Mata Kuliah
“Komputer dan Simulasi”

SLOPE/W Software: Geometry, Material Properties, Loadings Method of Analyses, Execution, and Post Processing

GeoStudio 2012

- SLOPE/W – A software for computing the factor of safety of earth and rock slopes based on **limit equilibrium method**.

- SEEP/W – A **finite element** software for analyzing groundwater seepage and excess pore-water pressure dissipation problems within porous materials such as soil and rock.

- SIGMA/W – A **finite element** software that can be used to perform stress and deformation analyses of earth structures.

PROBLEM 1

In the textbook, *Soil Mechanics* by Lambe and Whitman (1969), the authors present a hand-calculated factor of safety for a simple slope with an underdrain. The purpose of this example is to verify SLOPE/W by comparing its solution with the hand calculations. Features of this simulation include:

Analysis method: Bishop

Use of a piezometric line

Use of a single point Grid and Radius slip surface

Use of points on regions to control slice discretization

FoS = ?

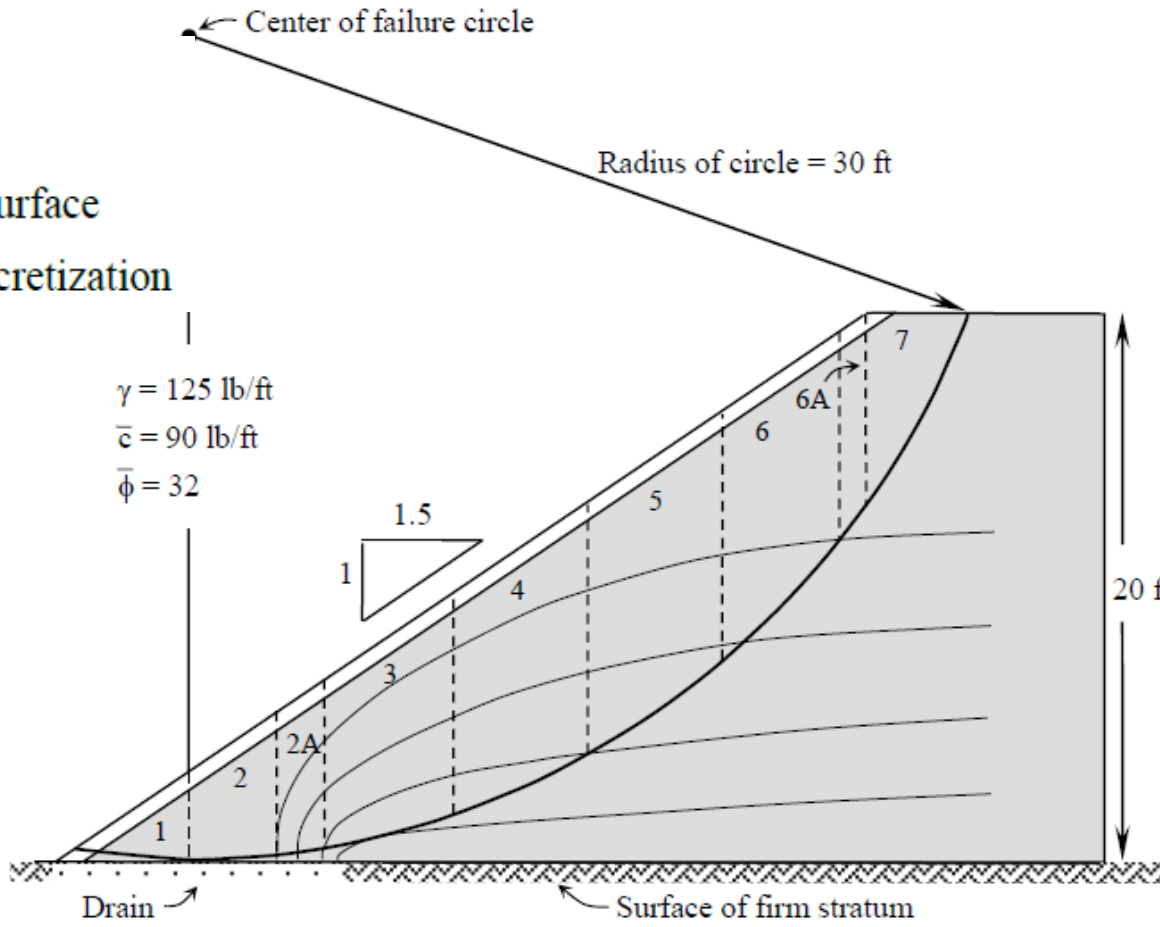

Figure 1 Stability of slope with an underdrain (after Lambe and Whitma

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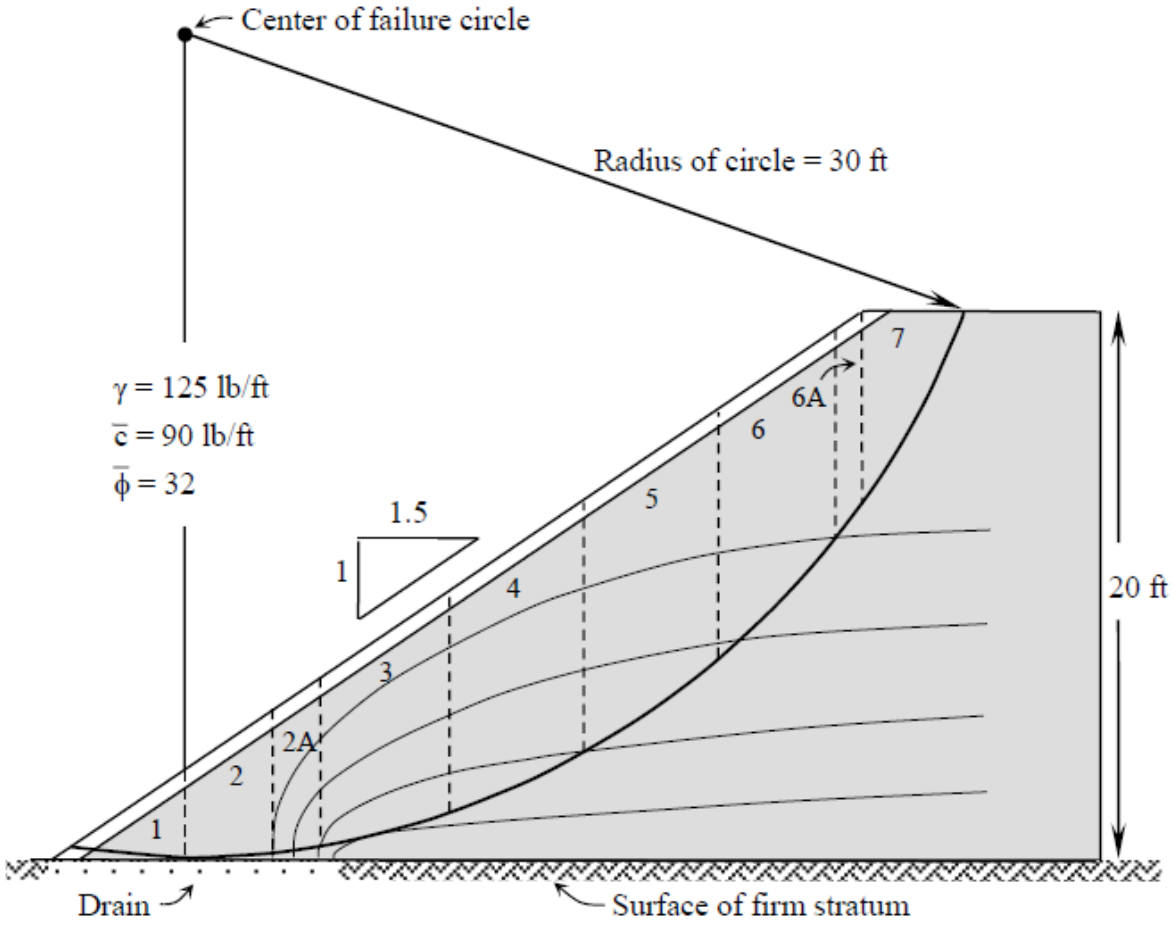

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Require:

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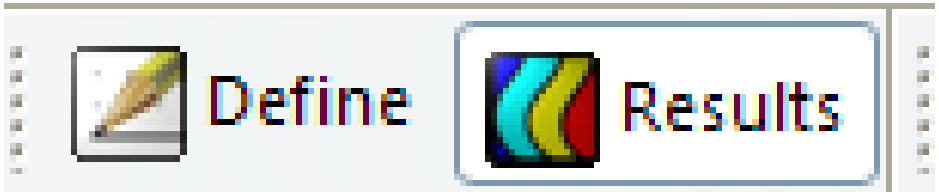

Two components of the Software:

- DEFINE → Input the geometry, material properties, loading, methods of analyses, and **execution**
- RESULTS → post processing (output)

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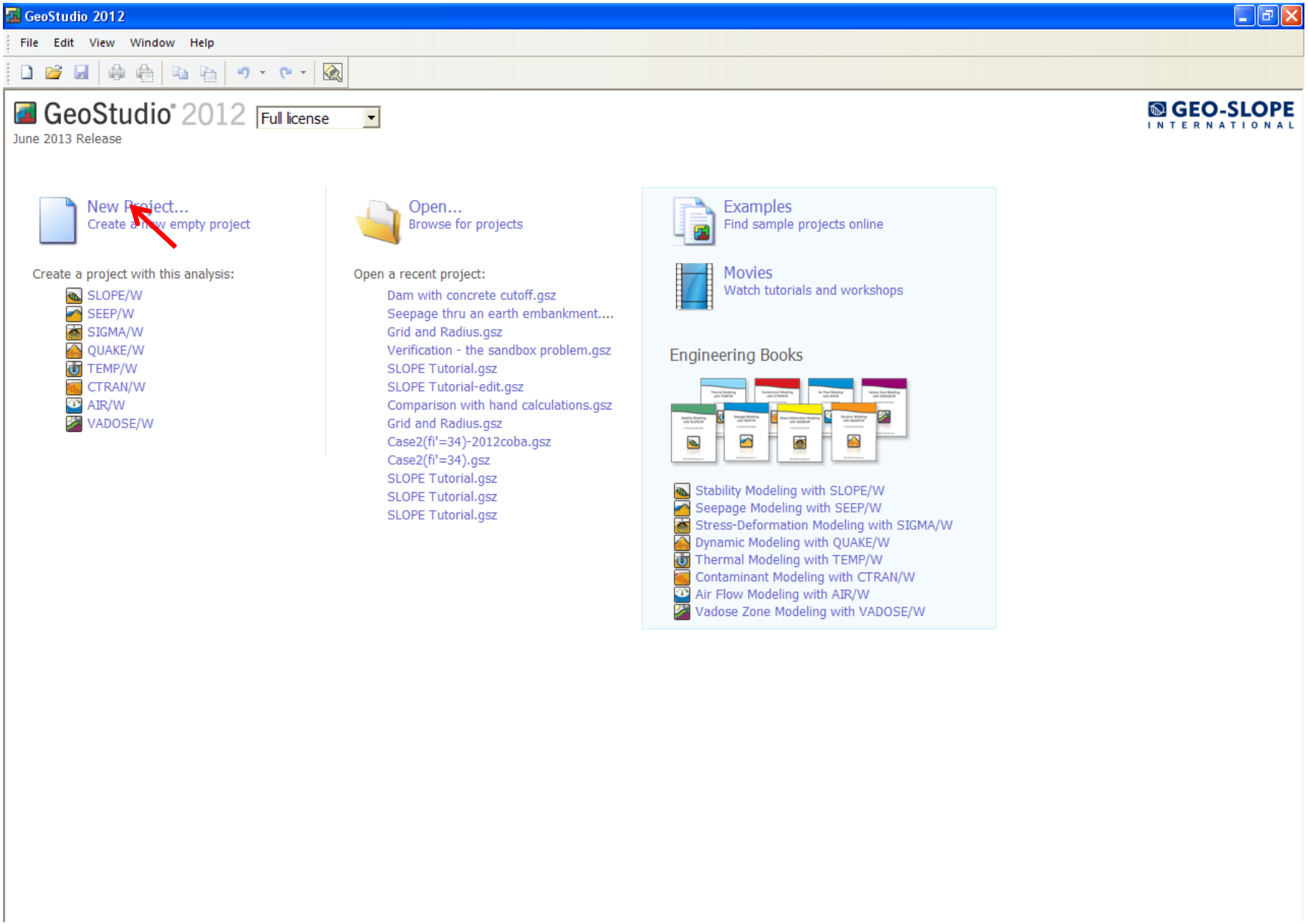

