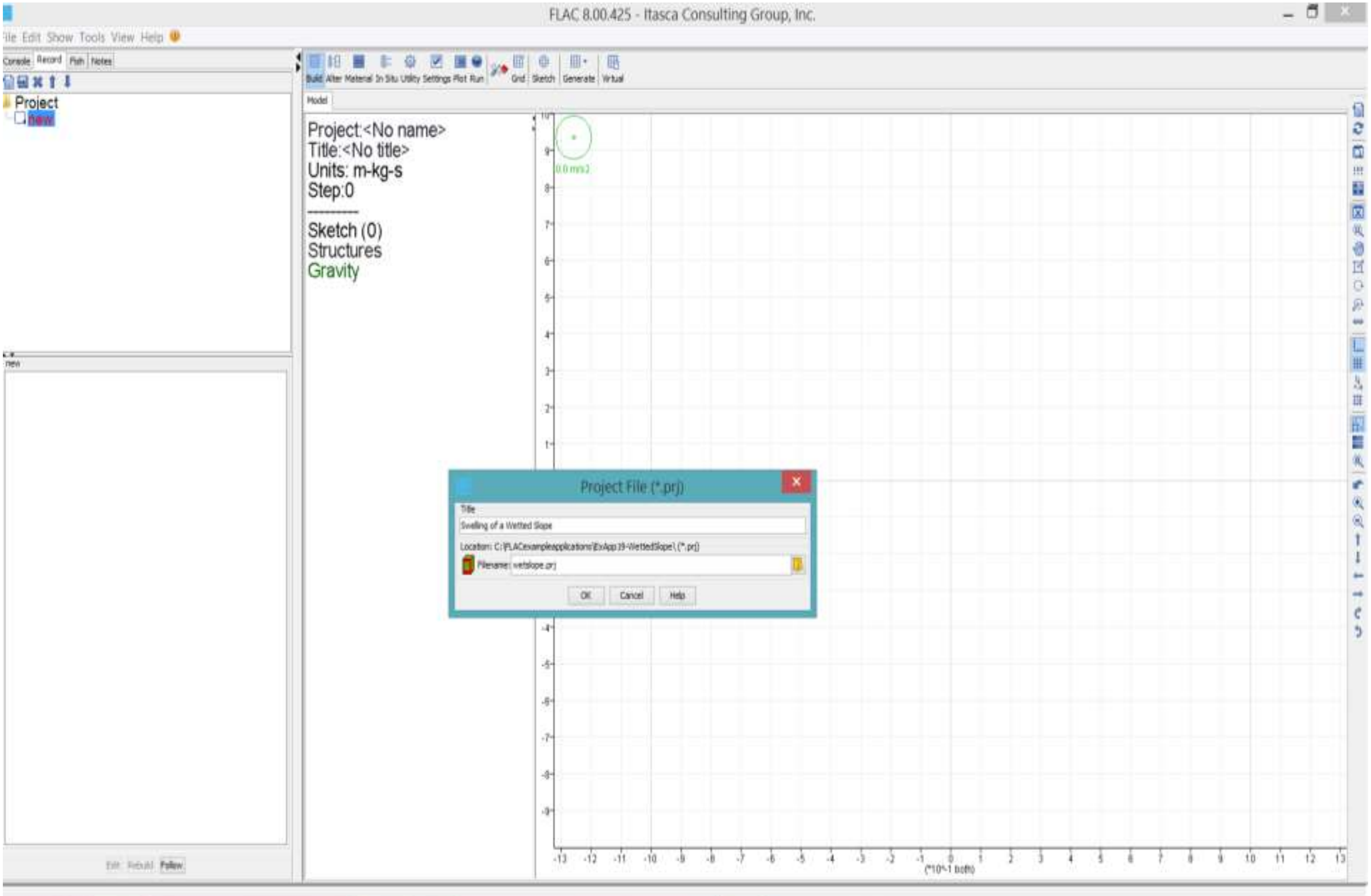
Step 2 Calculate the initial stress state in the slope.

Step 3 Simulate wetting by activating the swelling properties for the swell model.

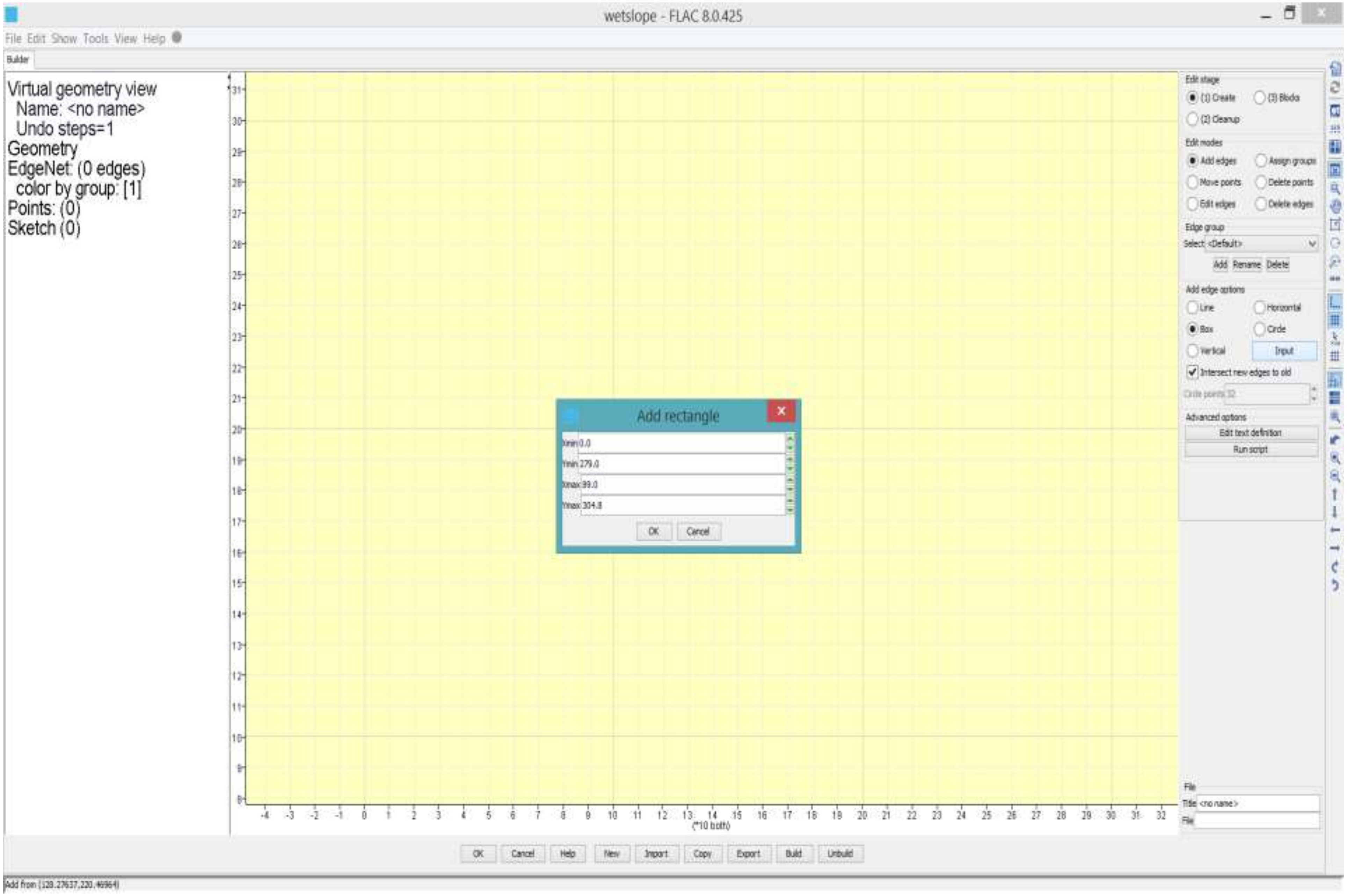
Step 4 Calculate the maximum swelling movement and compare to actual measurements.



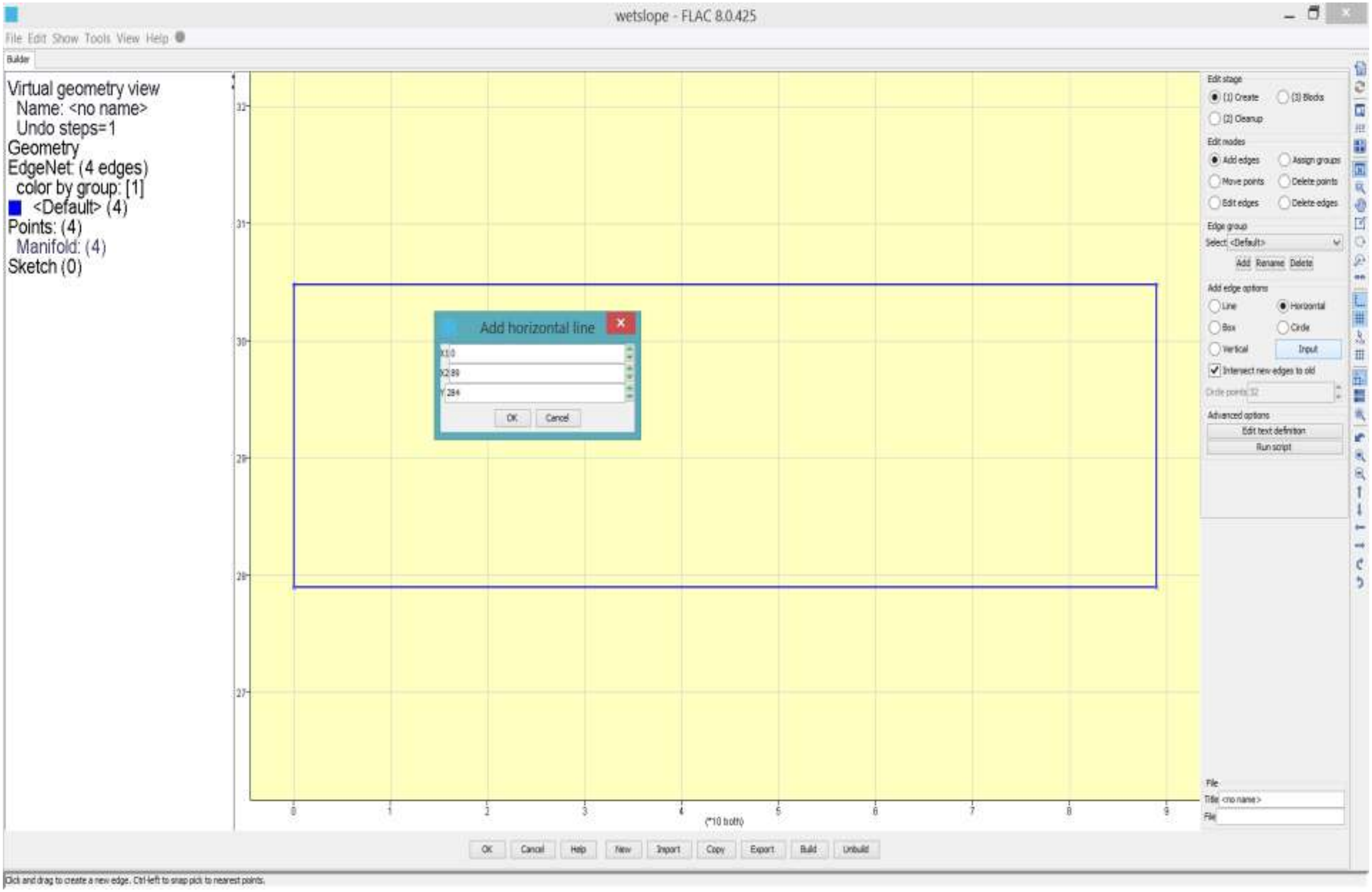
The [Include advanced constitutive models] is checked to allow access to the swell constitutive model.



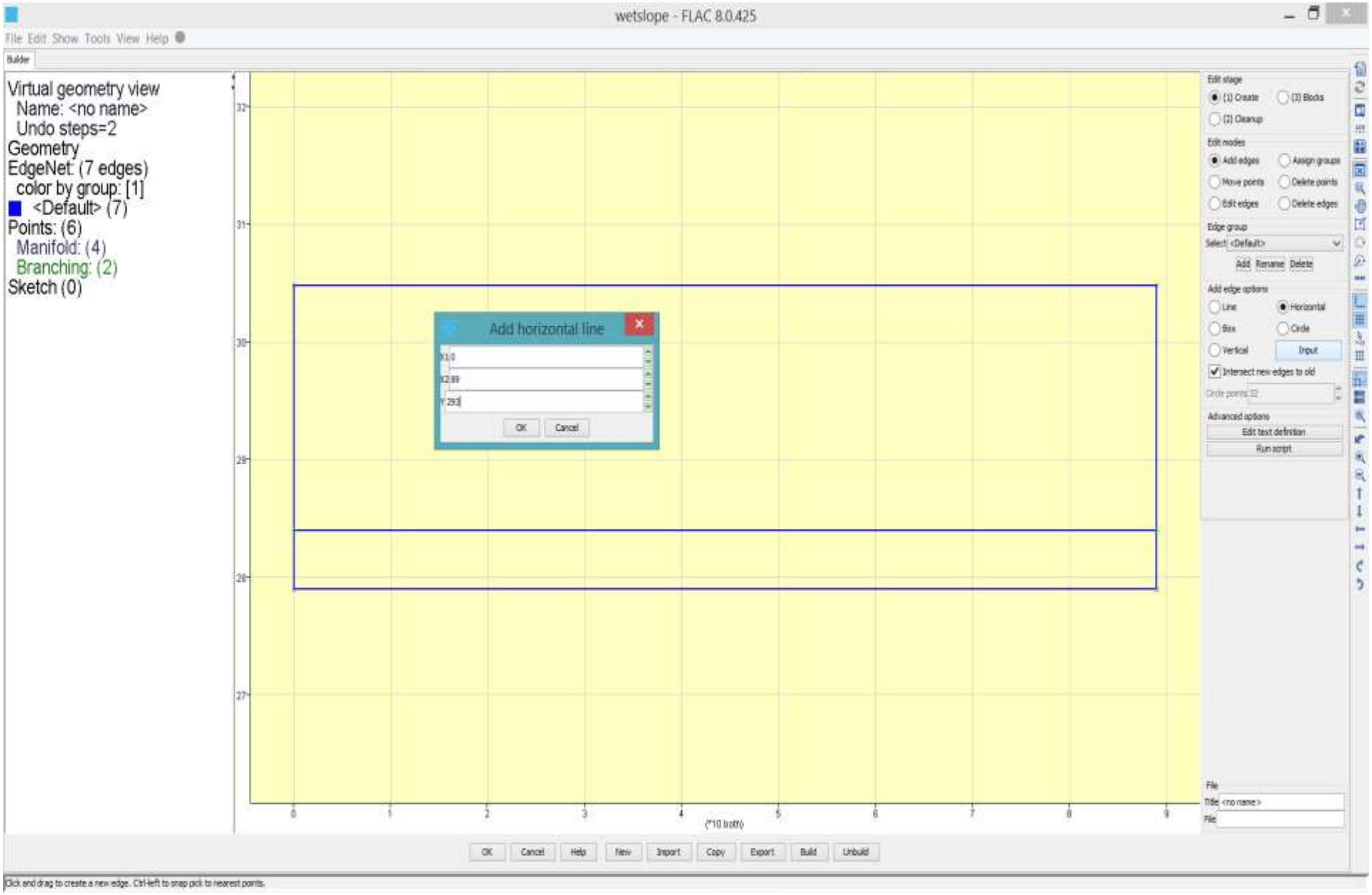
A project title is assigned, and a project file **wetslope.prj** is created and stored in a working directory.



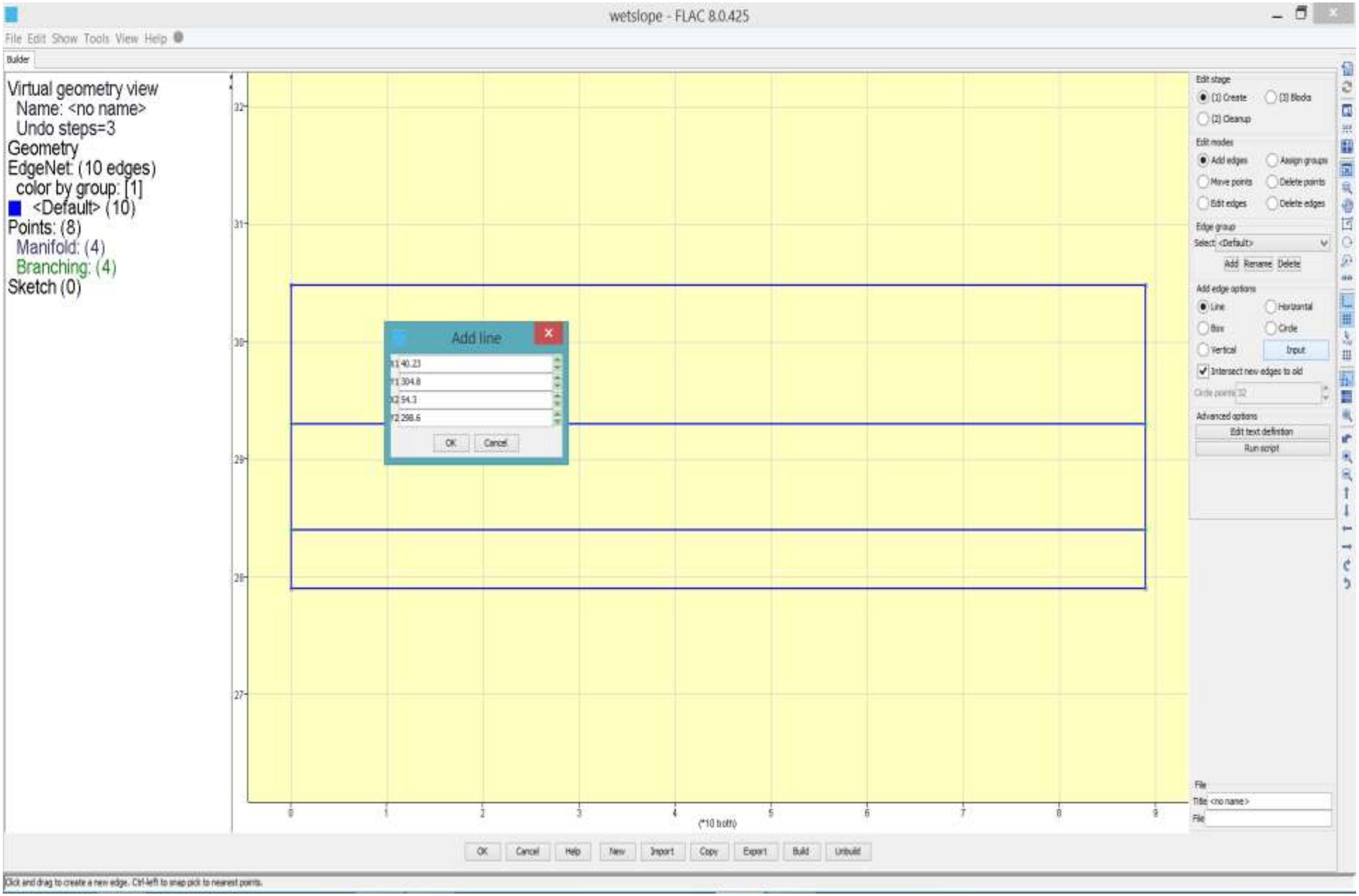
Step 1-1 Enter the [Build]/[Generate]/[Geometry Builder] tool, select [Box] and set the outer dimensions at 0.0 < x < 89.0, 279.0 < y < 304.8.