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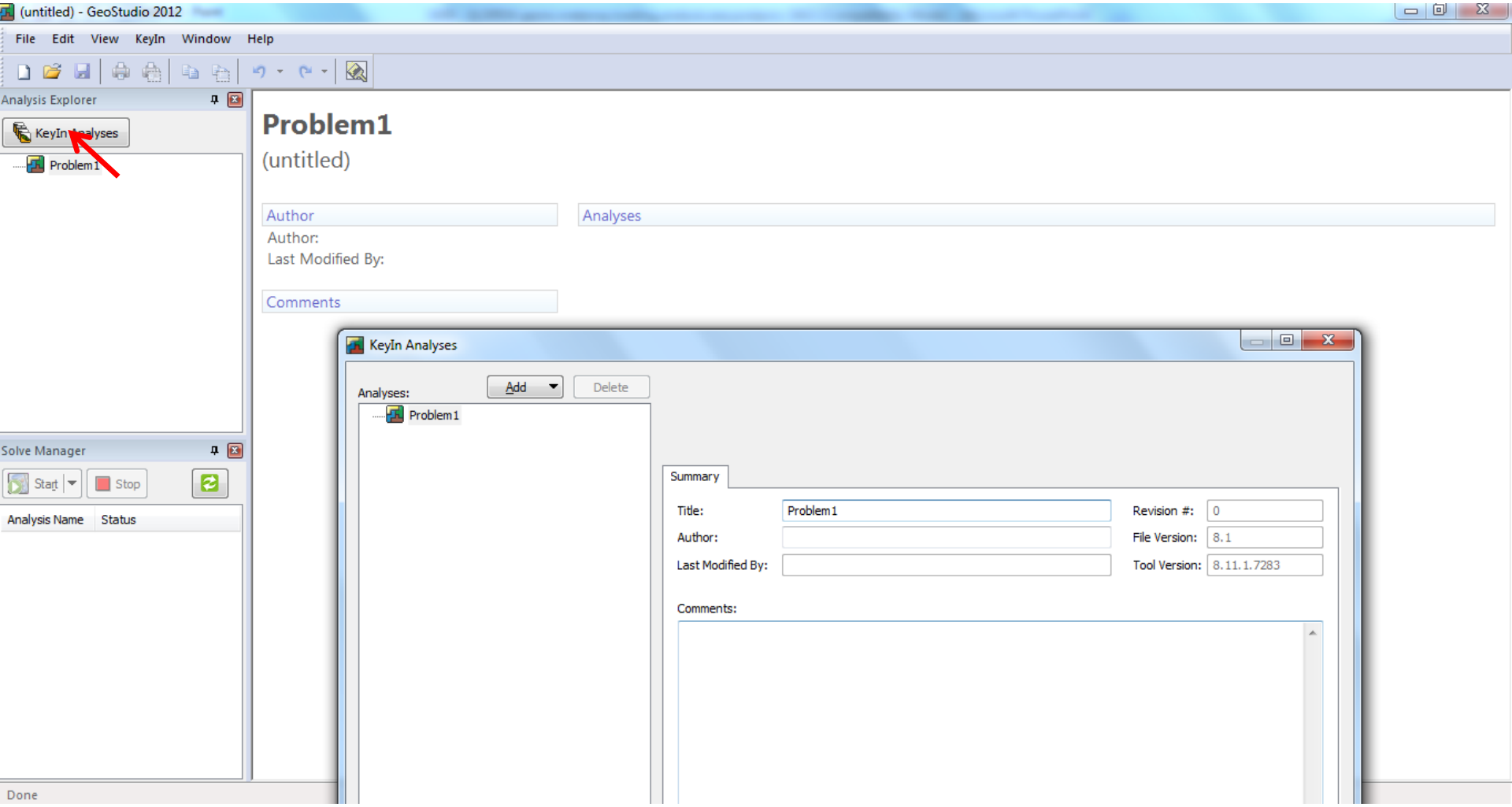

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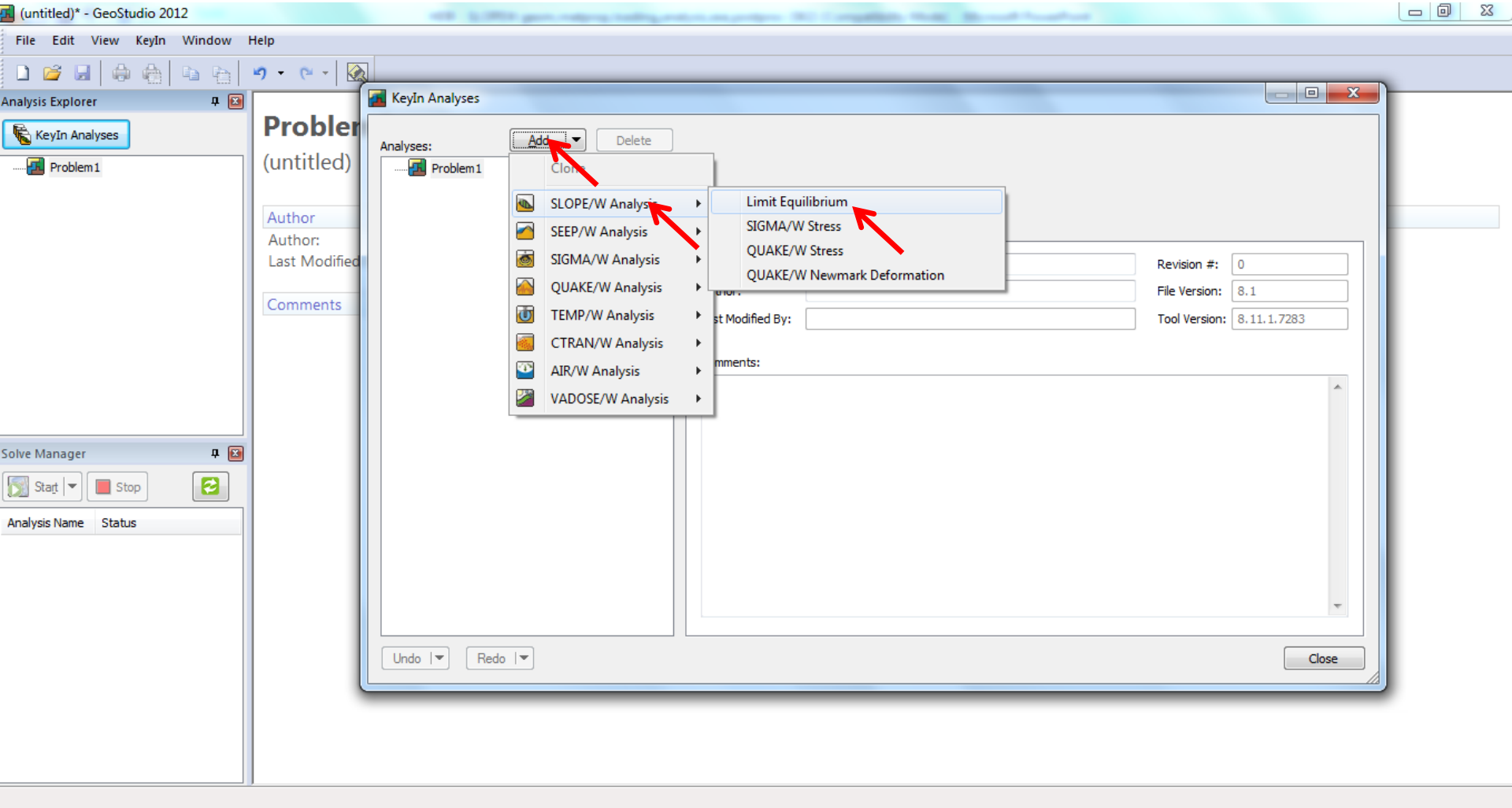

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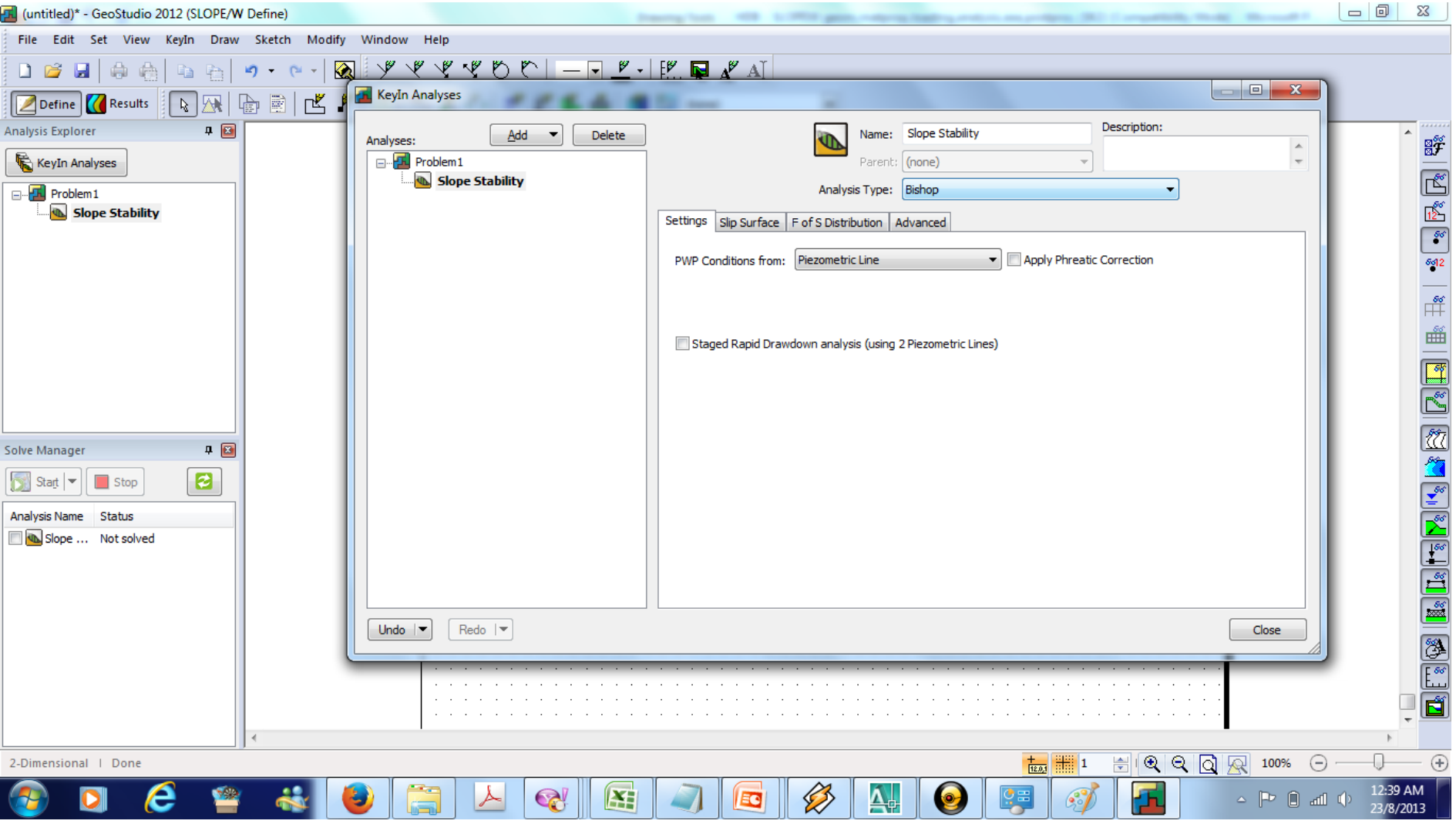

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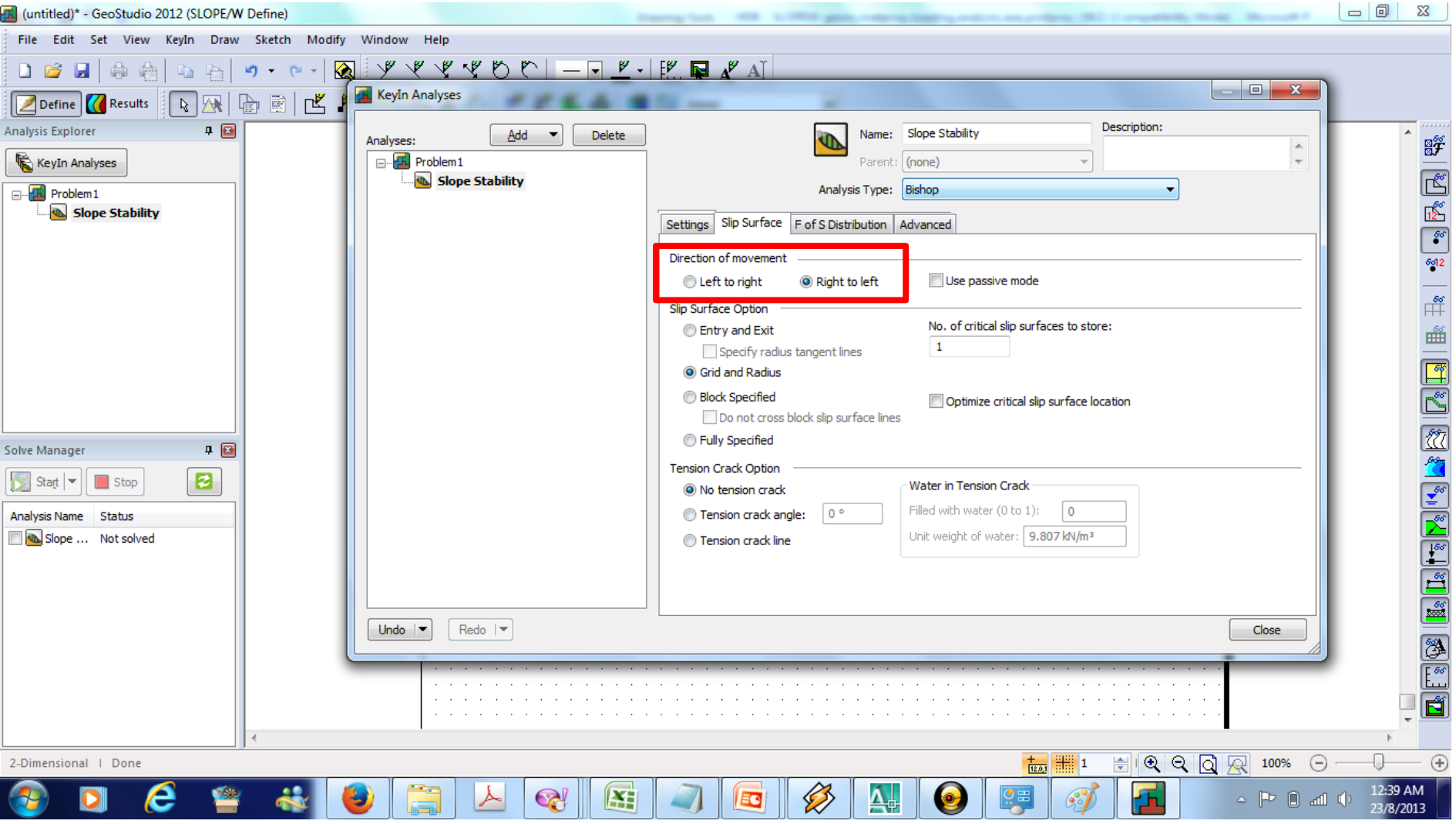

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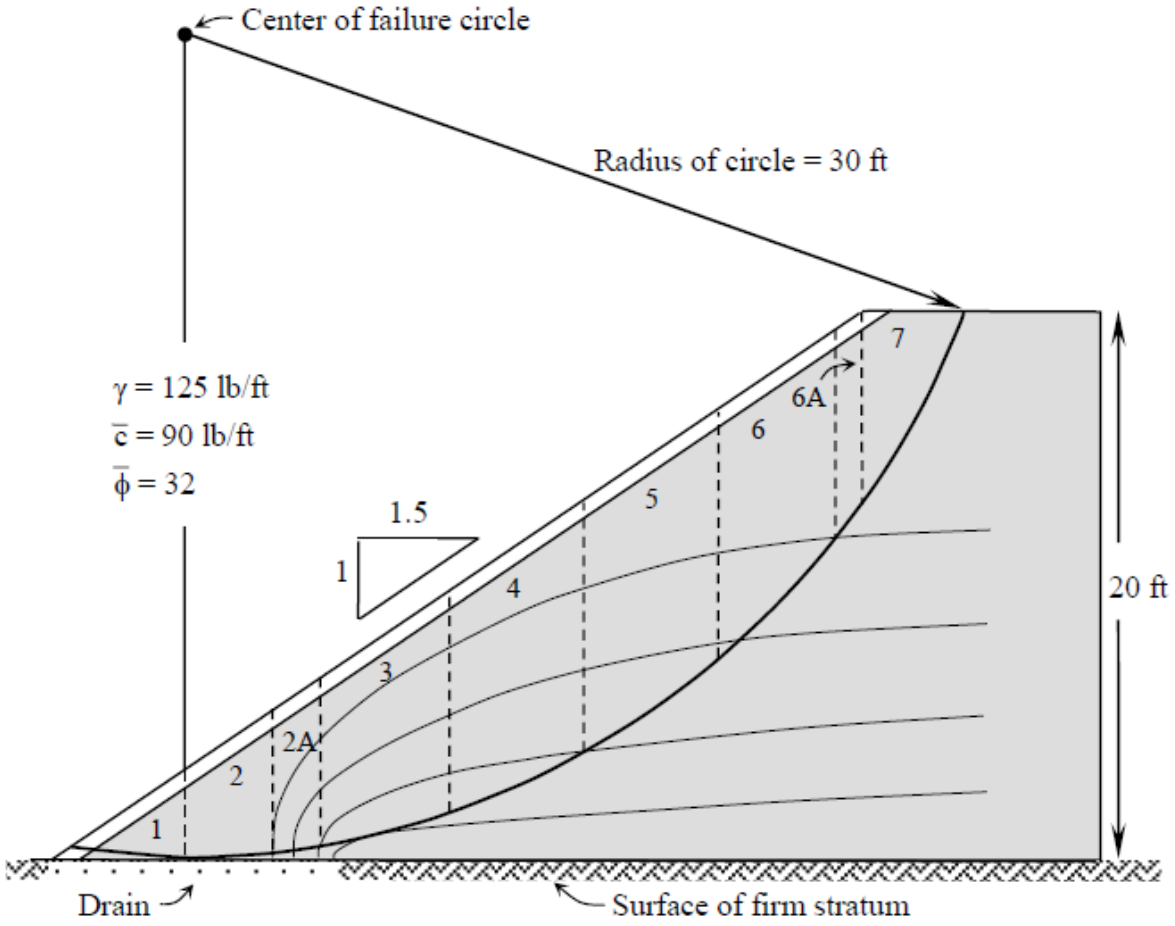

Figure 1 Stability of slope with an underdrain (after Lambe and Whitman)