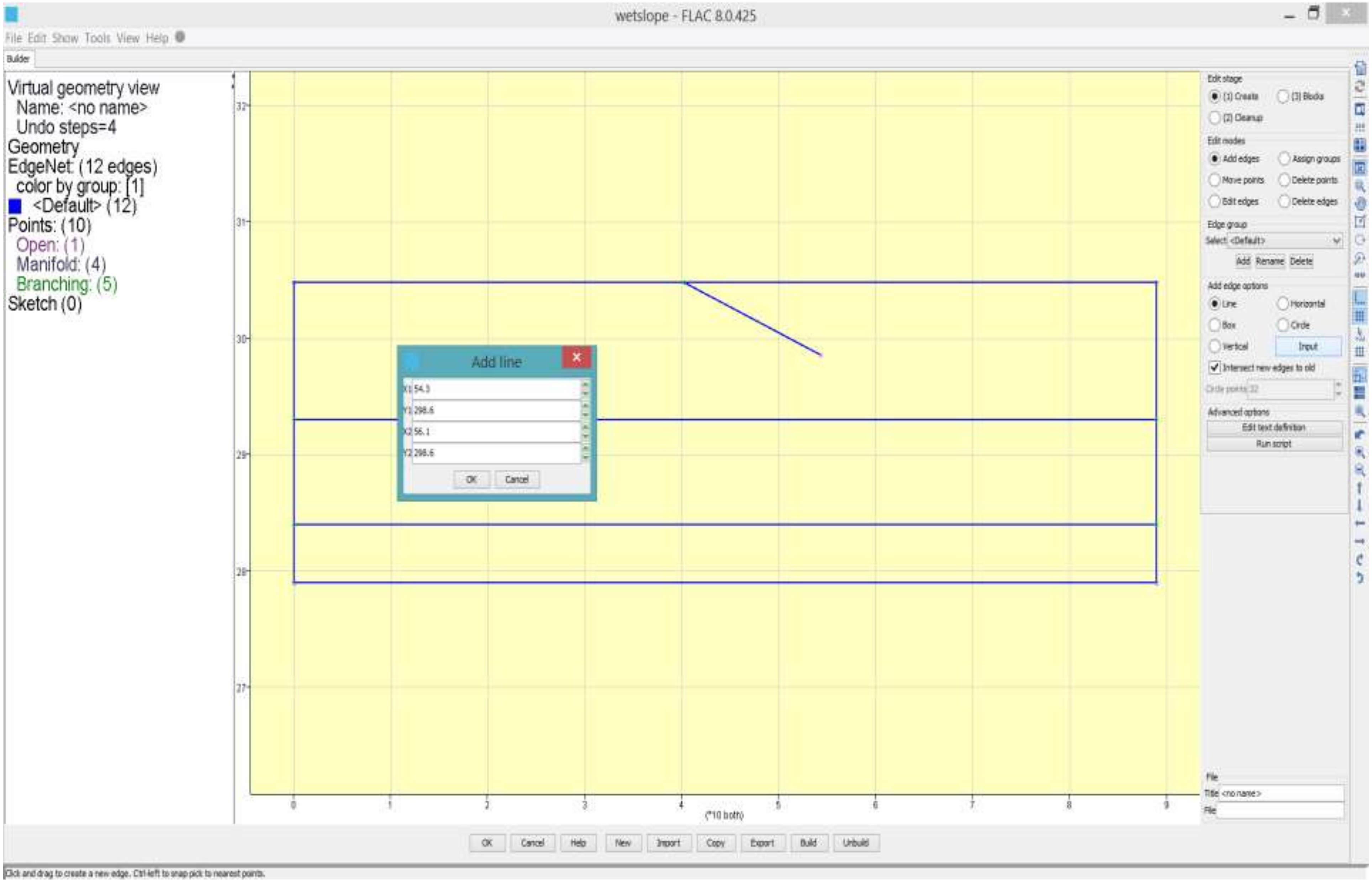
Step 1-2 Select [Add edges]/[Horizontal] and locate a layer boundary at y = 284.0.



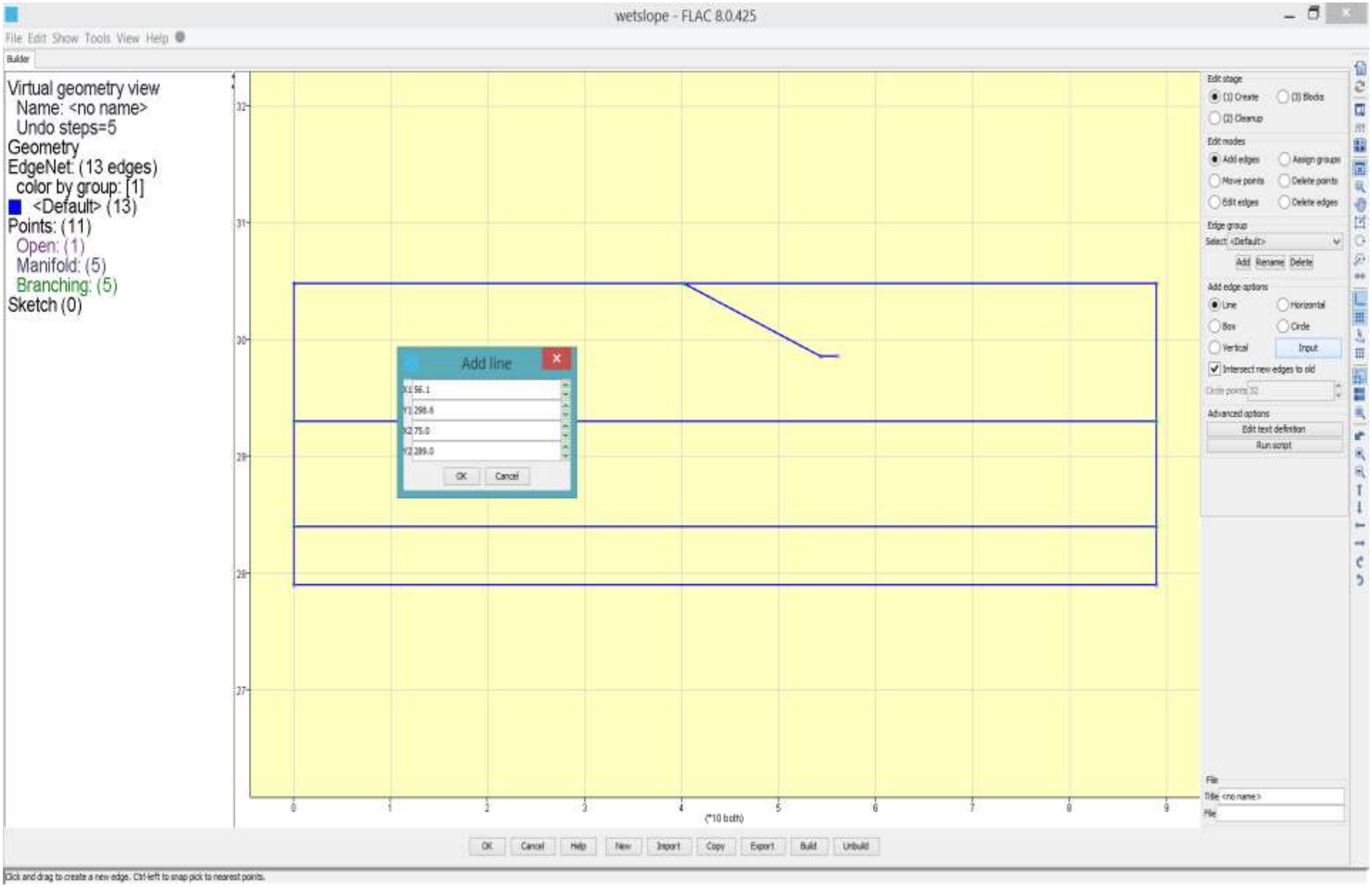
Step 1-3 Select [Add edges]/[Horizontal] and locate a layer boundary at y = 293.0.



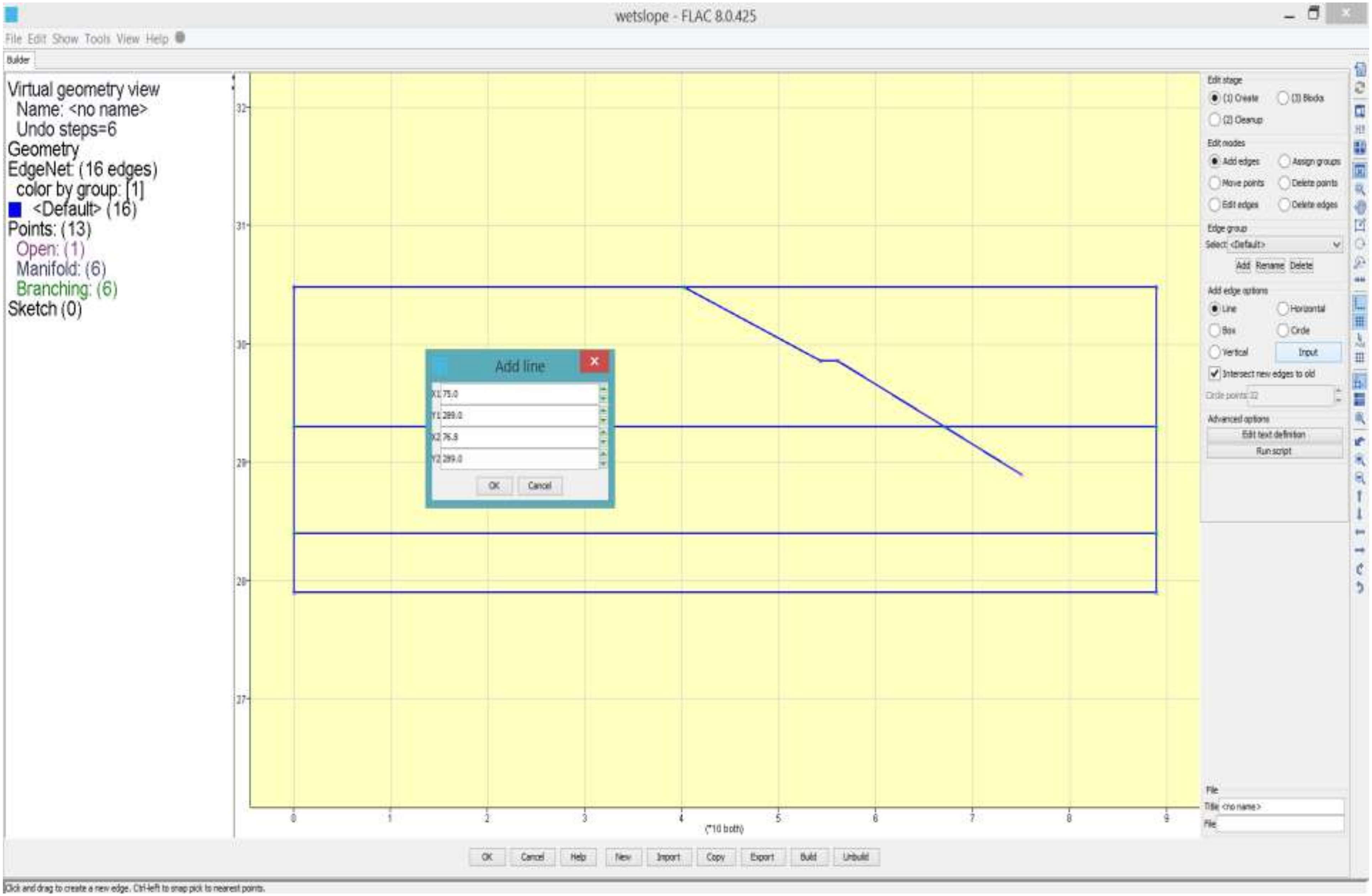
Step 1-4 Select [Add edges]/[Line] to create the slope surface. Create the first line from x1=40.23, y1=308.8 to x2=54.3, y2=298.6.



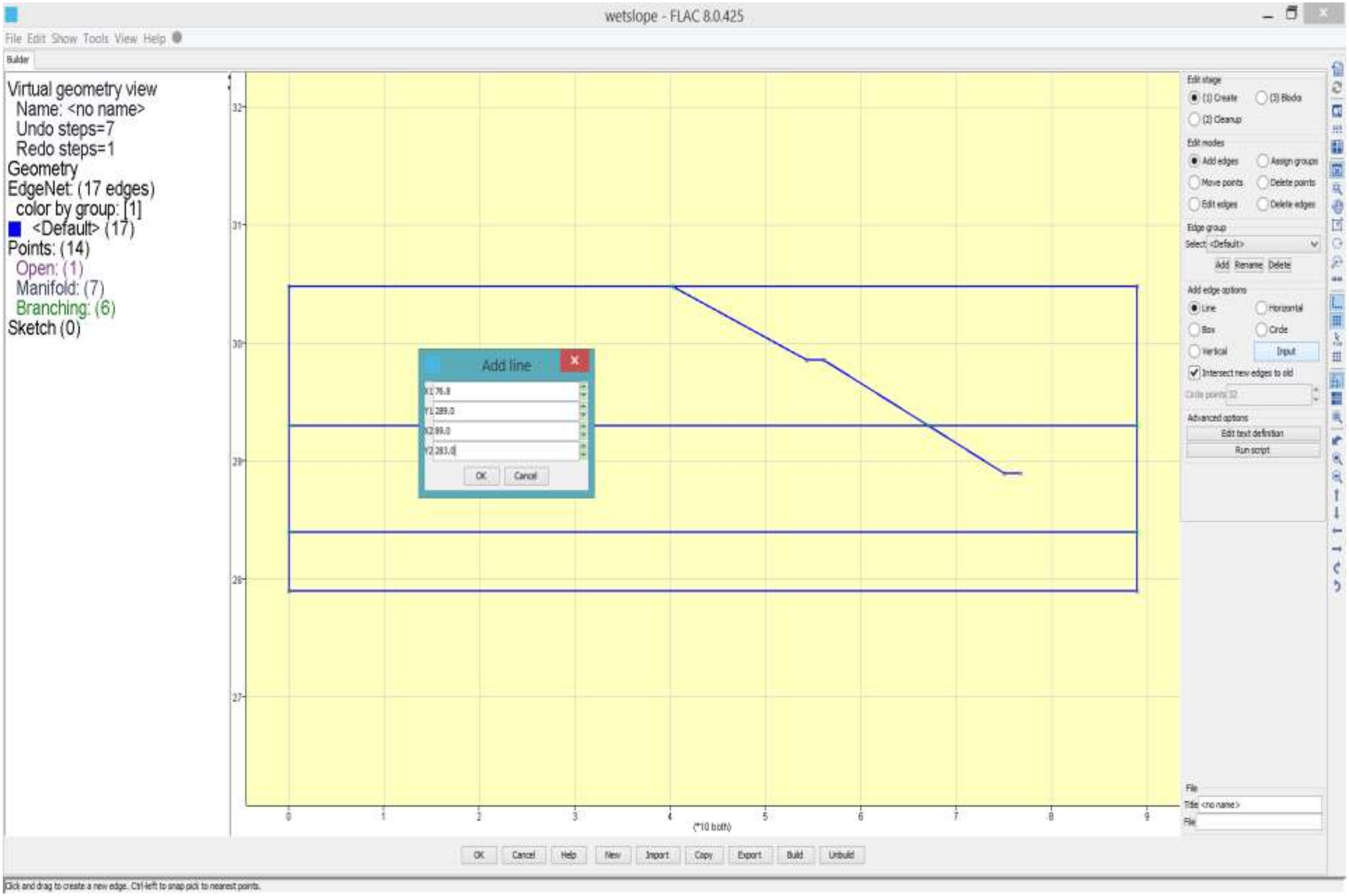
Step 1-5 Create the next line from x1=54.3, y1=298.6 to x2=56.1, y2=298.6.