Direction of movement: right to left

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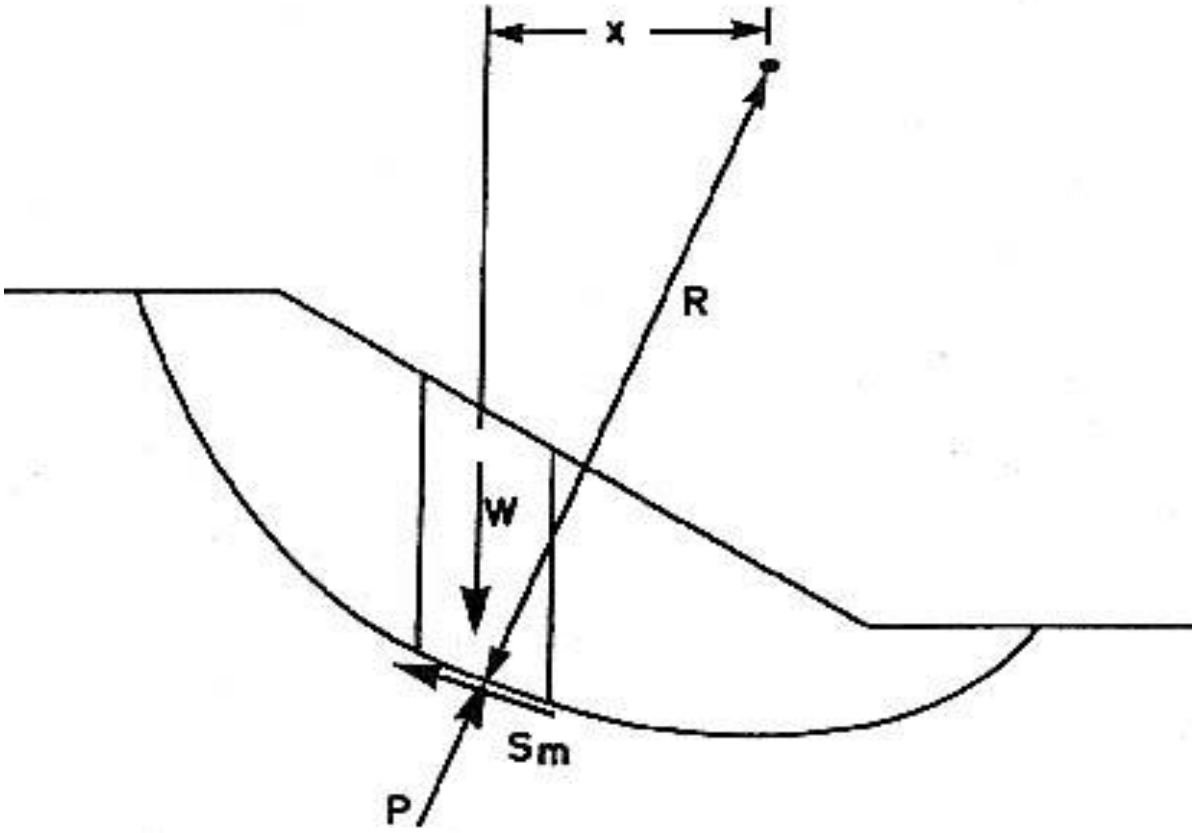

Direction of movement: left to right

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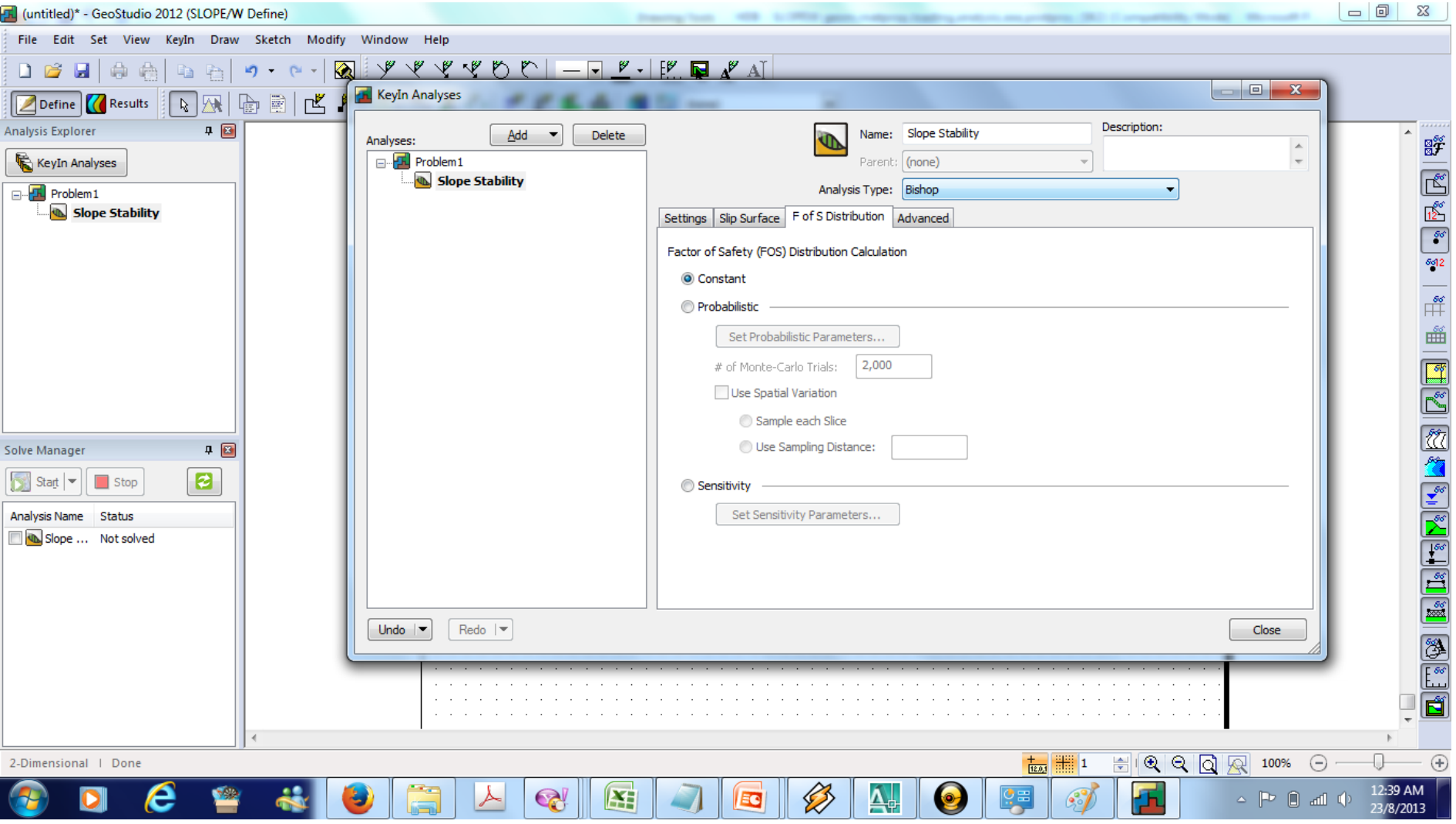

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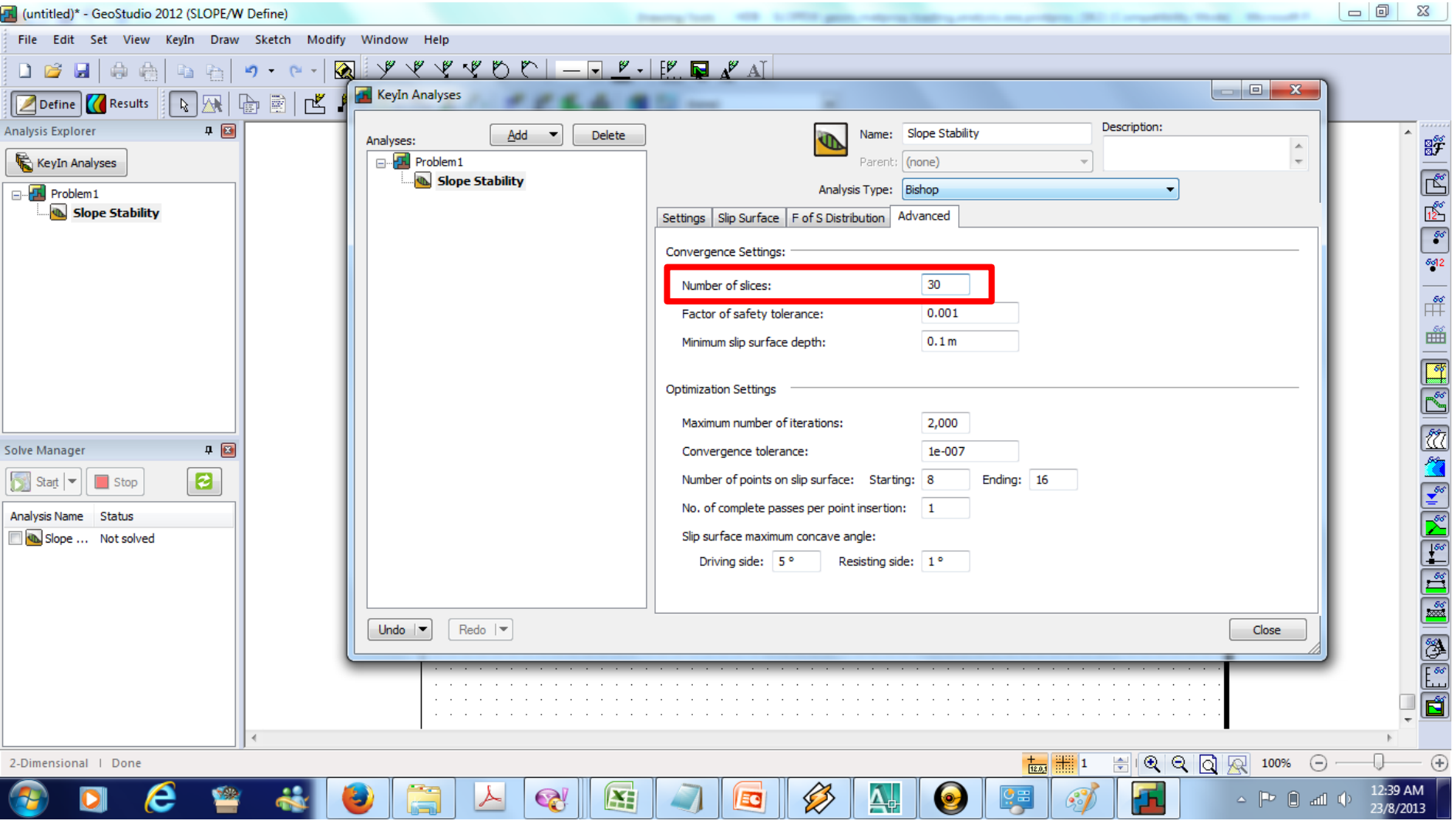