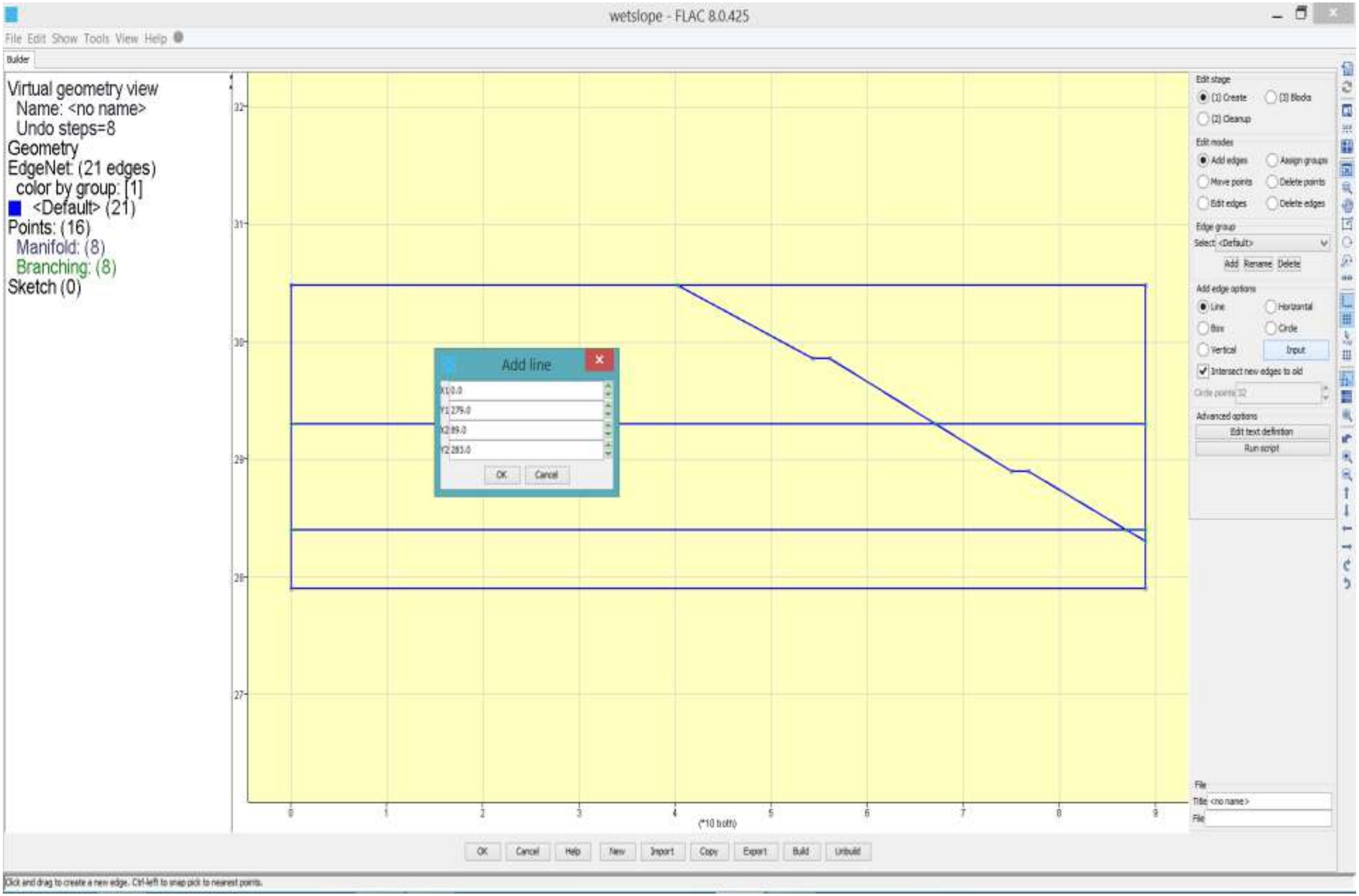
Step 1-6 Create the next line from x1=56.1, y1=298.6 to x2=75.0, y2=289.0.



Step 1-7 Create the next line from x1=75.0, y1=289.0 to x2=76.8, y2=289.0.

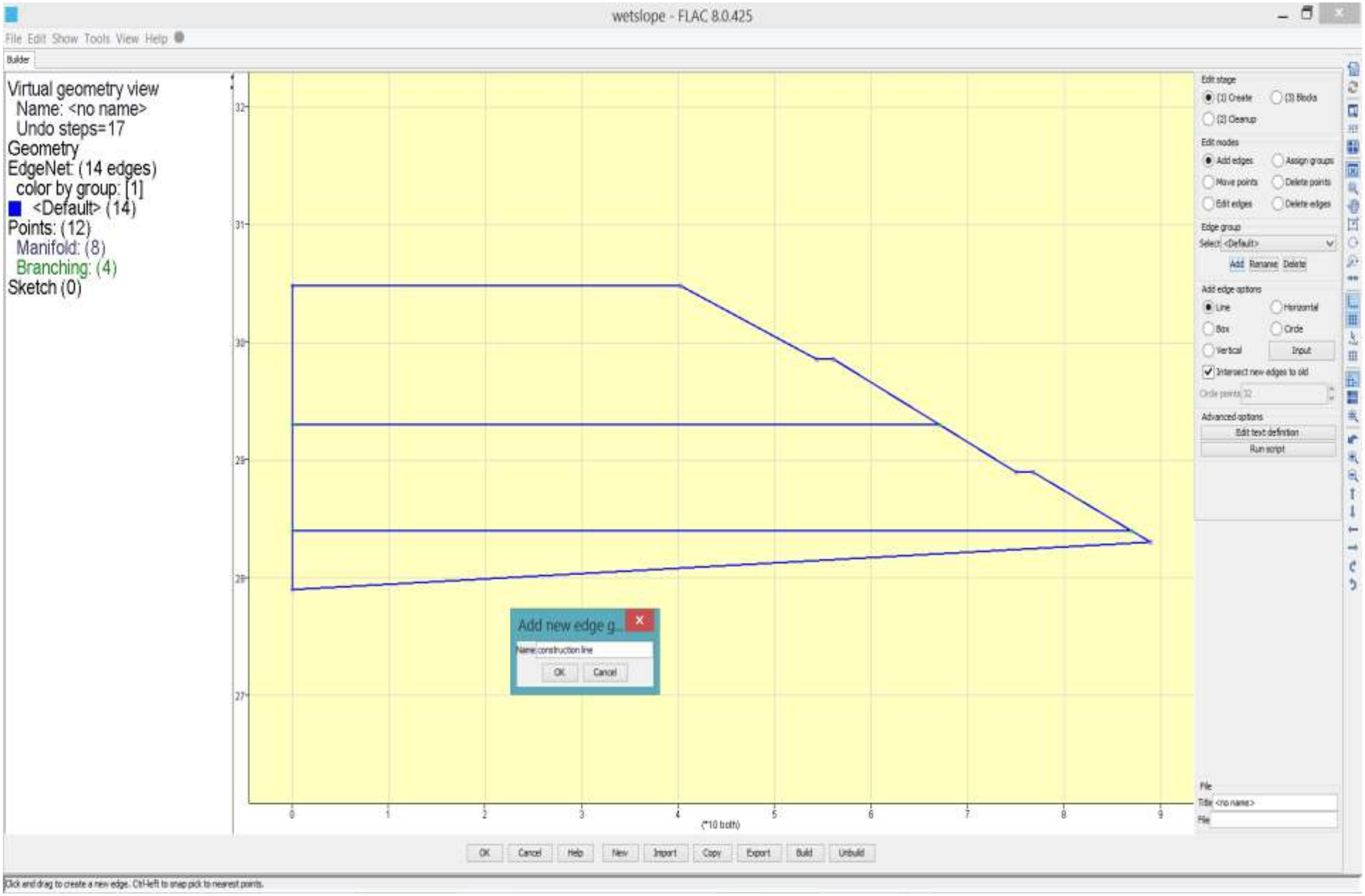


Step 1-8 Create the next line from x1=76.8, y1=289.0 to x2=89.0, y2=283.0.



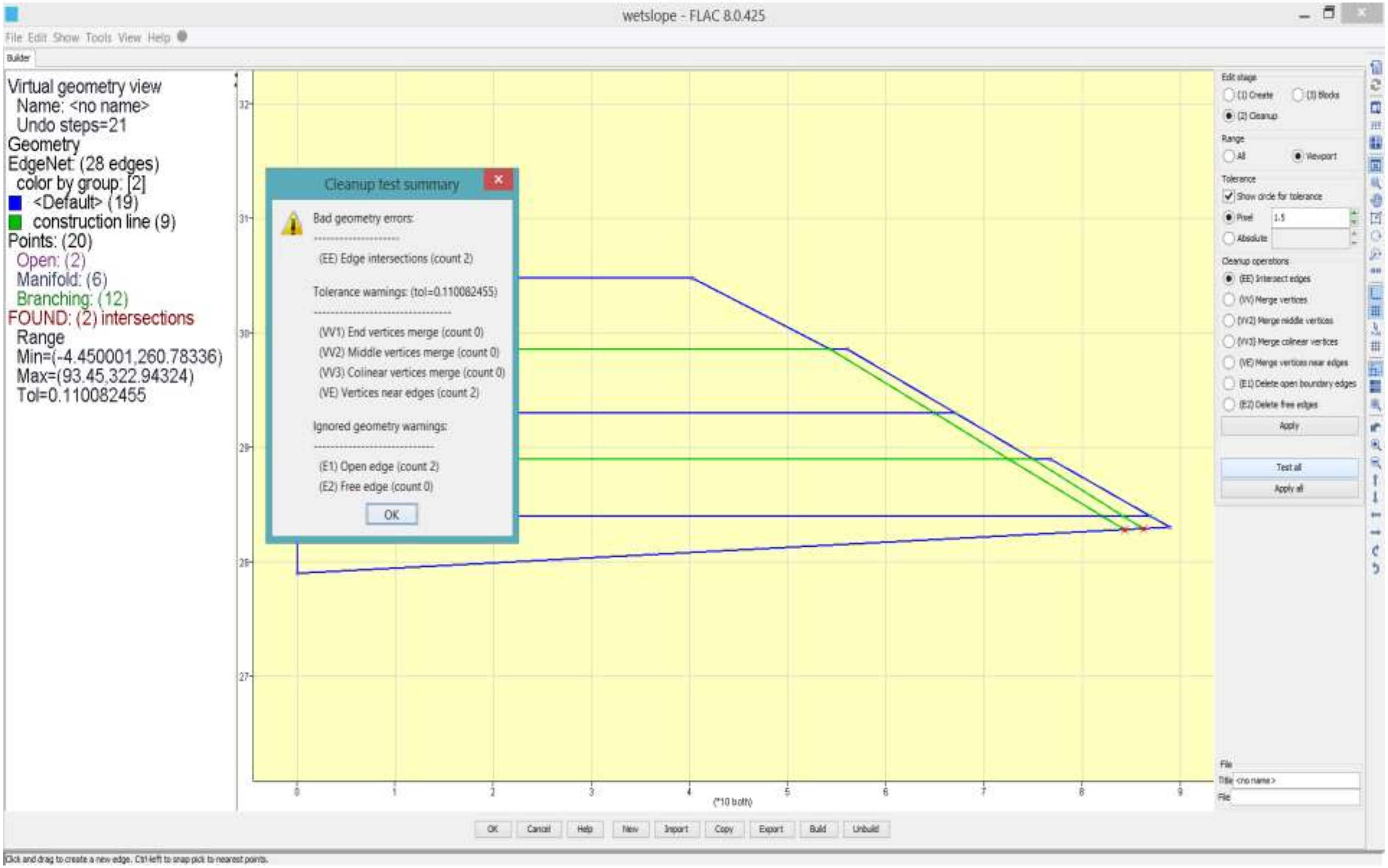
Step 1-9 Create the line for the bottom boundary from x1=0.0, y1=279.0 to x2=89.0, y2=283.0

Step 1-10 Select [Delete edges] to delete lines outside the slope.

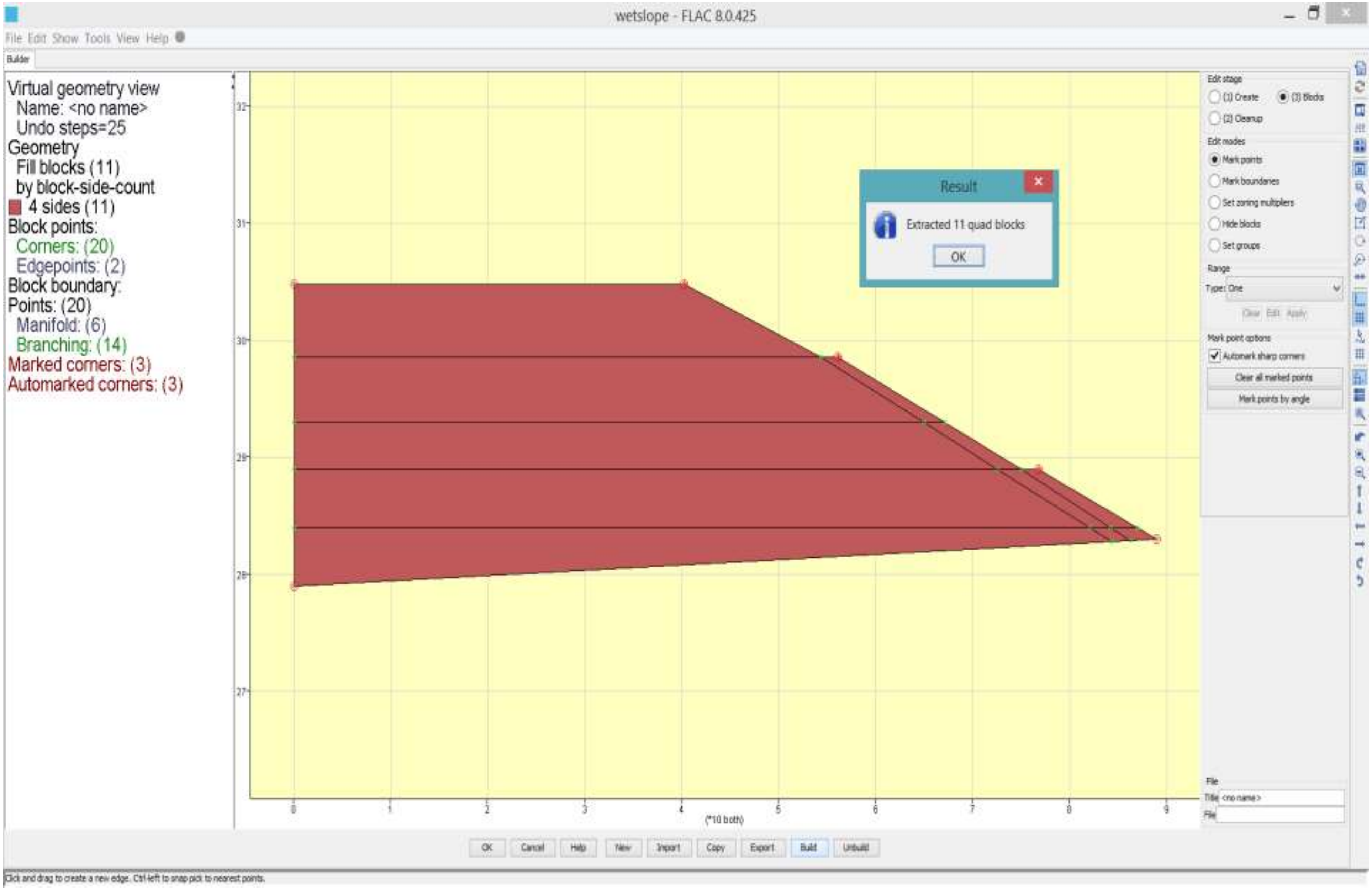


Step 1-11 Create construction lines to divide the model into 4-sided blocks.

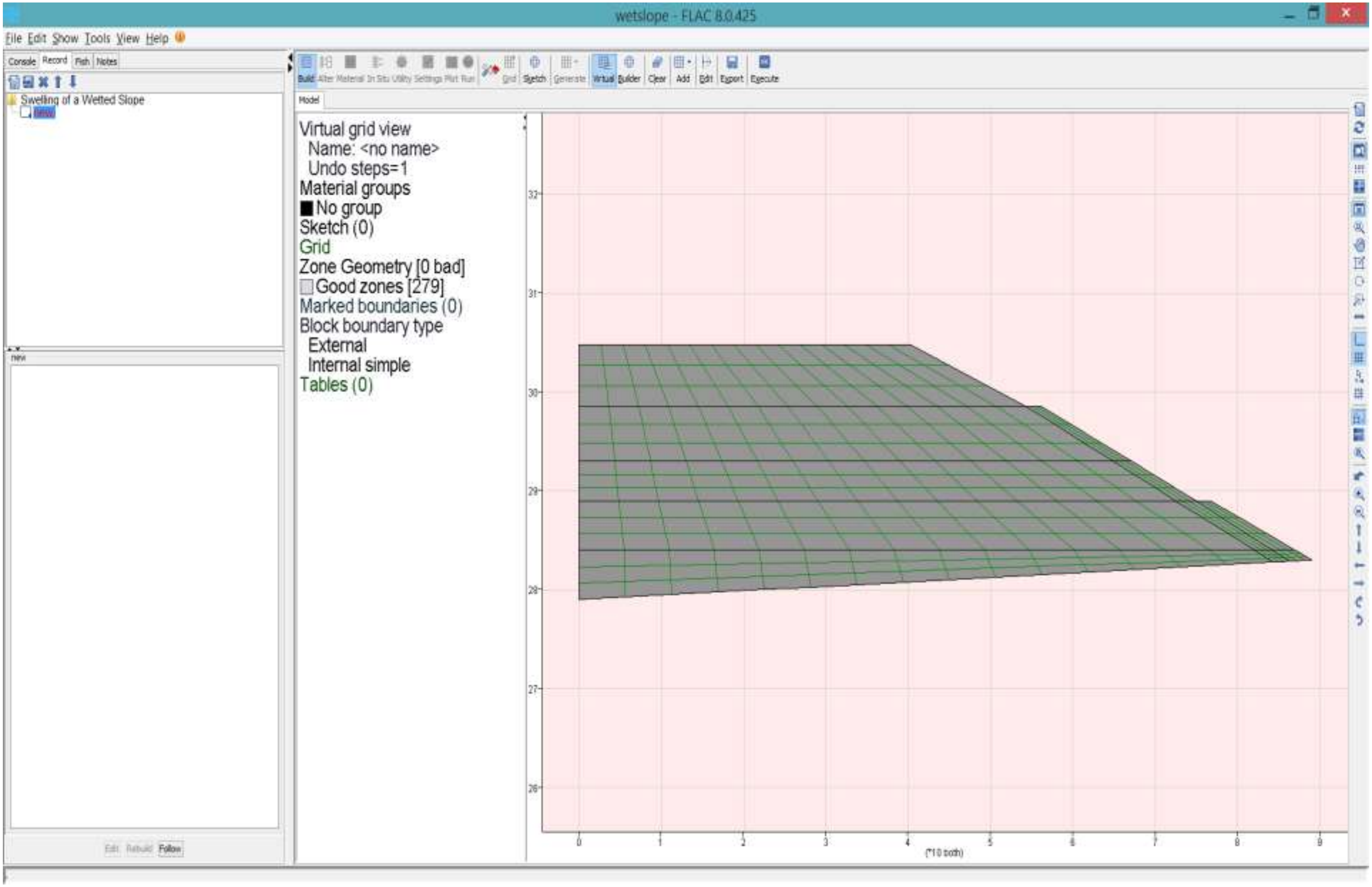
Step 1-12 Create blocks as shown above.