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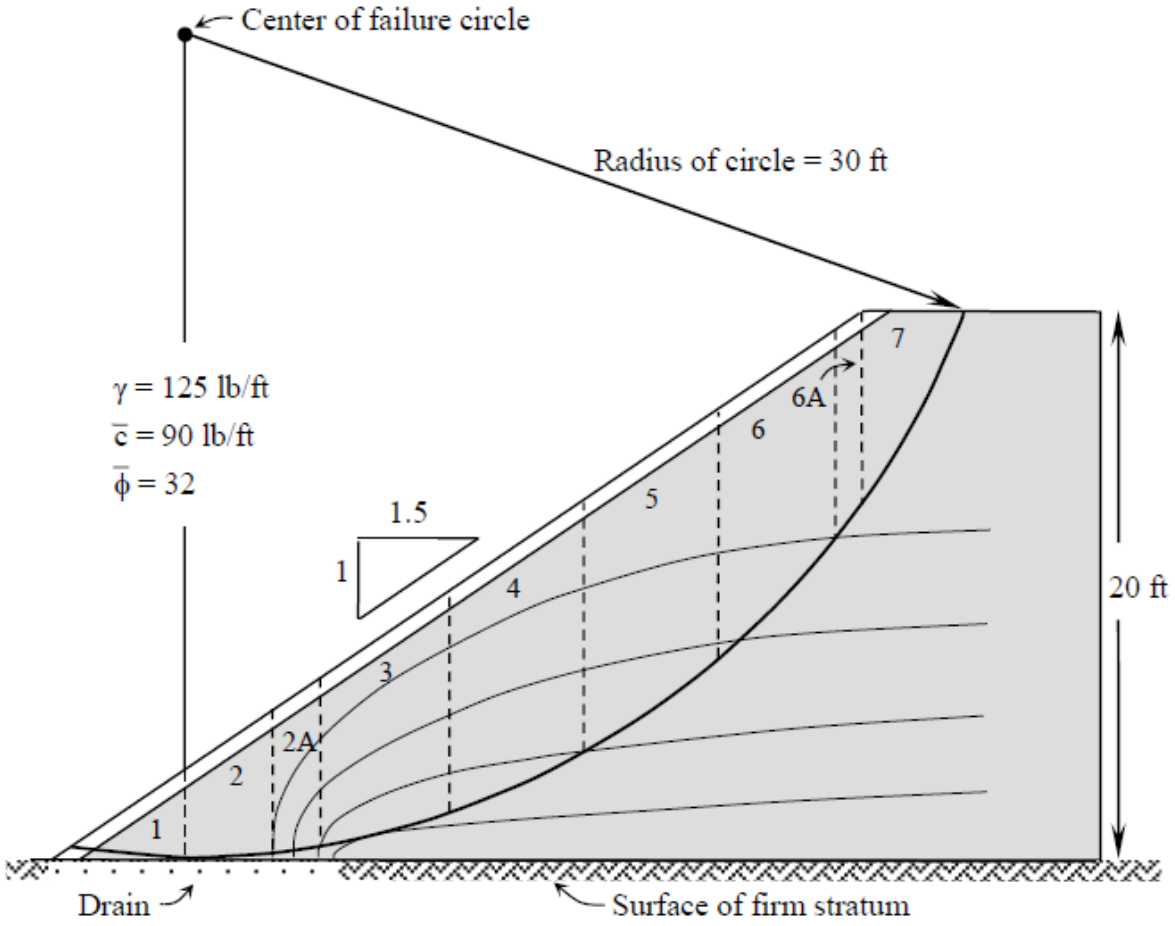

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Suggested sequence of analysis using SLOPE/W:

- Geometry: sketch the geometry
- Set page size, unit and scale
- Geometry:
  - Draw points
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- Material properties:
  - Input material properties data
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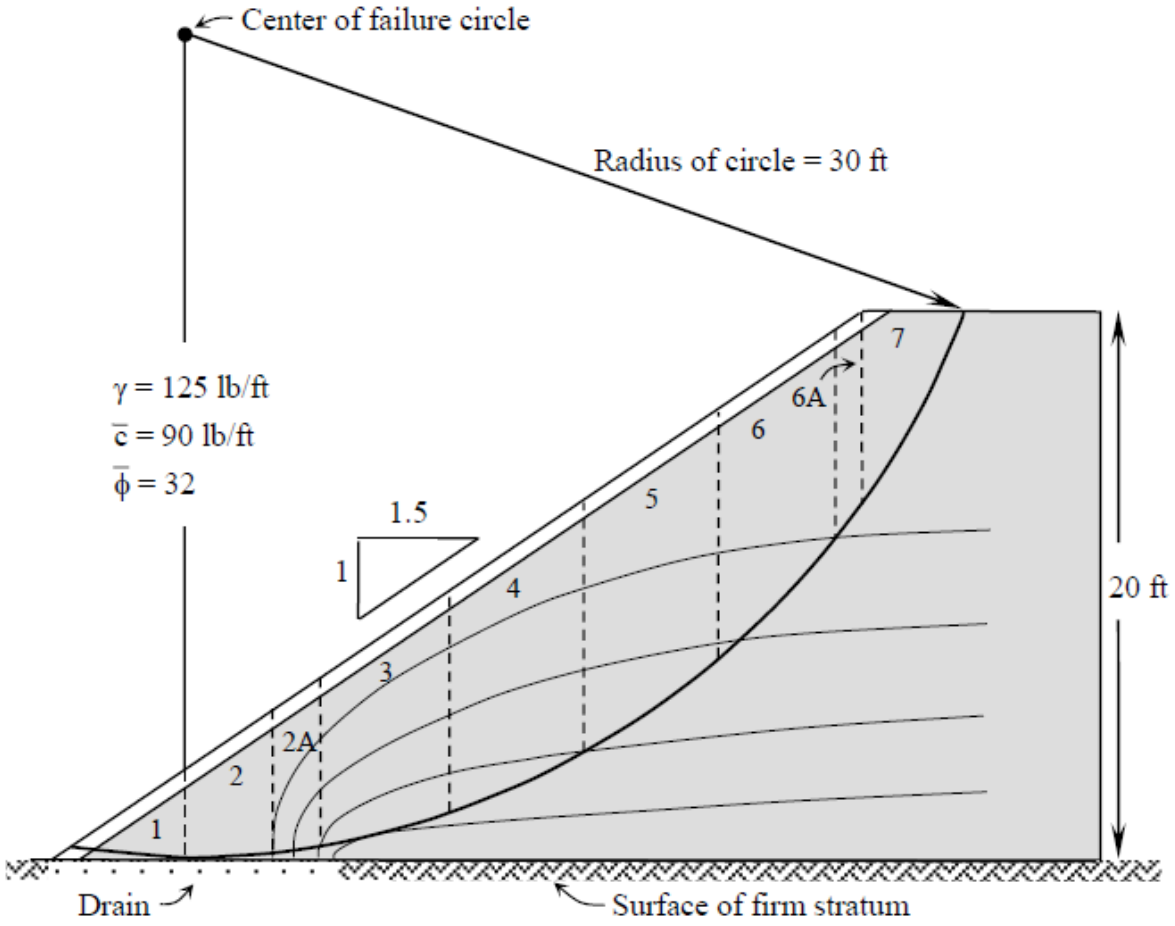

Figure 1 Stability of slope with an underdrain (after Lambe and Whitman)

Require:

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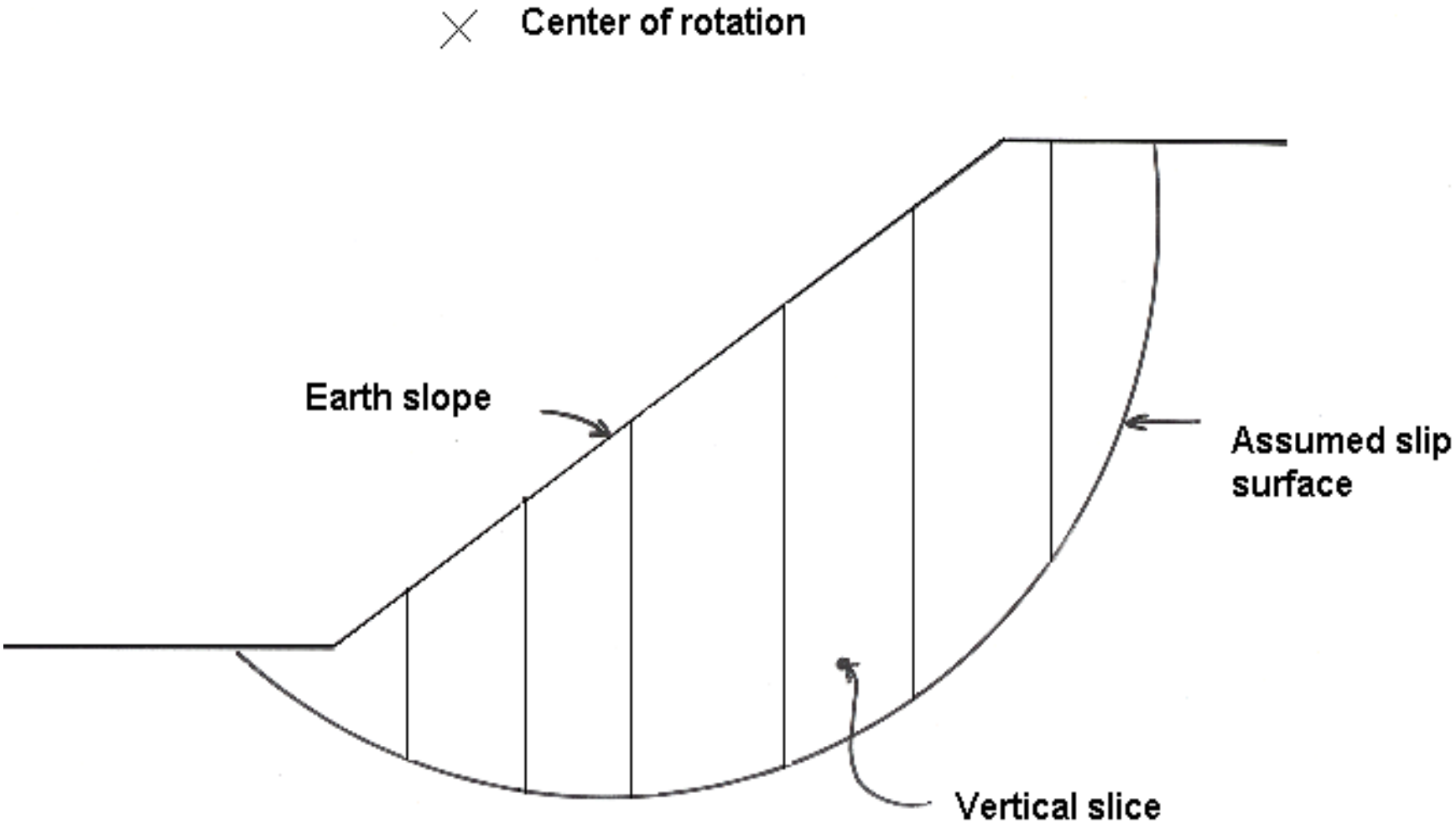
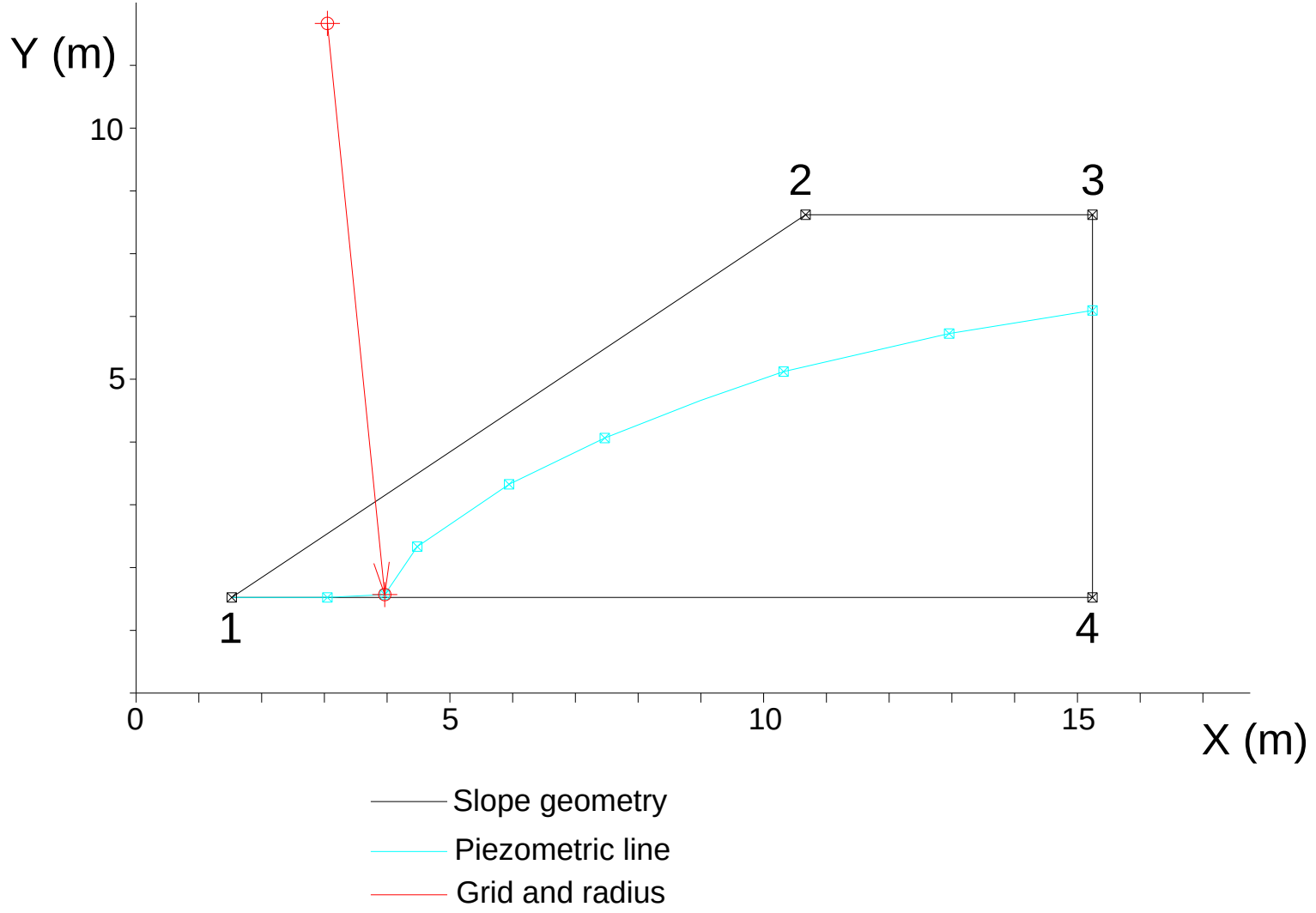