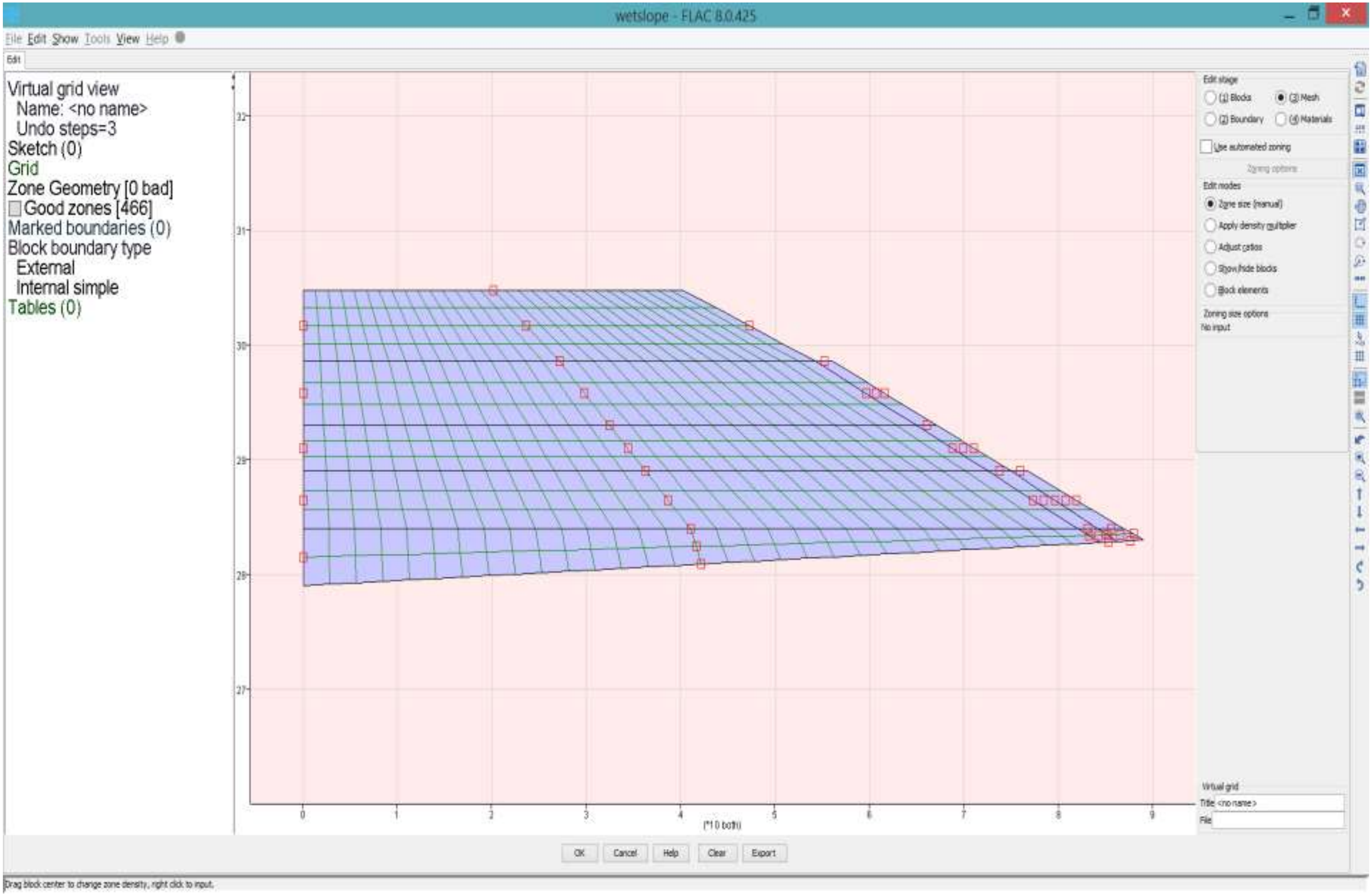
Step 1-13 Select [Cleanup] and check edges.



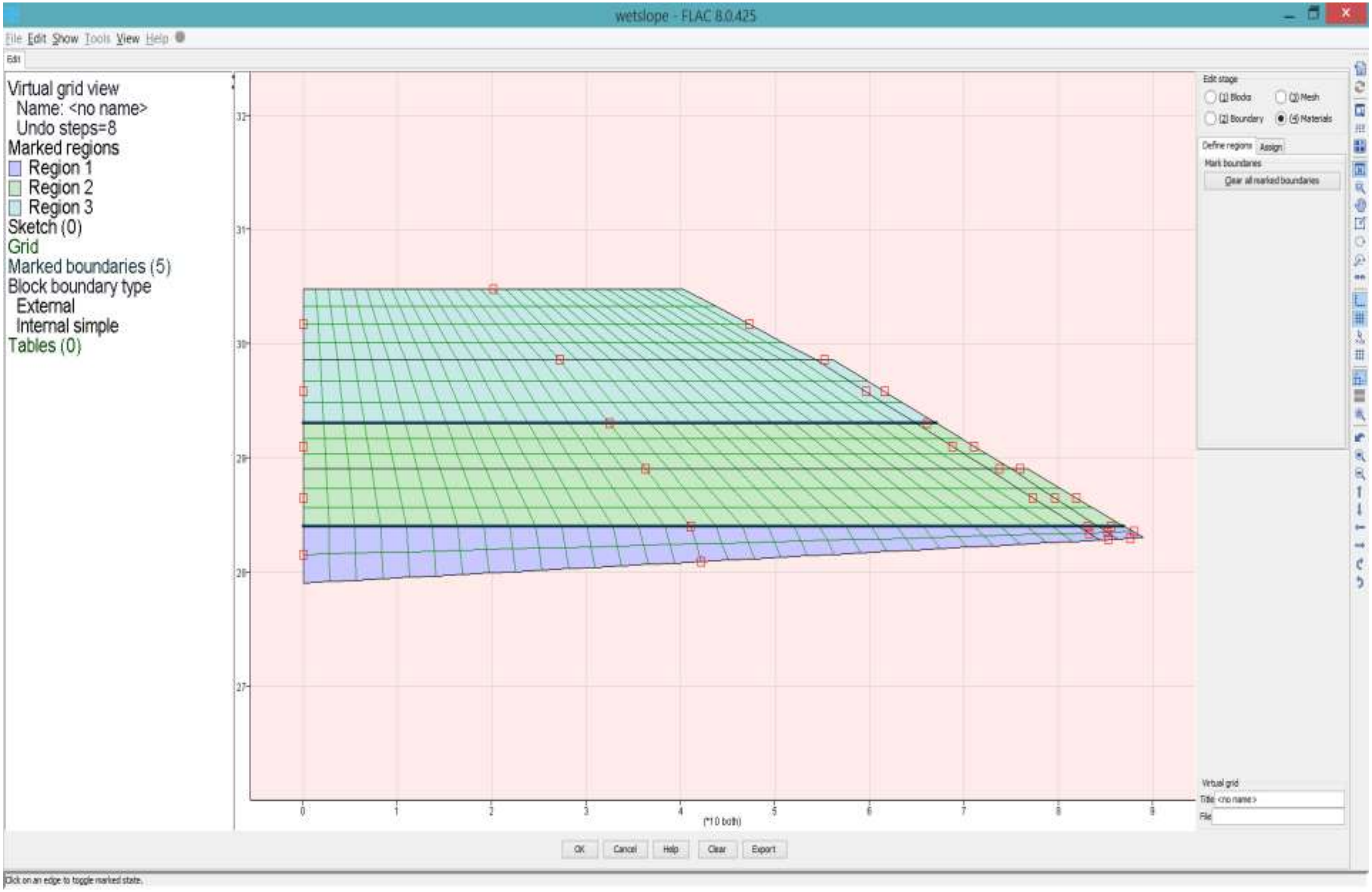
Step 1-14 Select [Blocks]. 11 quad blocks should be created.



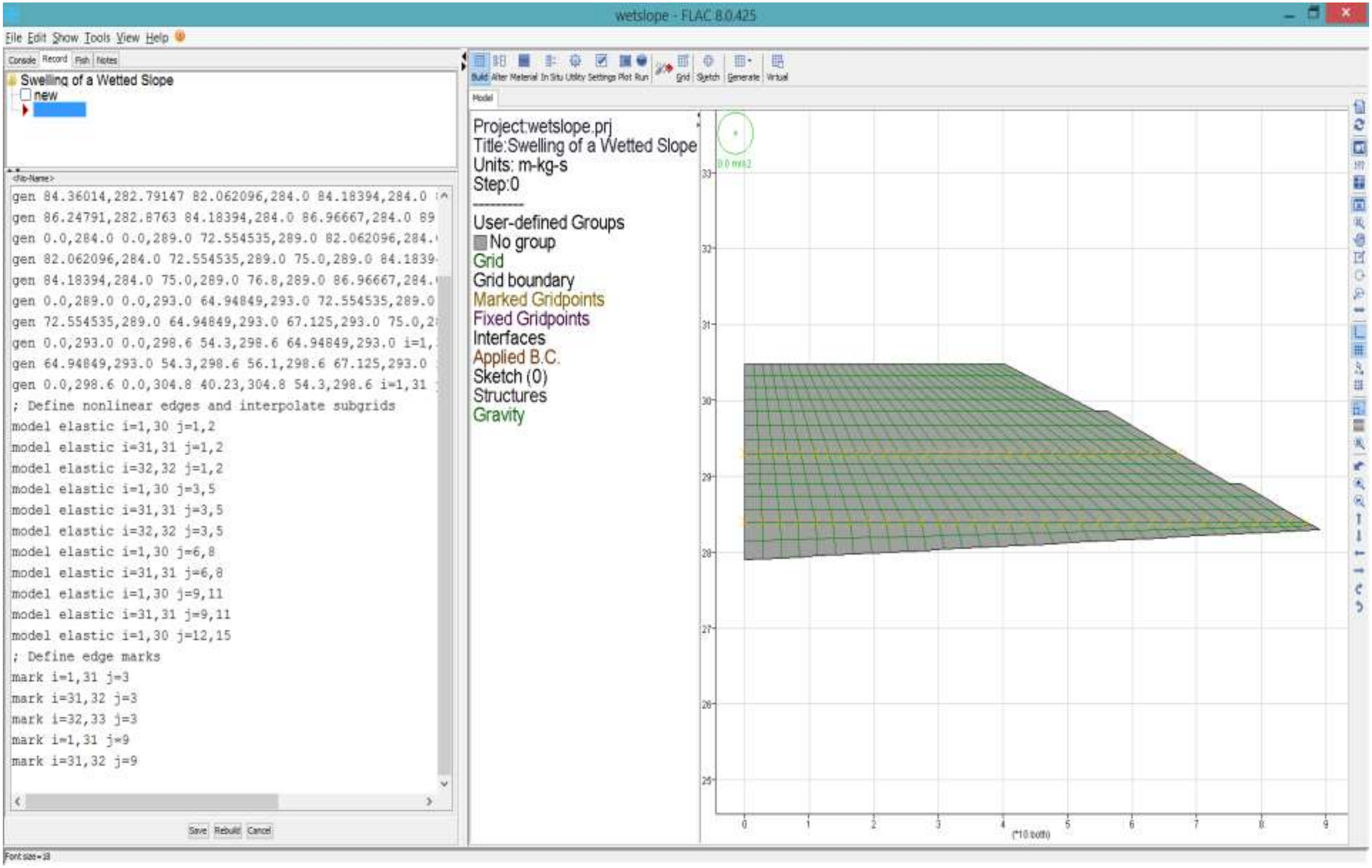
Step 1-15 Press [Build] and [OK] to create the virtual mesh.



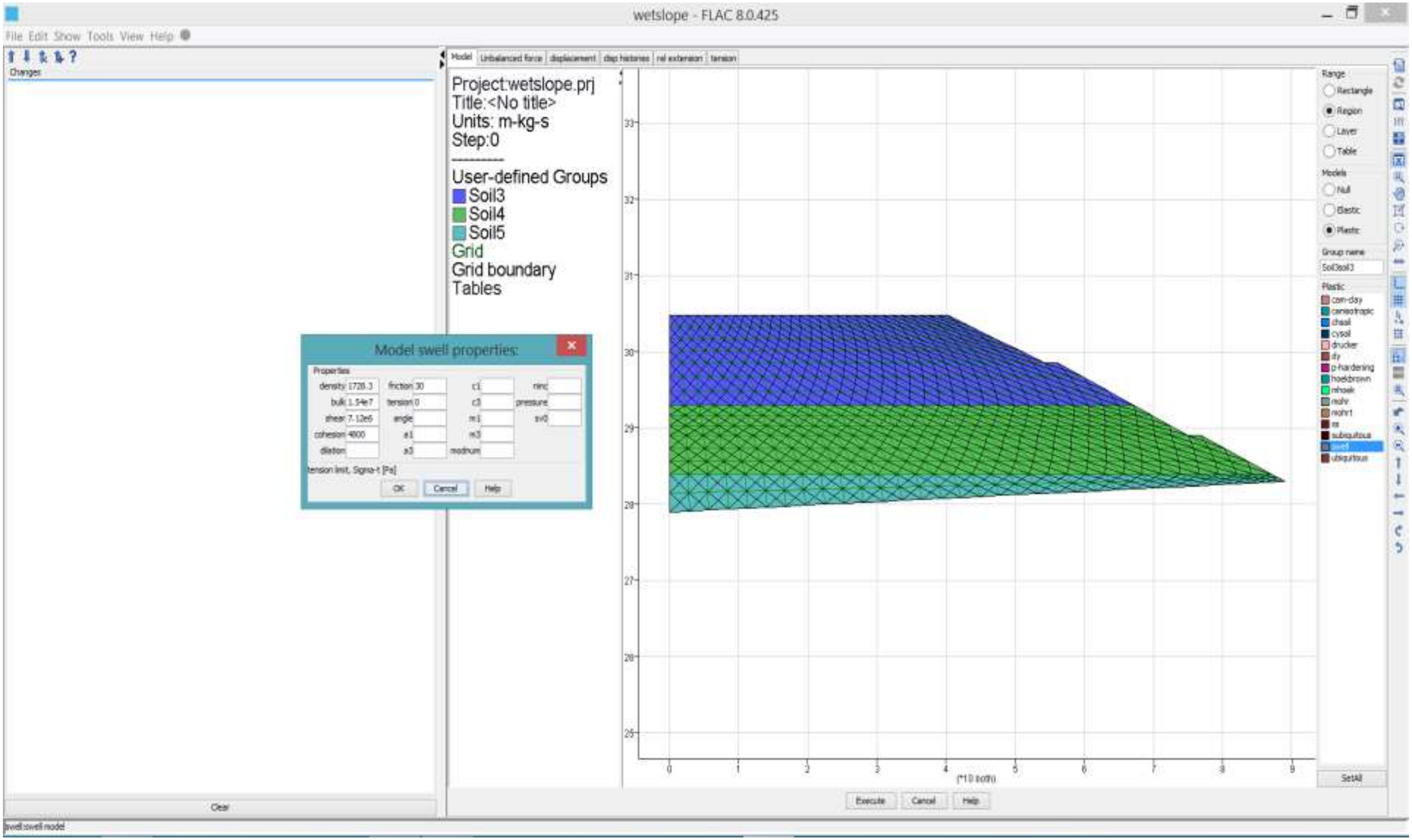
Step 1-16 Press [Edit] to enter the Edit stage. Select the [Mesh] edit stage and manually divide the model into zoning as shown.