Center of rotation
Earth slope
Assumed slip surface
Vertical slice

PROBLEM 1

Model for Numerical Analysis



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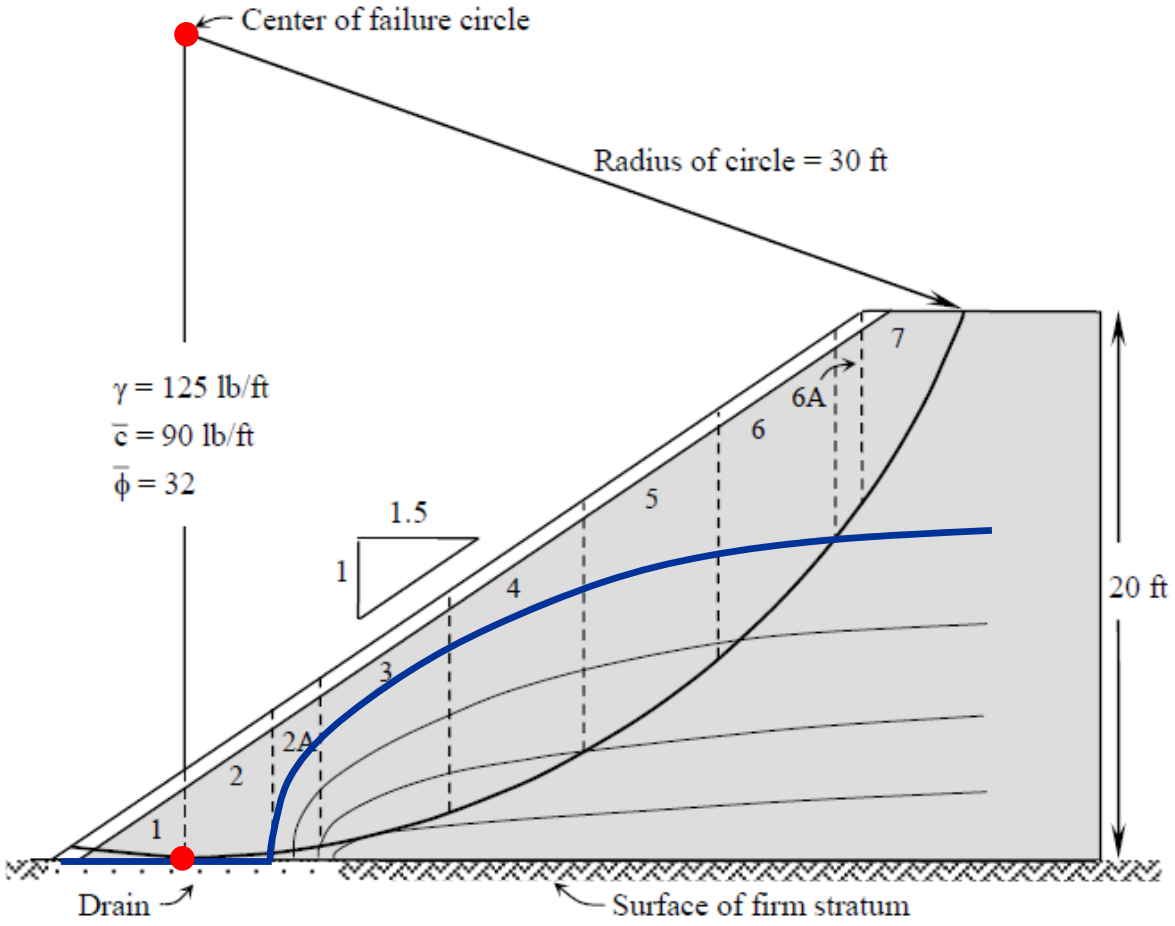

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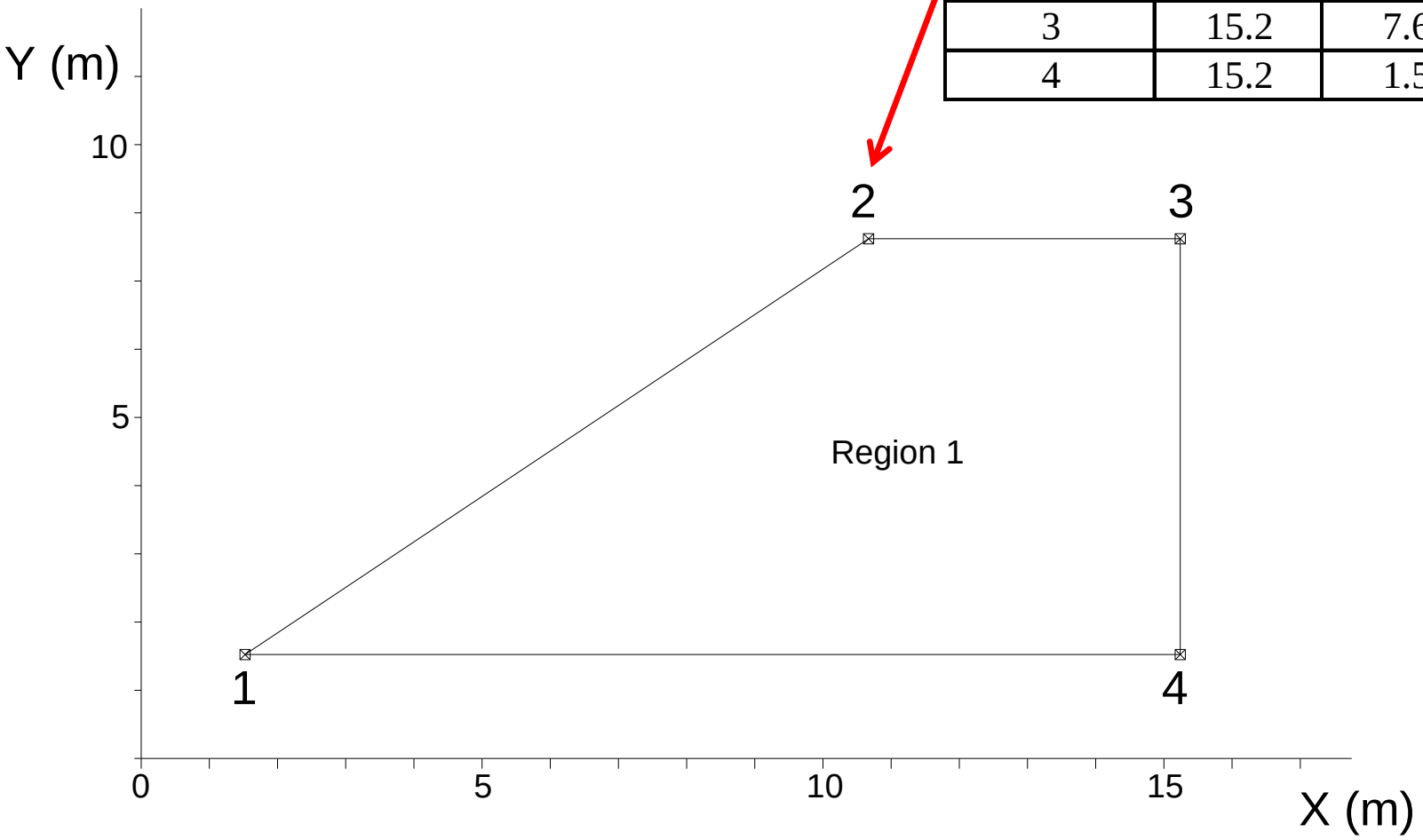
PROBLEM 1

Slope Geometry

POINT ID	X (m)	Y (m)
1	1.5	1.5
2	10.7	7.6
3	15.2	7.6
4	15.2	1.5



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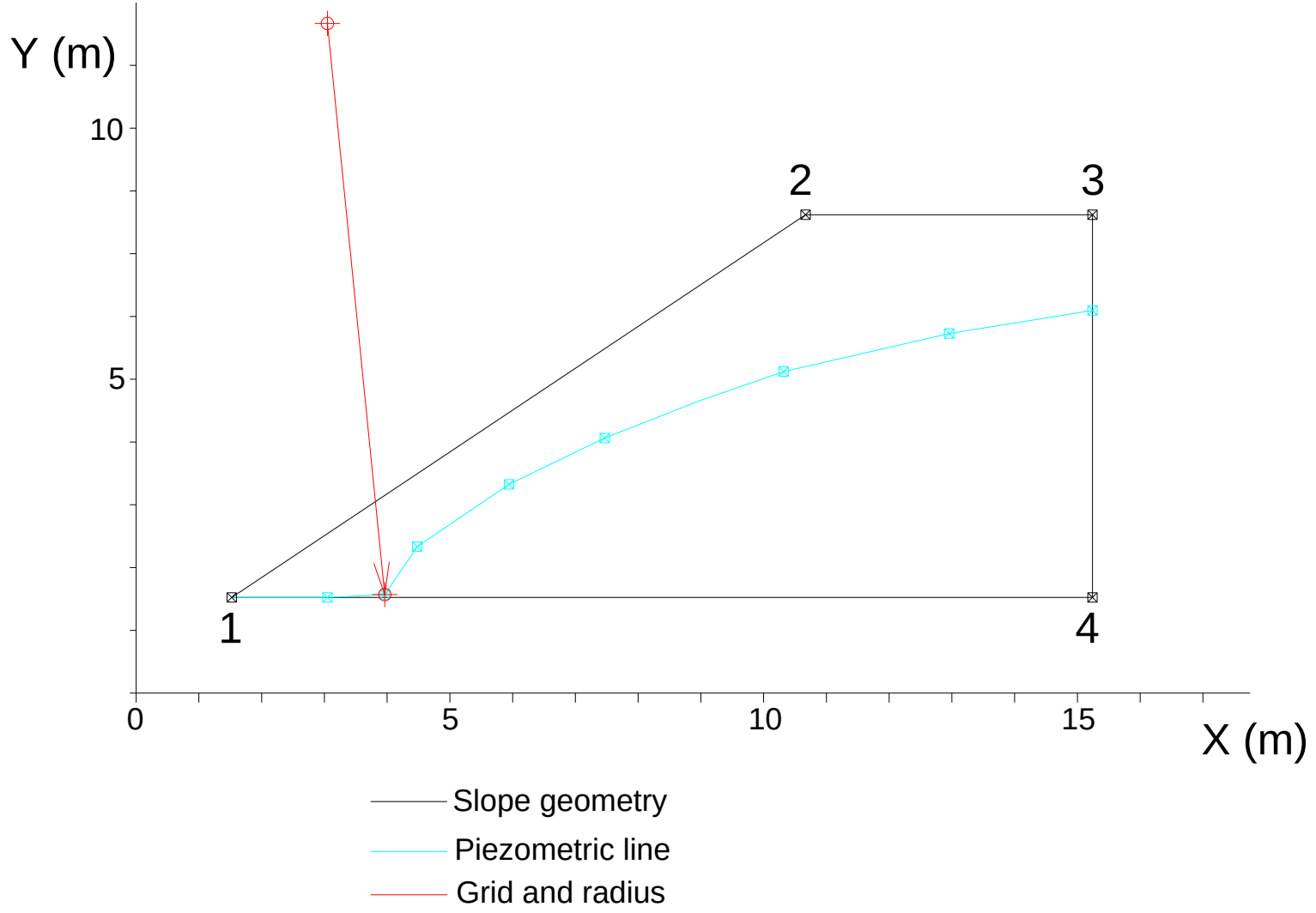
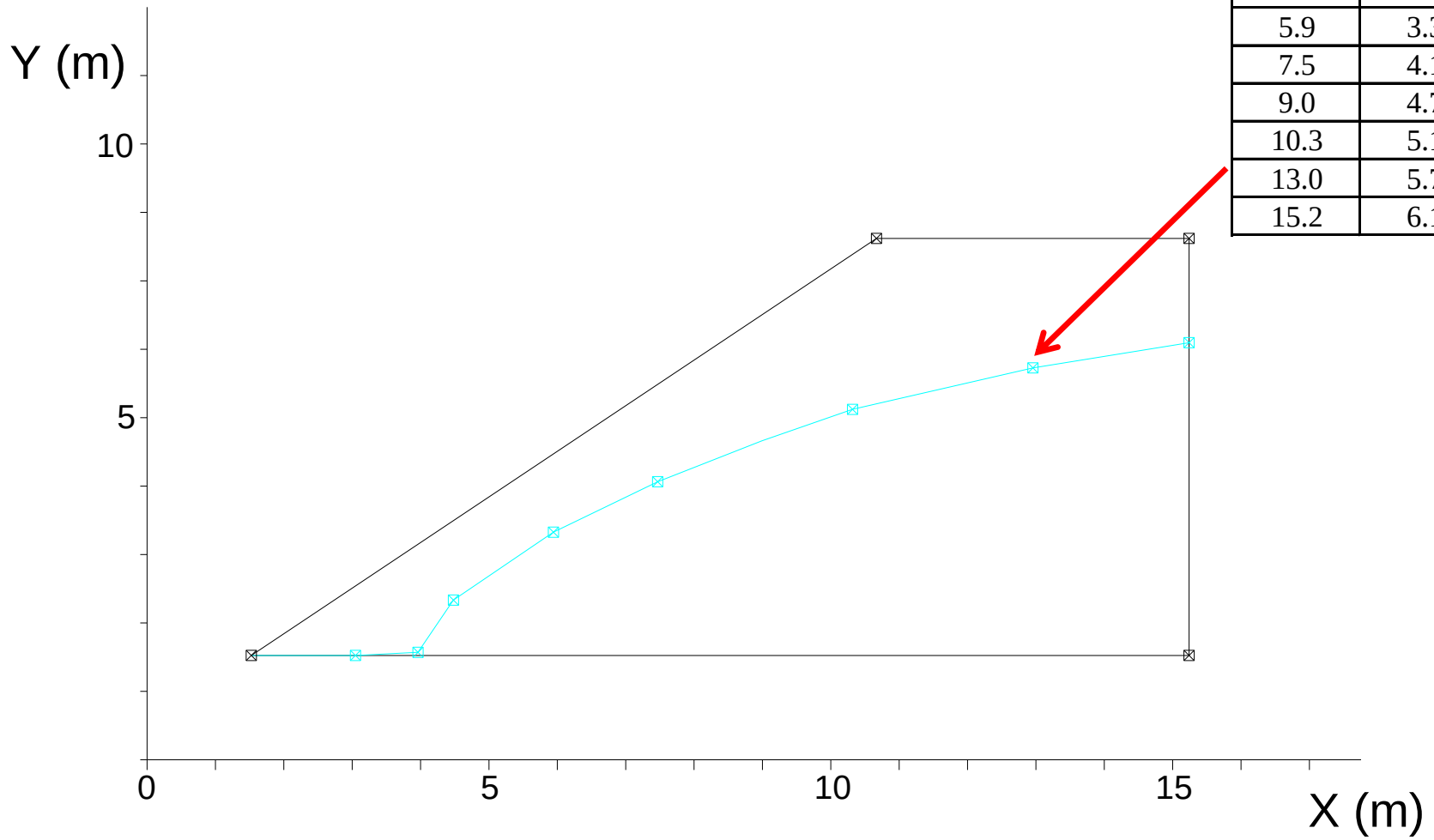


PROBLEM 1

Piezometric Line

X (m)	Y (m)
1.5	1.5
3.0	1.5
4.0	1.6
4.5	2.3
5.9	3.3
7.5	4.1
9.0	4.7
10.3	5.1
13.0	5.7
15.2	6.1



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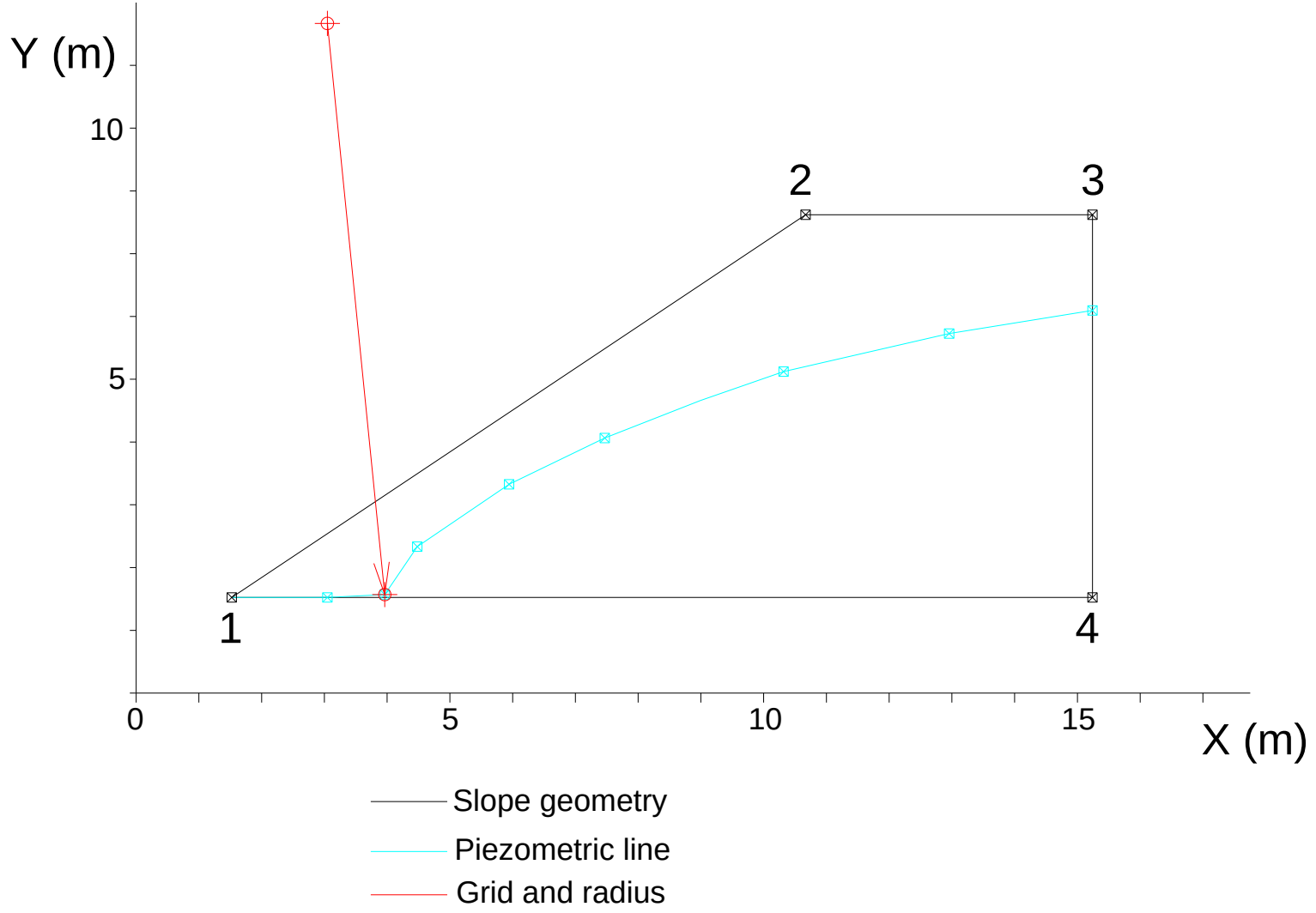
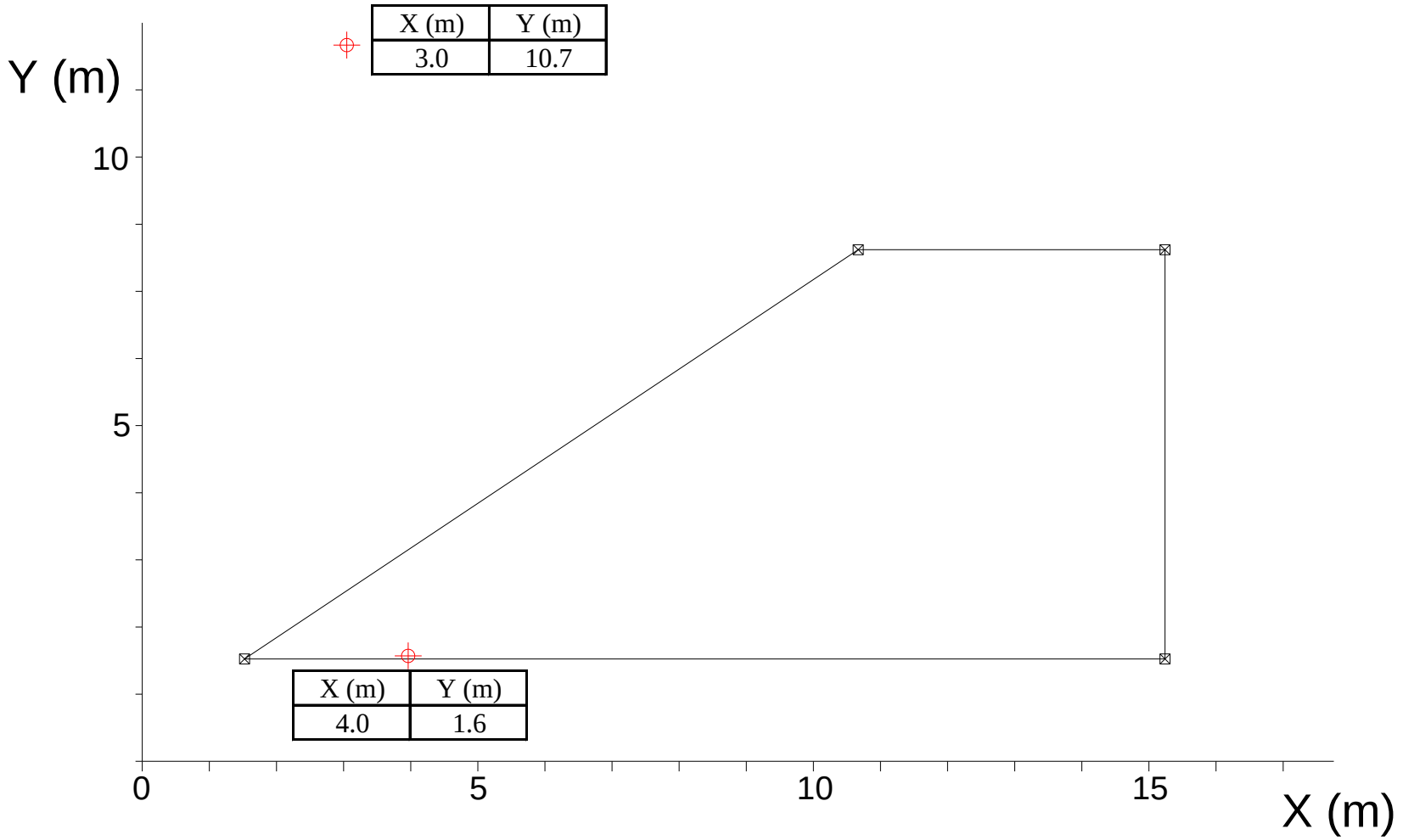