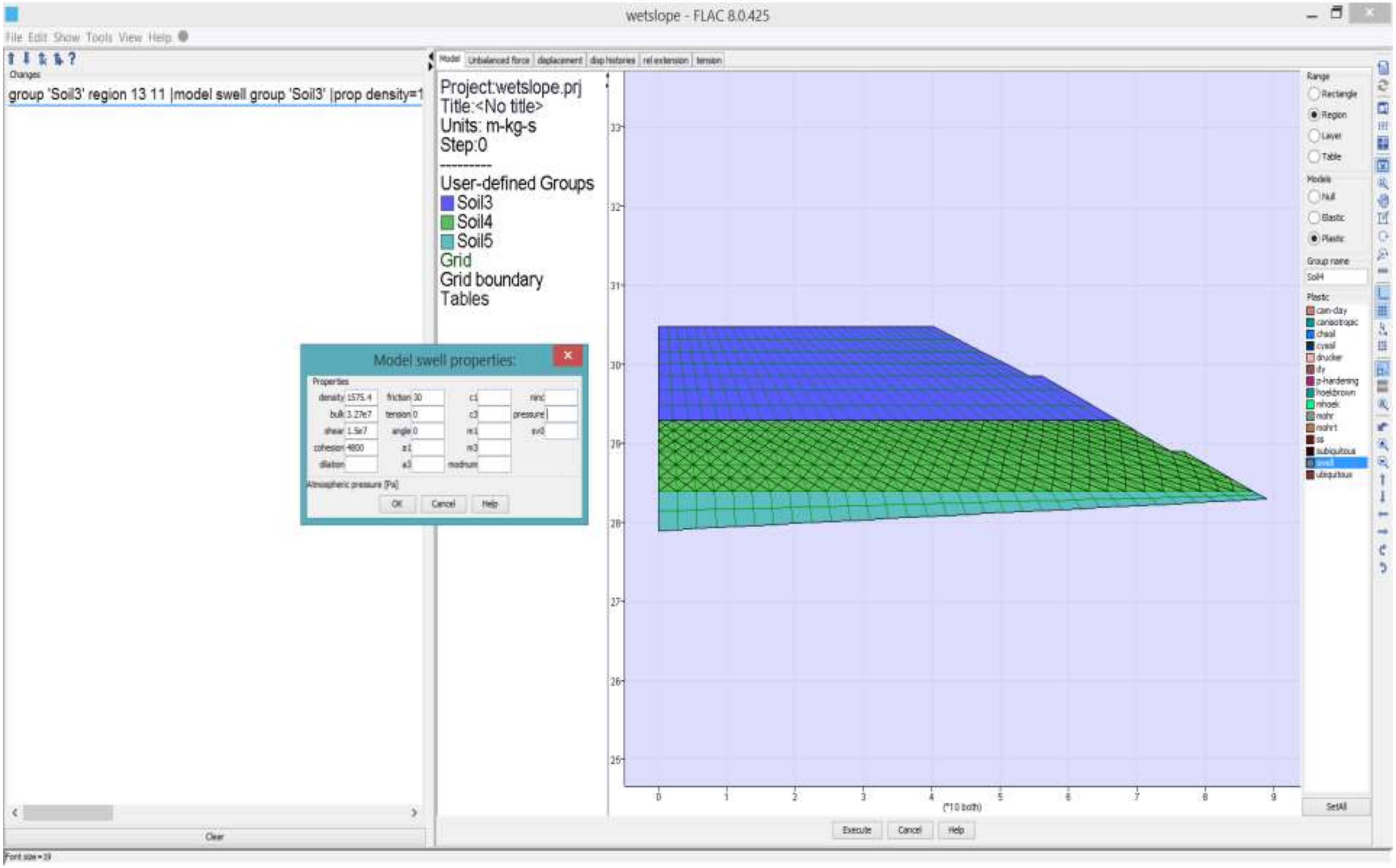
Step 1-17 Enter the [Materials] stage and select [Define regions] to set the marked boundaries between layers.



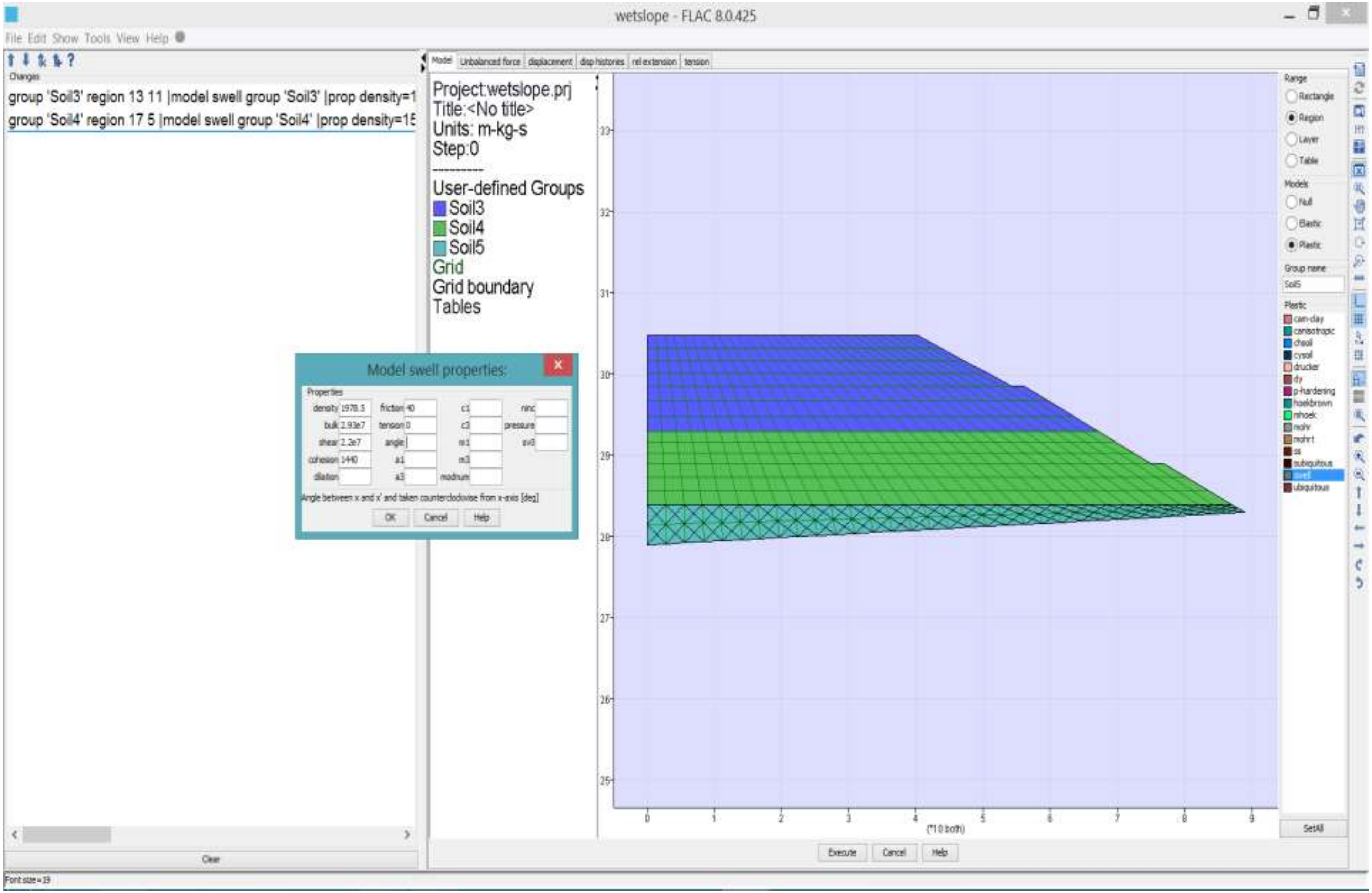
Step 1-18 Press [OK] and then [Execute] to create the *FLAC* commands for this model.



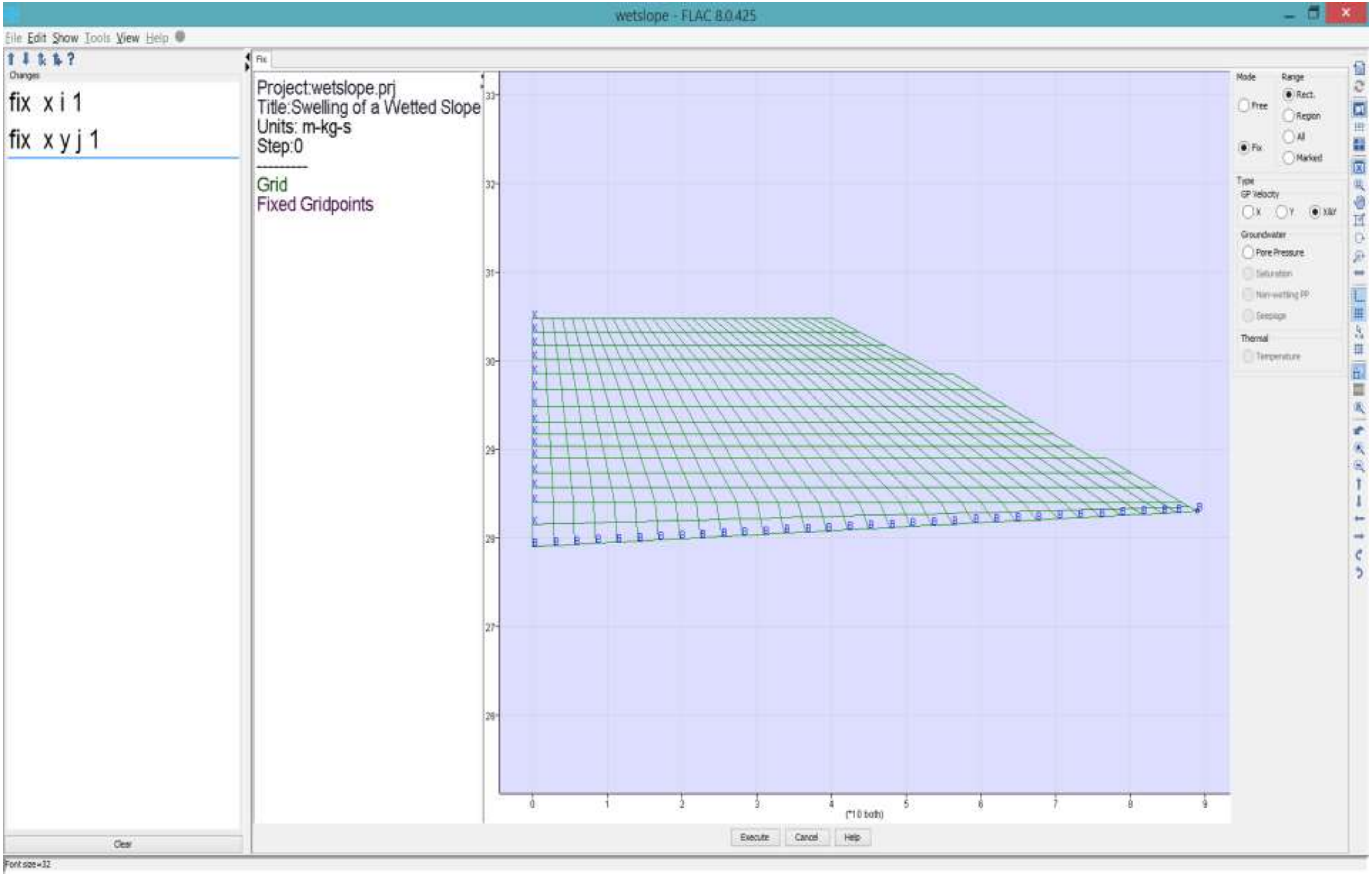
Step 1-19 Enter the [Material]/[Model], select [Region] range, specify the group name **Soil3** and select the [swell] plastic model. Click the mouse on a zone inside the **Soil3** layer to open the *Model swell properties* dialog. Input the elastic and plastic properties. Leave the swelling properties blank, and the initial behavior will be a Mohr-Coulomb material. Press [OK] to create the *FLAC* command.



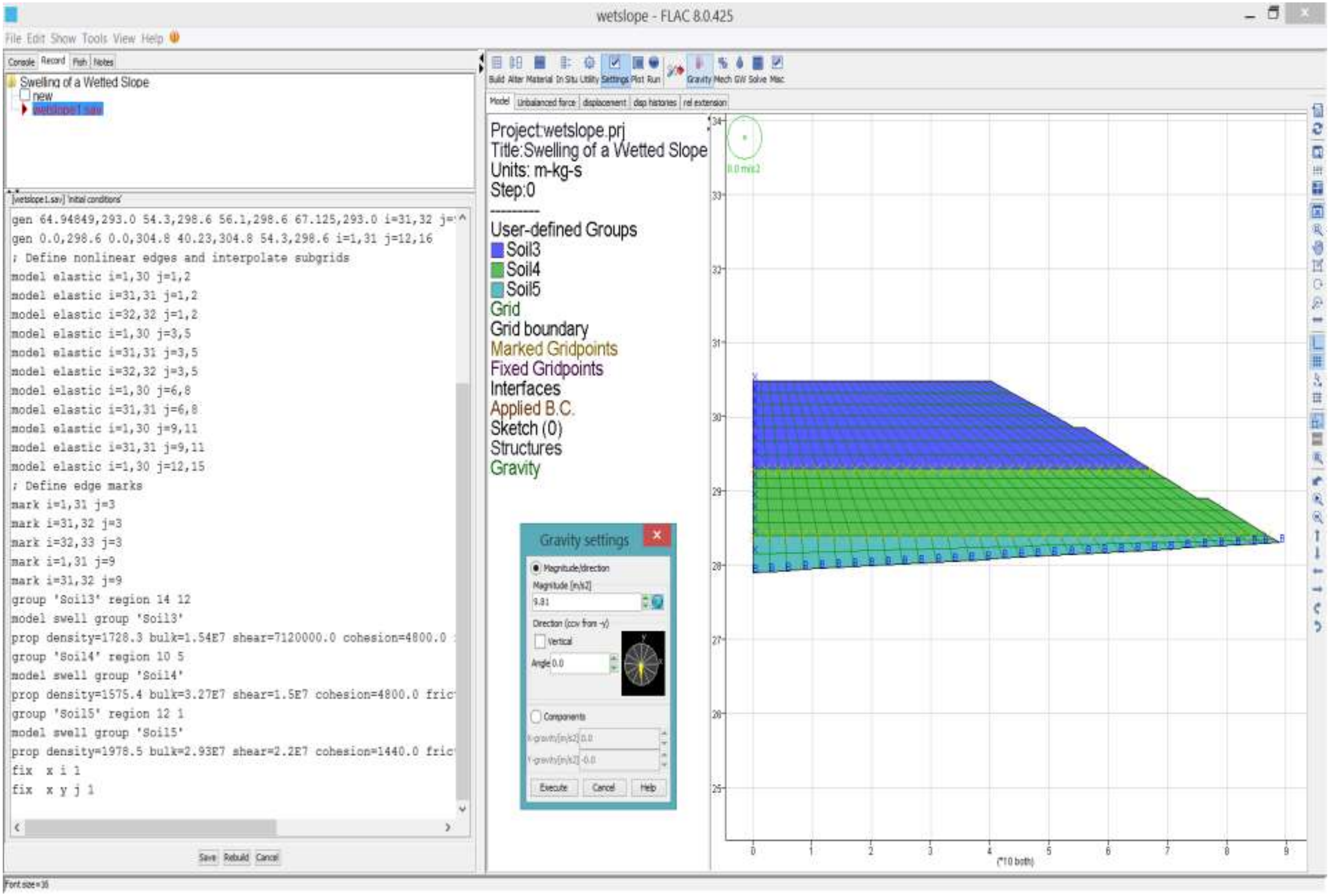
Step 1-20 Repeat Step 1-19 for **Soil4.**



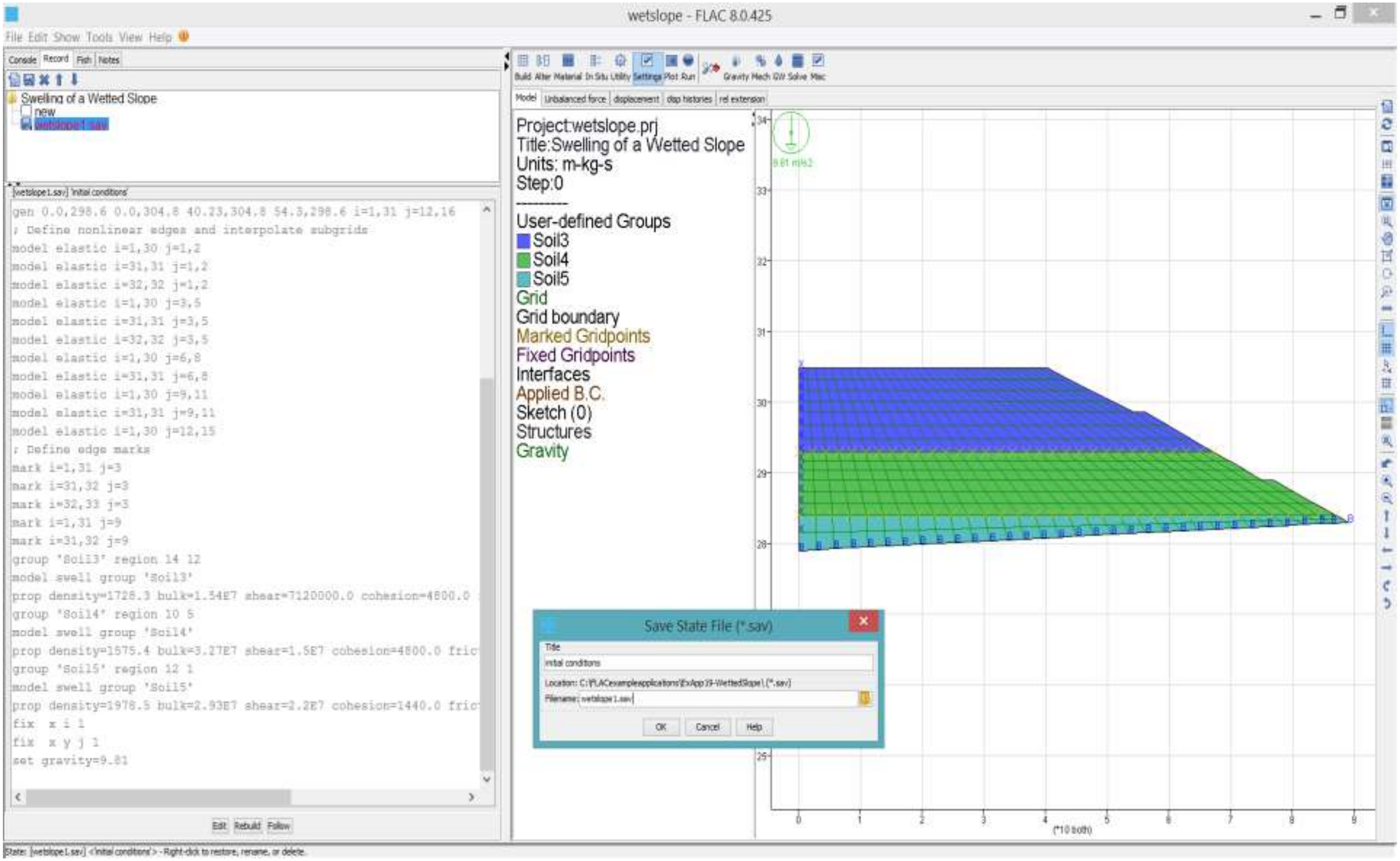
Step 1-21 Repeat Step 1-19 for **Soil5.** Press [Execute] to send these commands to *FLAC*.



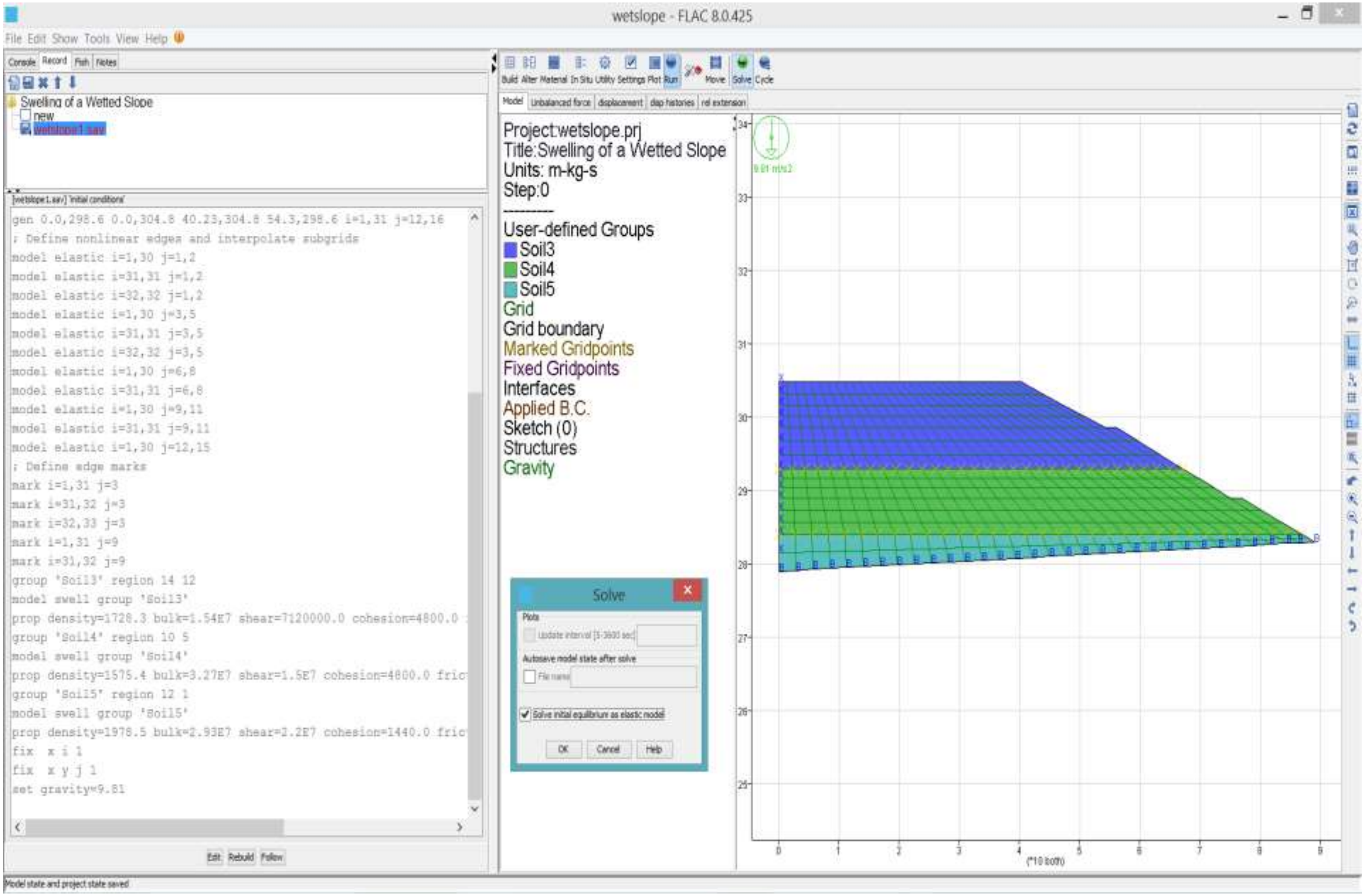
Step 1-22 Enter [In Situ]/[Fix], select [Fix]/[X] and drag the mounse along the left boundary to fix the boundary in the x-direction. Select [Fix]/[X&Y] and drag the mouse along the bottom boundary to fix the boundary in both x- and y-directions.



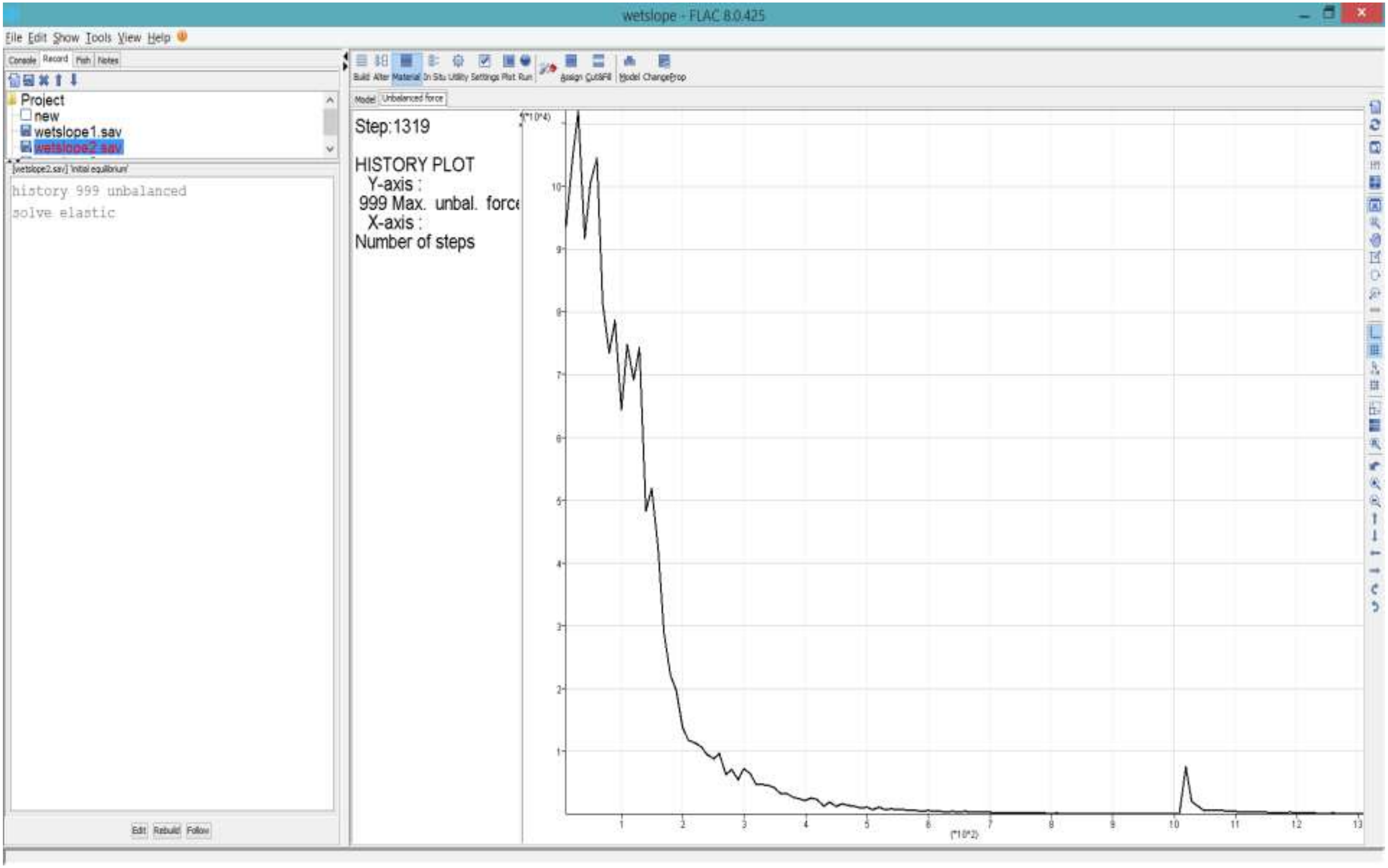
Step 1-23 Select [Settings]/[Gravity] and assign gravitational loading.



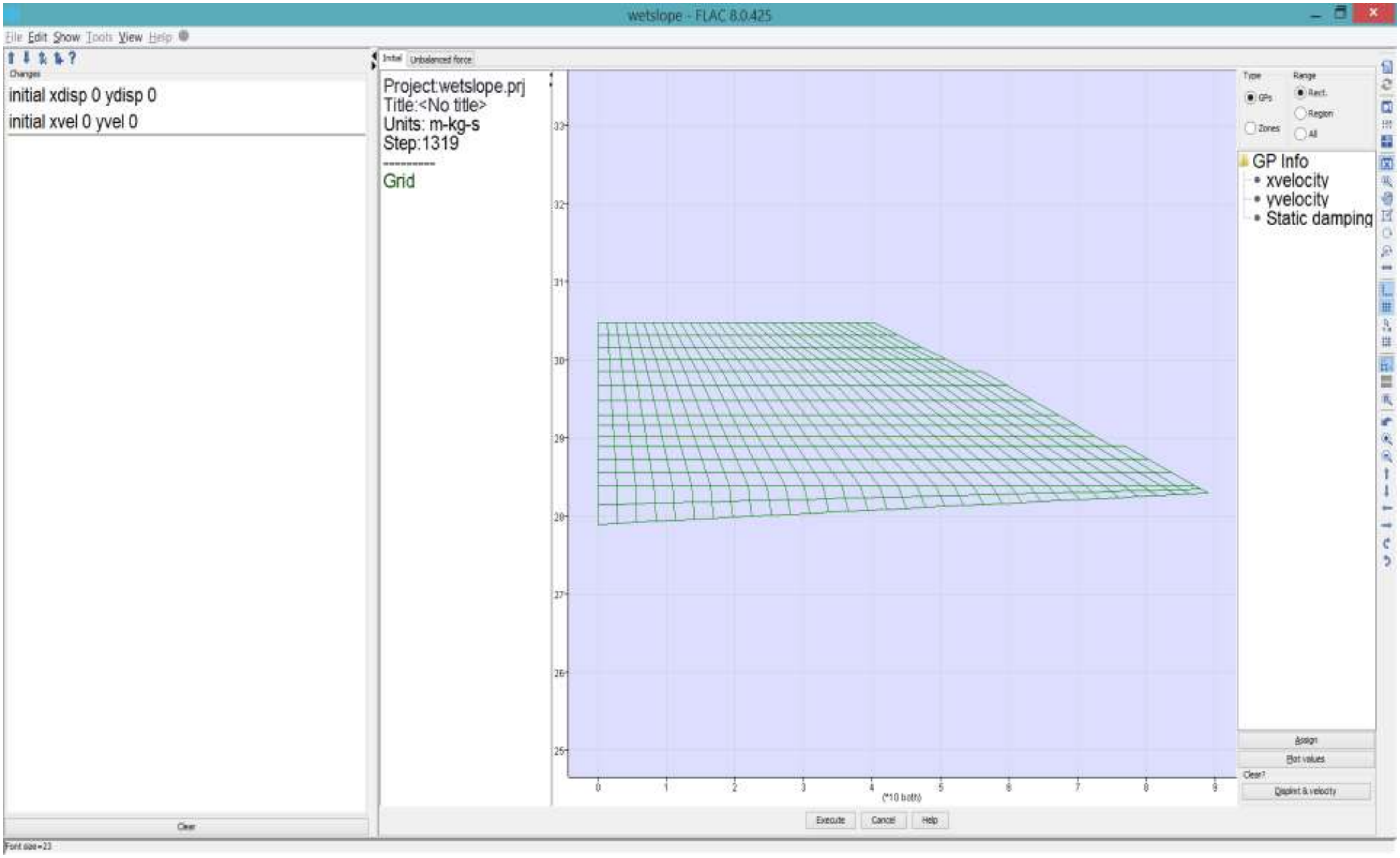
Step 1-24 Save the state as wetslope1.sav.



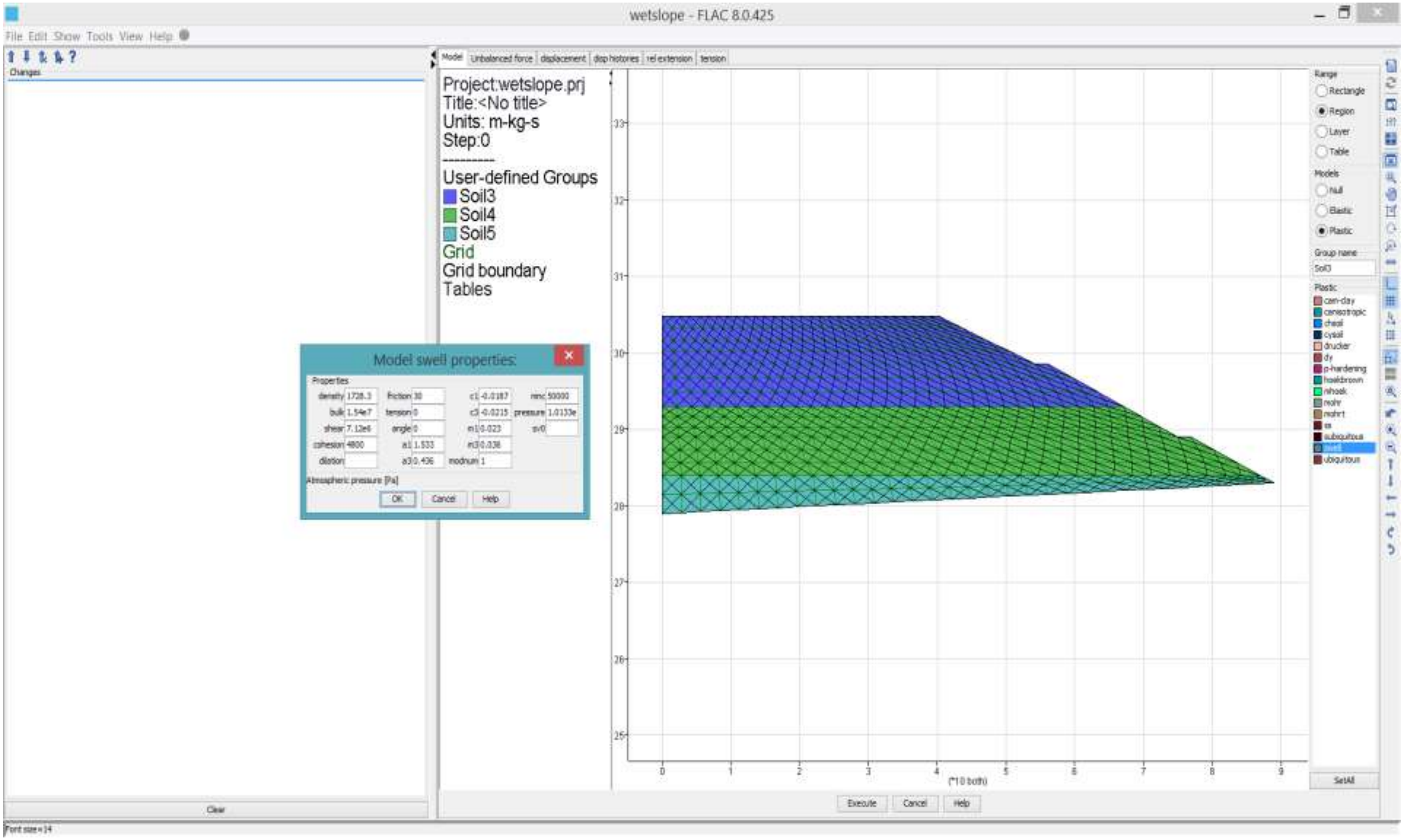
Step 2-1 Select [Run]/[Solve], check [Solve initial equilibrium as elastic model] and press [OK] to calculate the initial stress state in the slope.



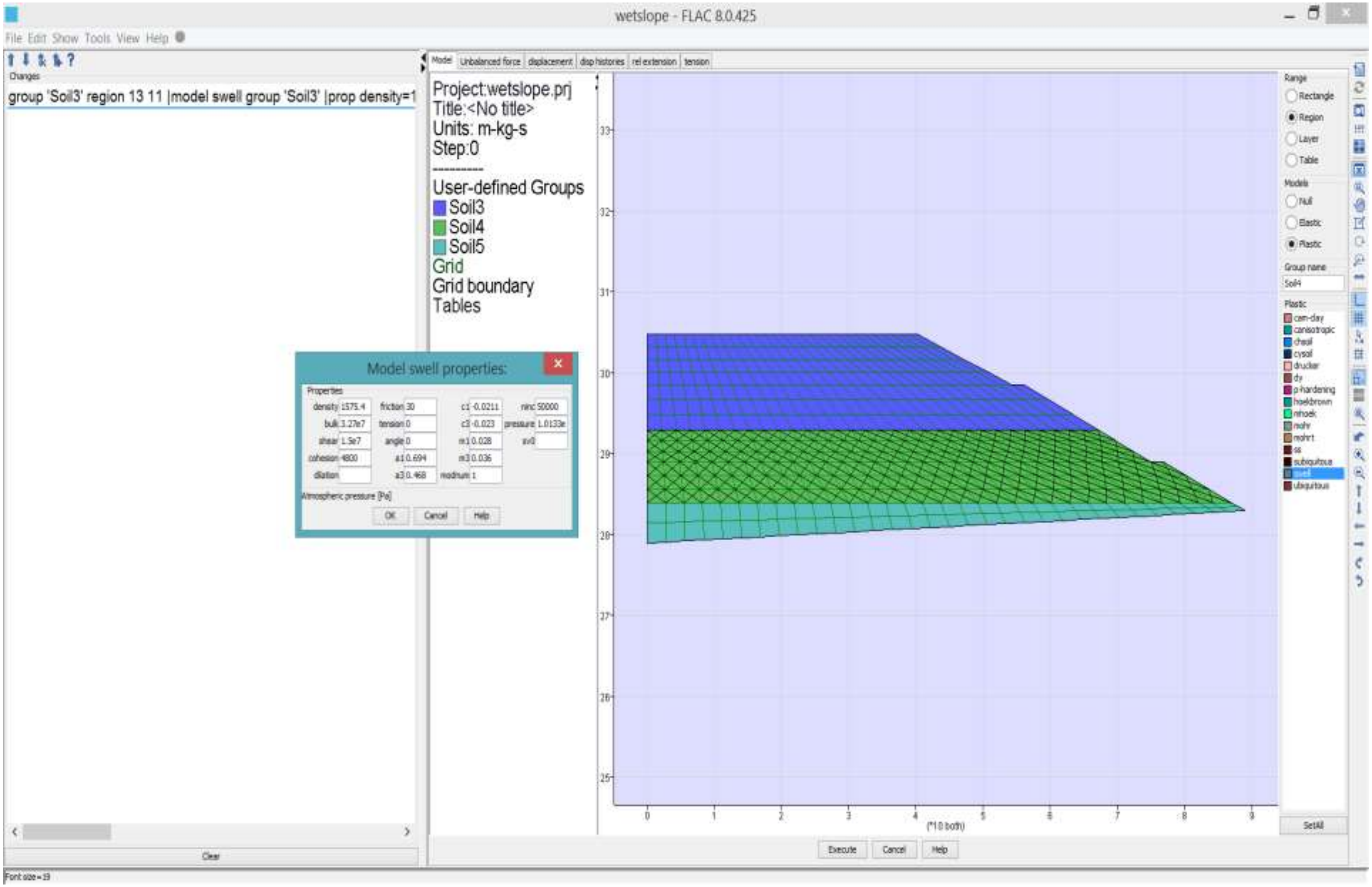
Step 2-2 When the run stops, select [Plot]/[Quick] and [Unbalanced force] to plot the maximum unbalanced force history to check that equilibrium is reached.. Save the state as wetslope2.sav



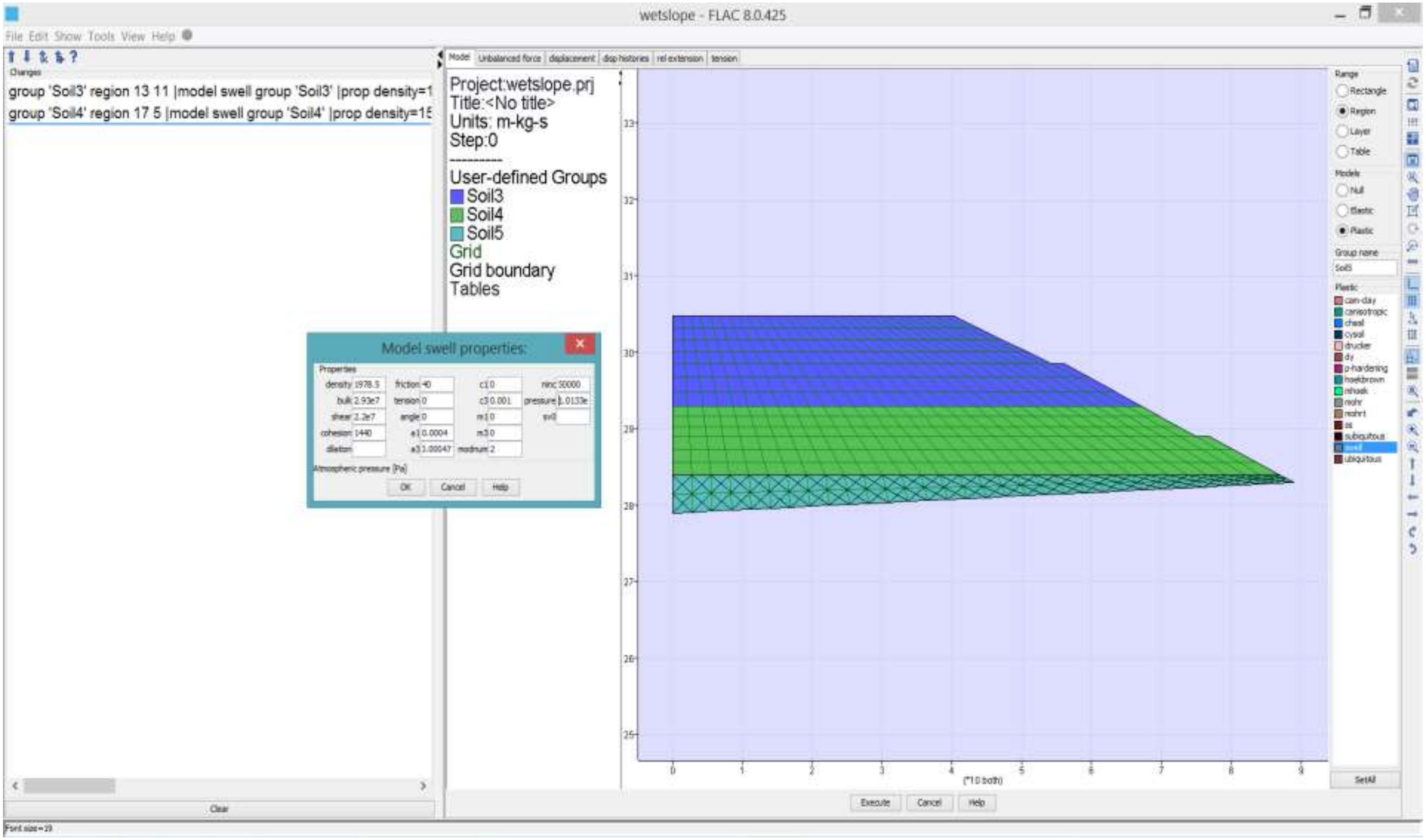
Step 3-1 Enter the [In Situ]/[Initial] tool and press [Clear? (Displmt&velocity)] to reset displacements and velocities to zero. Press [Execute] to send the commands to *FLAC*.



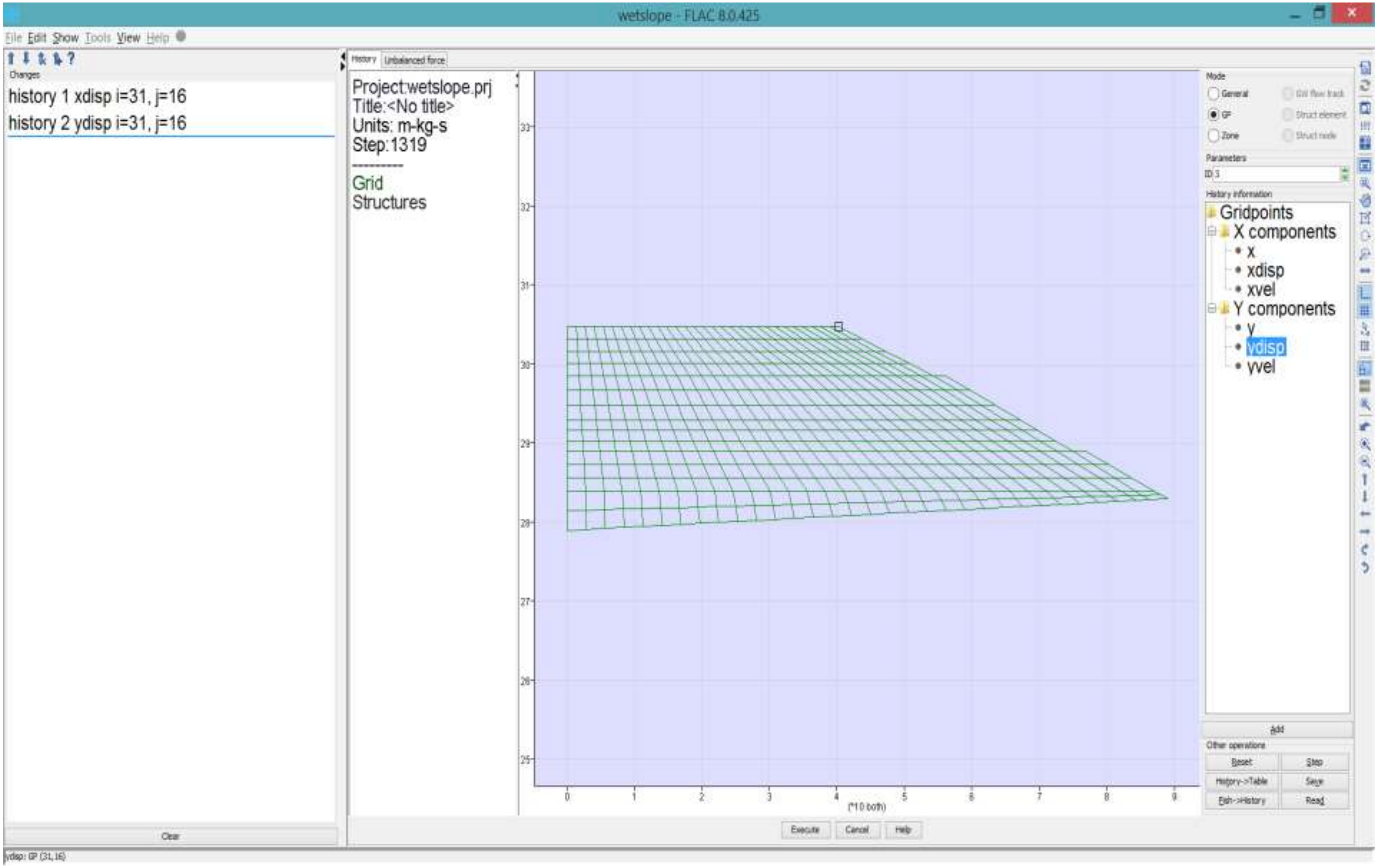
Step 3-2 Enter the [Material]/[Model] tool, select [region] range, assign the group name **Soil3** and select the [swell] plastic model. Click on a zone inside the Soil3 region open the *Model swell properties* dialog. Enter all of the properties for **Soil3.**



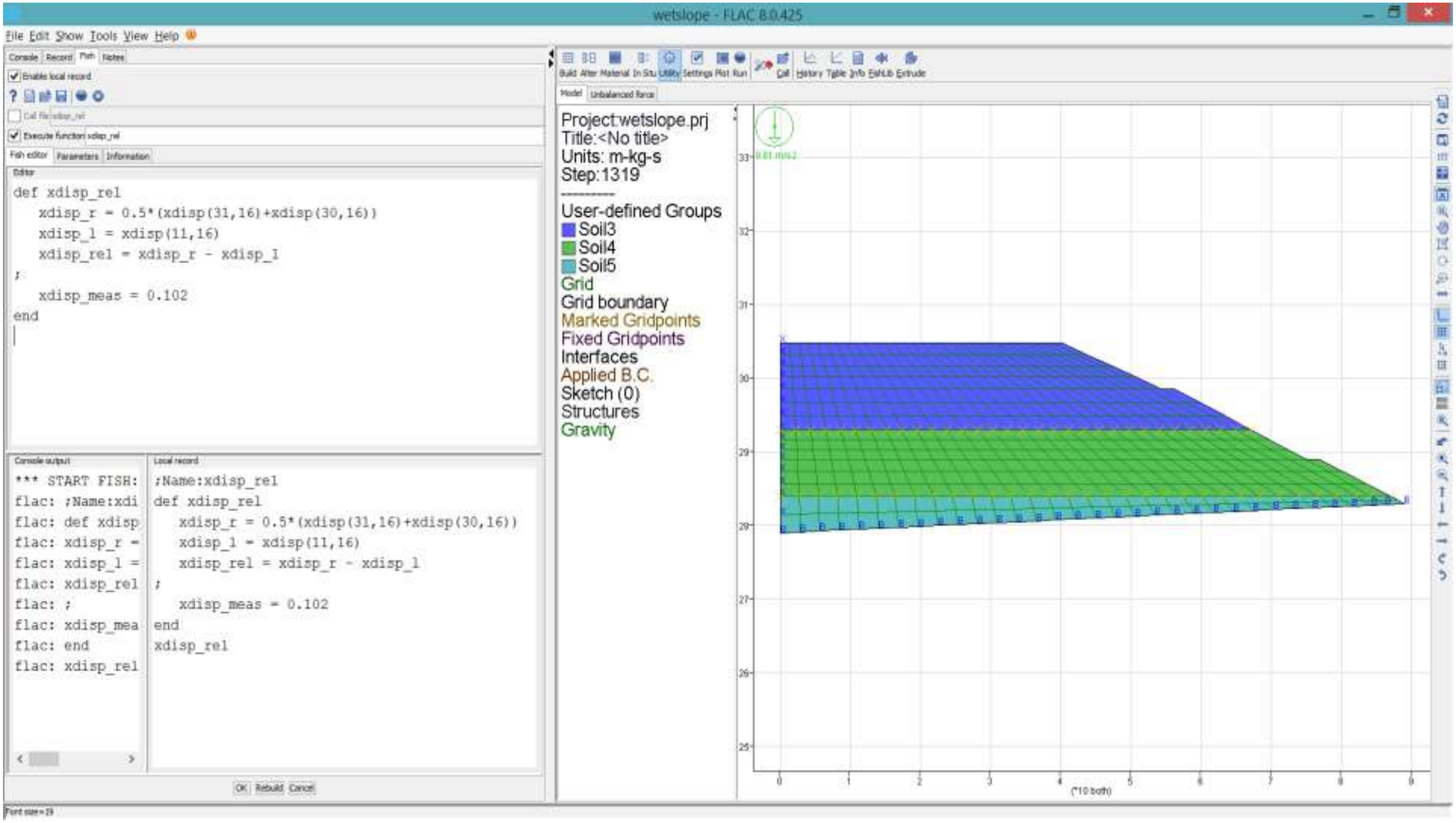
Step 3-3 Repeat **Step 3-2** for **Soil4.**



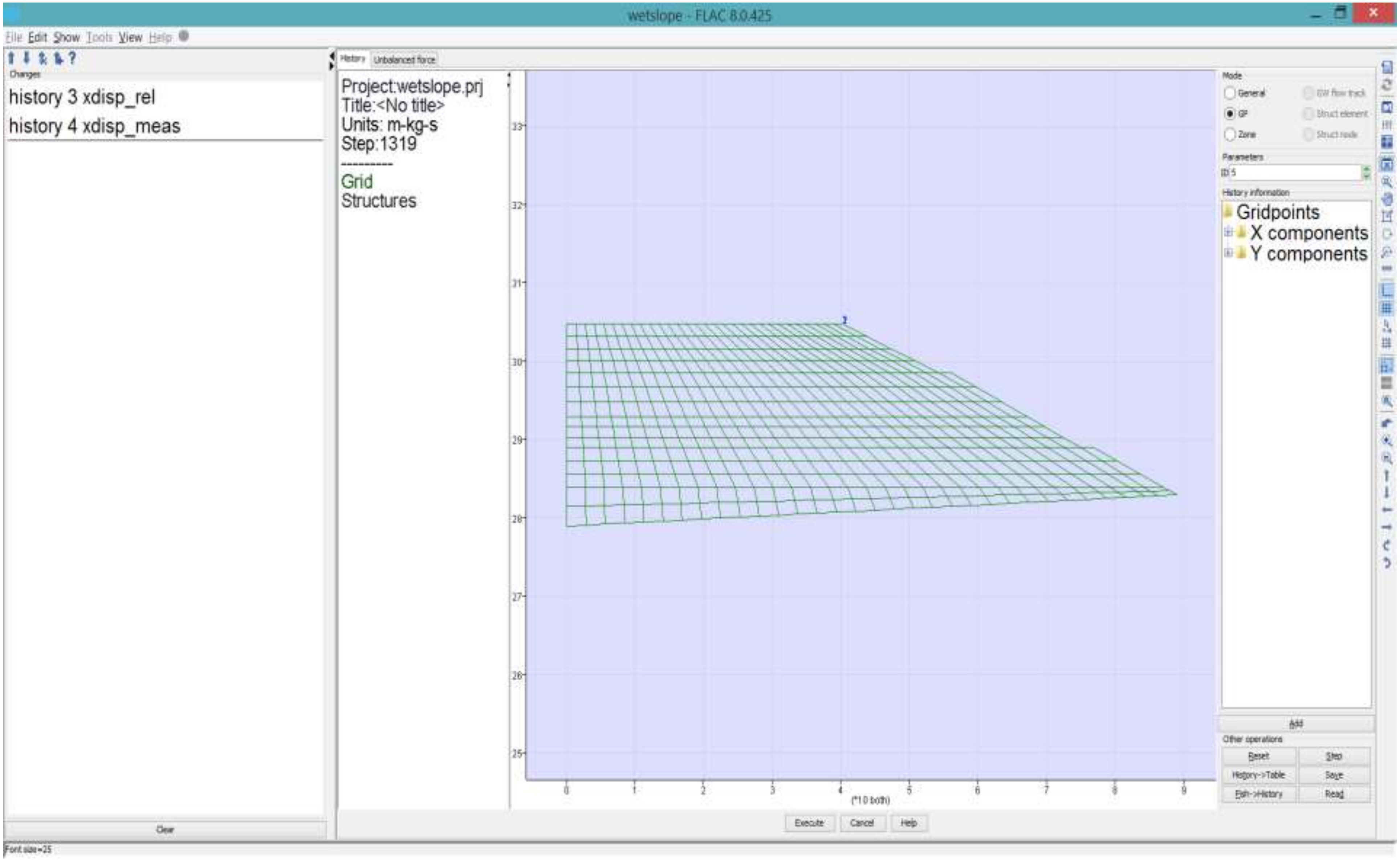
Step 3-5 Repeat **Step 3-2** for **Soil5.**



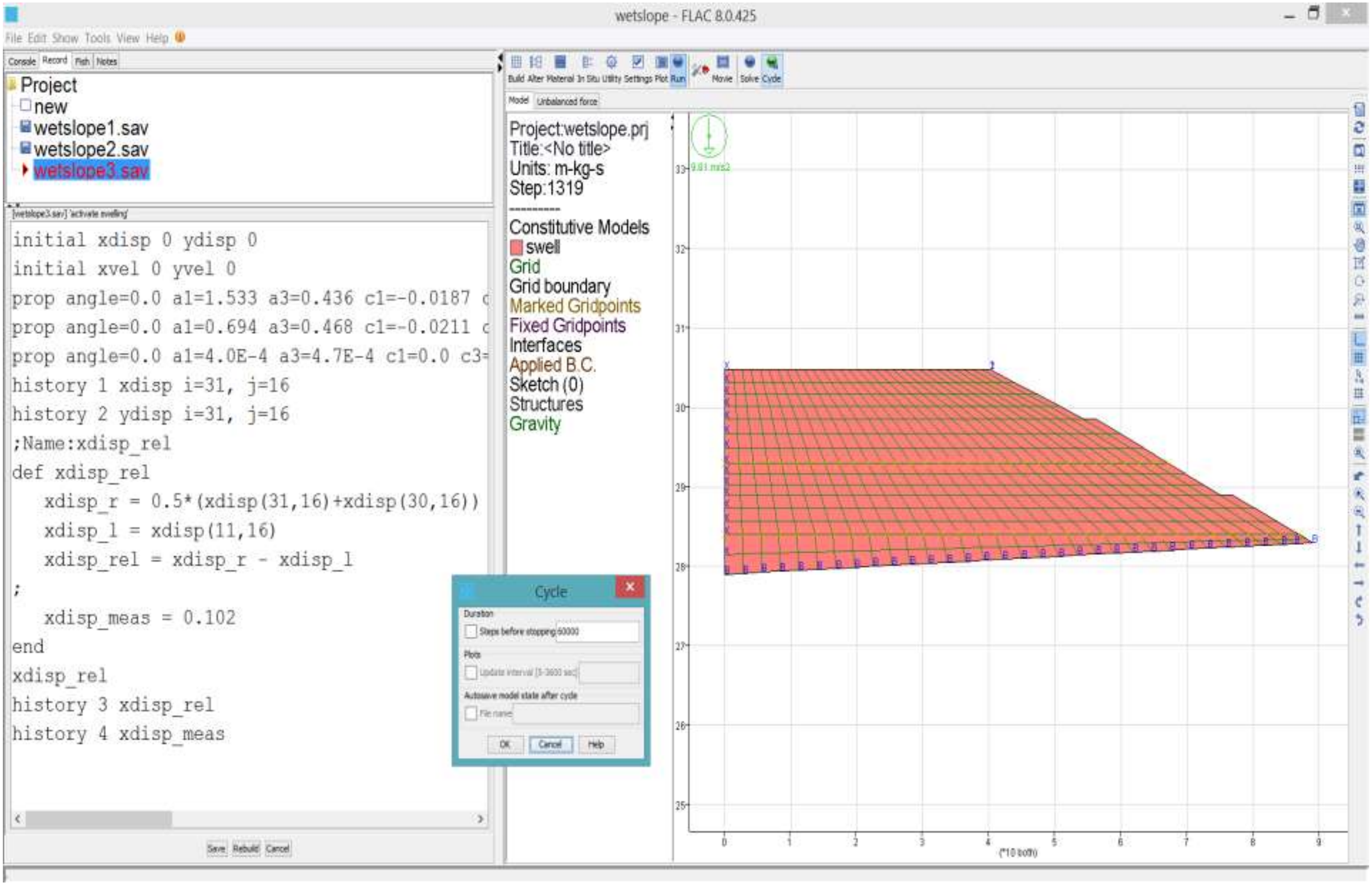
Step 3-6 Monitor the x- and y-displacement at the slope crest in the [Utility]/[History] tool.



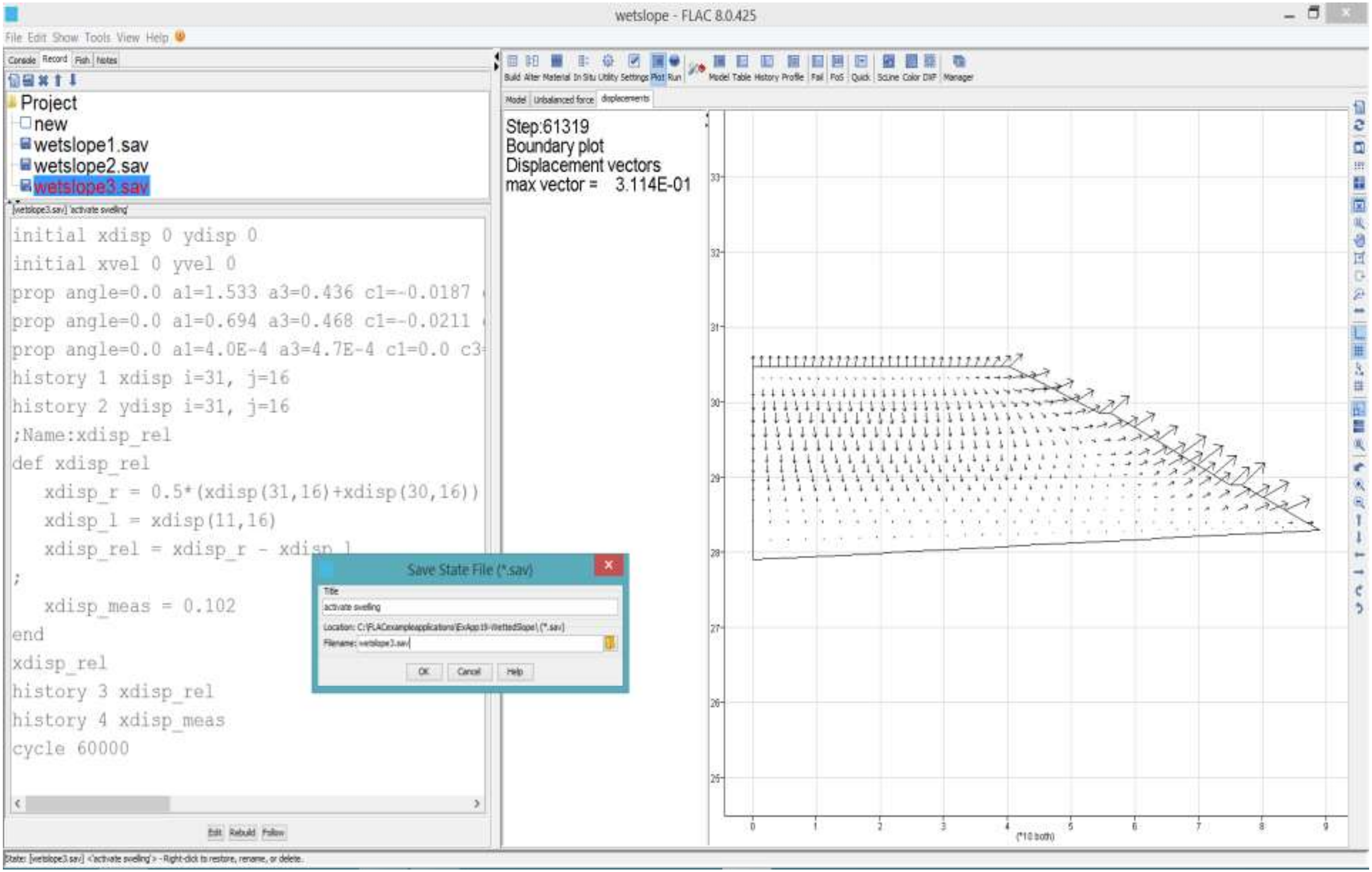
Step 3-7 In the [FISH editor] pane, create a FISH function to monitor the relative motion at the crest between the midpoint of gridpoints i=31,j=16 and i=30,j=16 and gridpoint i=11,j=16. This relative horizontal movement corresponds to the location of the measured movement in the field. The measured movement (102mm) is defined by FISH variable, **xdisp_meas**, for comparison to the calculated value.



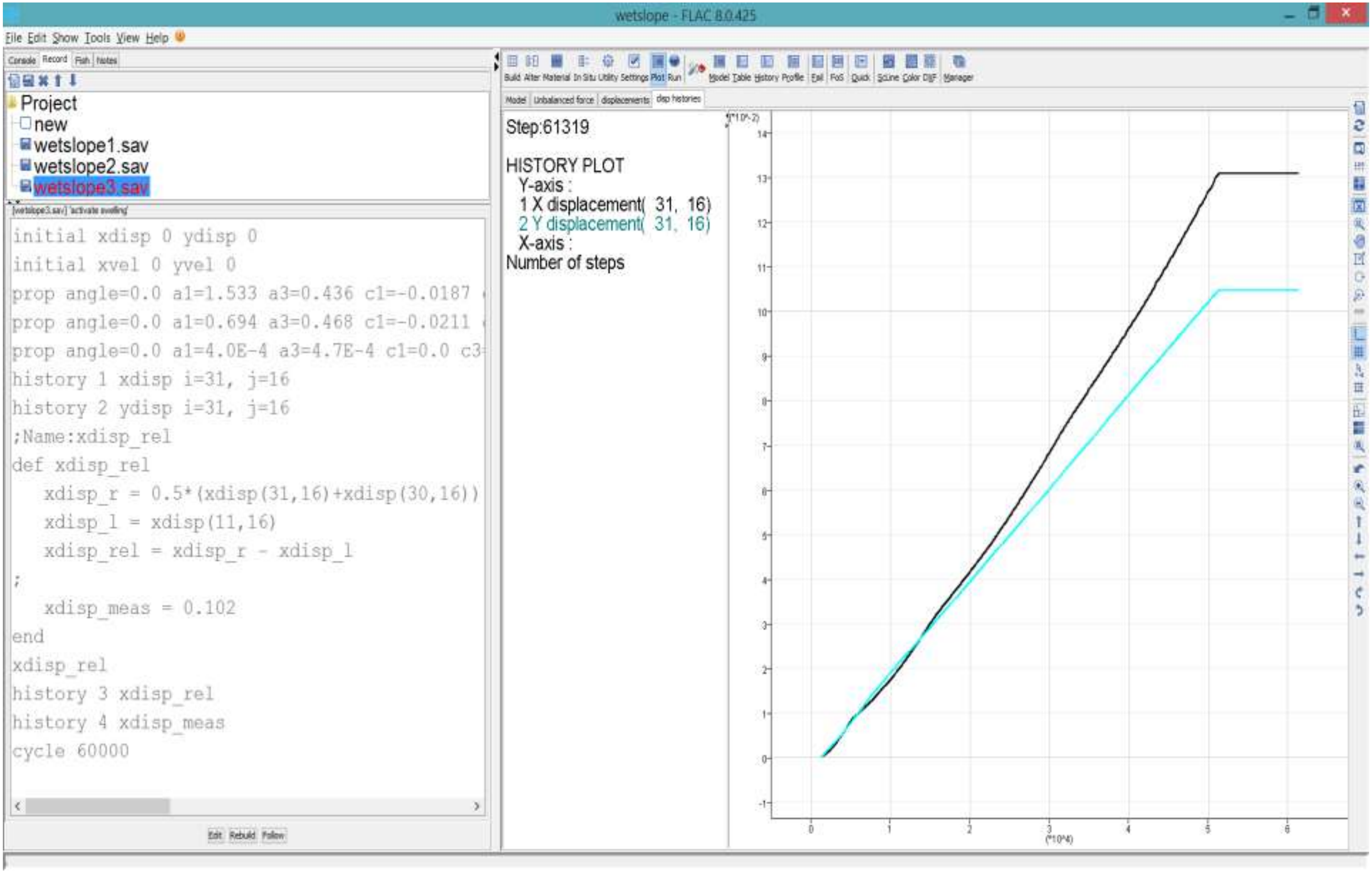
Step 3-8 The FISH variables, **xdisp_rel** and **xdisp_meas**, are recorded as histories in the [Utility]/[History] tool by selecting [Fish-> History].



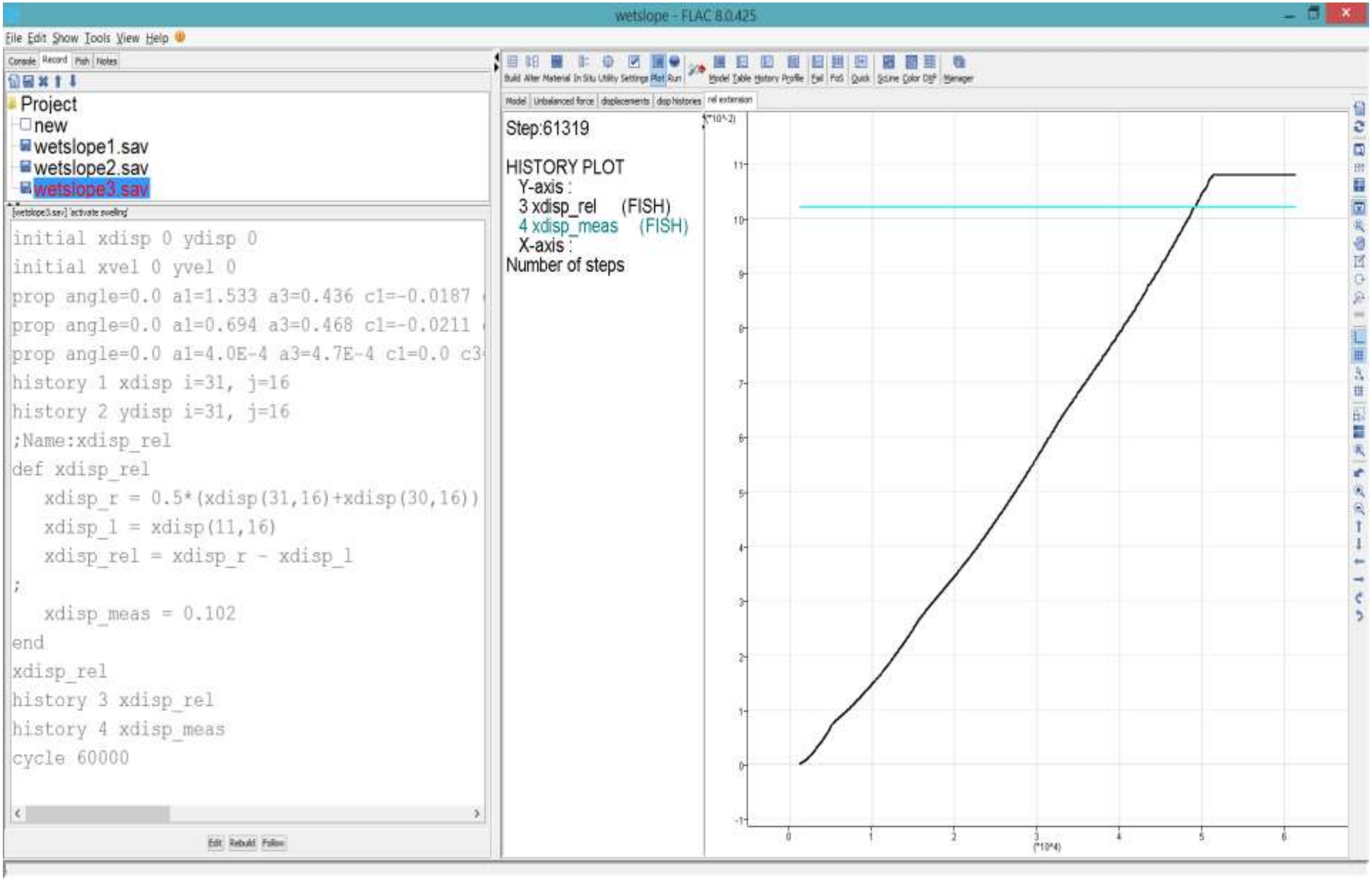
Step 3-9 The model is run for 60,000 steps using the [Run]/[Cycle] tool.



Step 4-1 When the run stops, the swell motion is evaluated from a displacement vector plot. The state is saved as wetslope3.sav.



Step 4-2 The horizontal movement at the slope crest is calculated to be 130.8mm and the vertical motion 104.5mm as noted from the x- and y-displacement history plots.



Step 4-3 The relative extension (swelling motion) along the slope crest is calculated to be 108mm, and is compared to the measured value of 102mm in the history plot above.