PROBLEM 1

Grid and Radius



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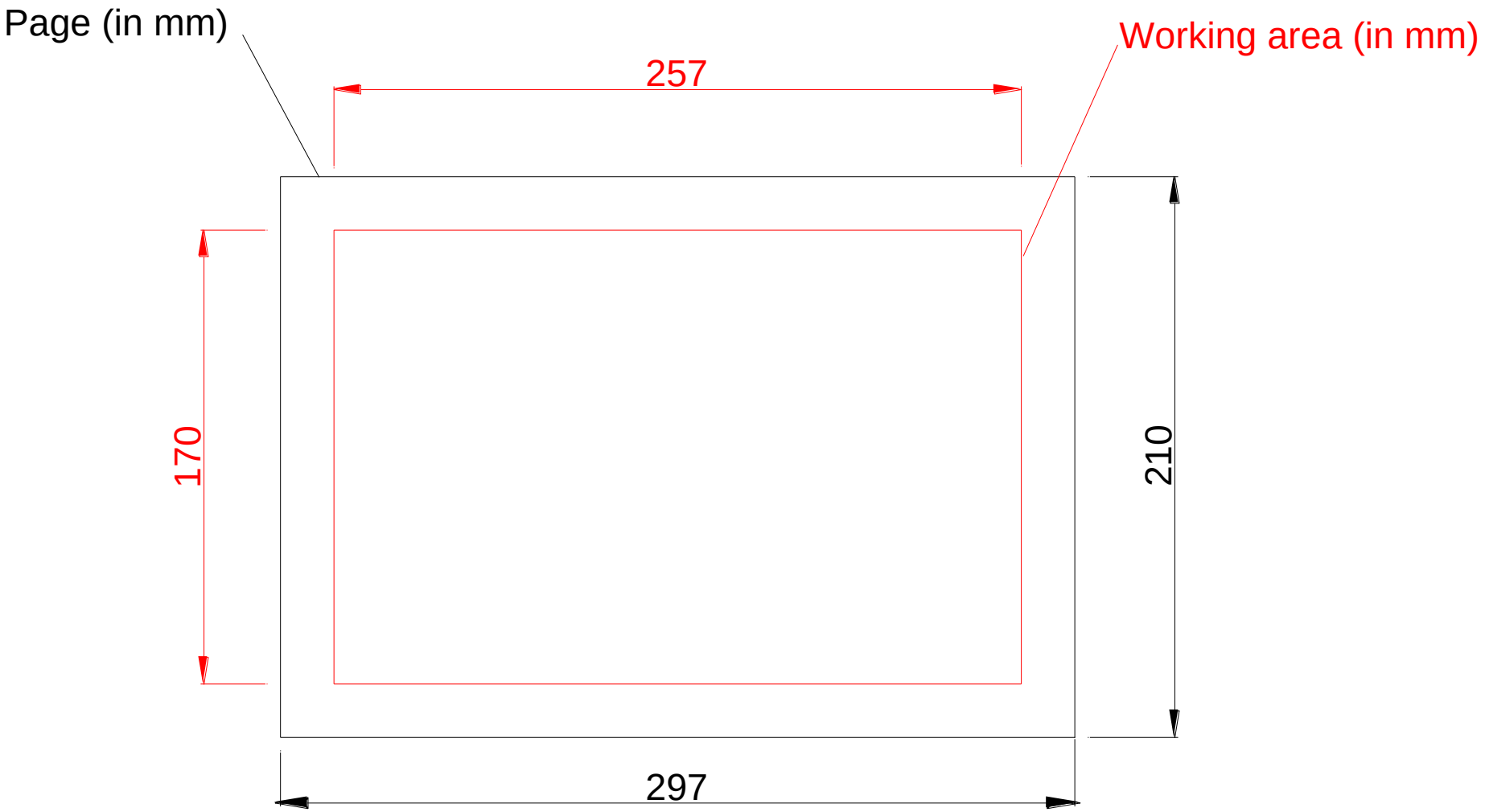
Set Page and Working Area



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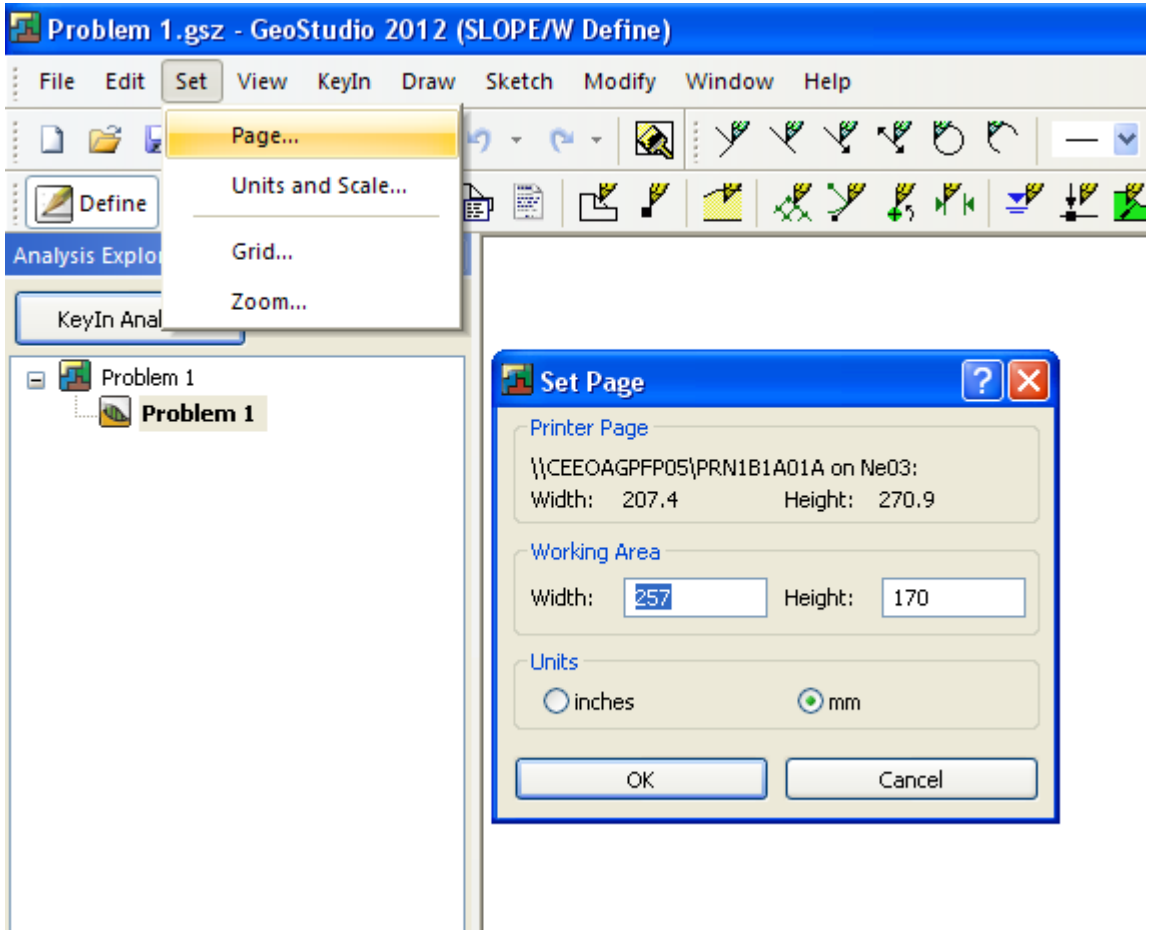

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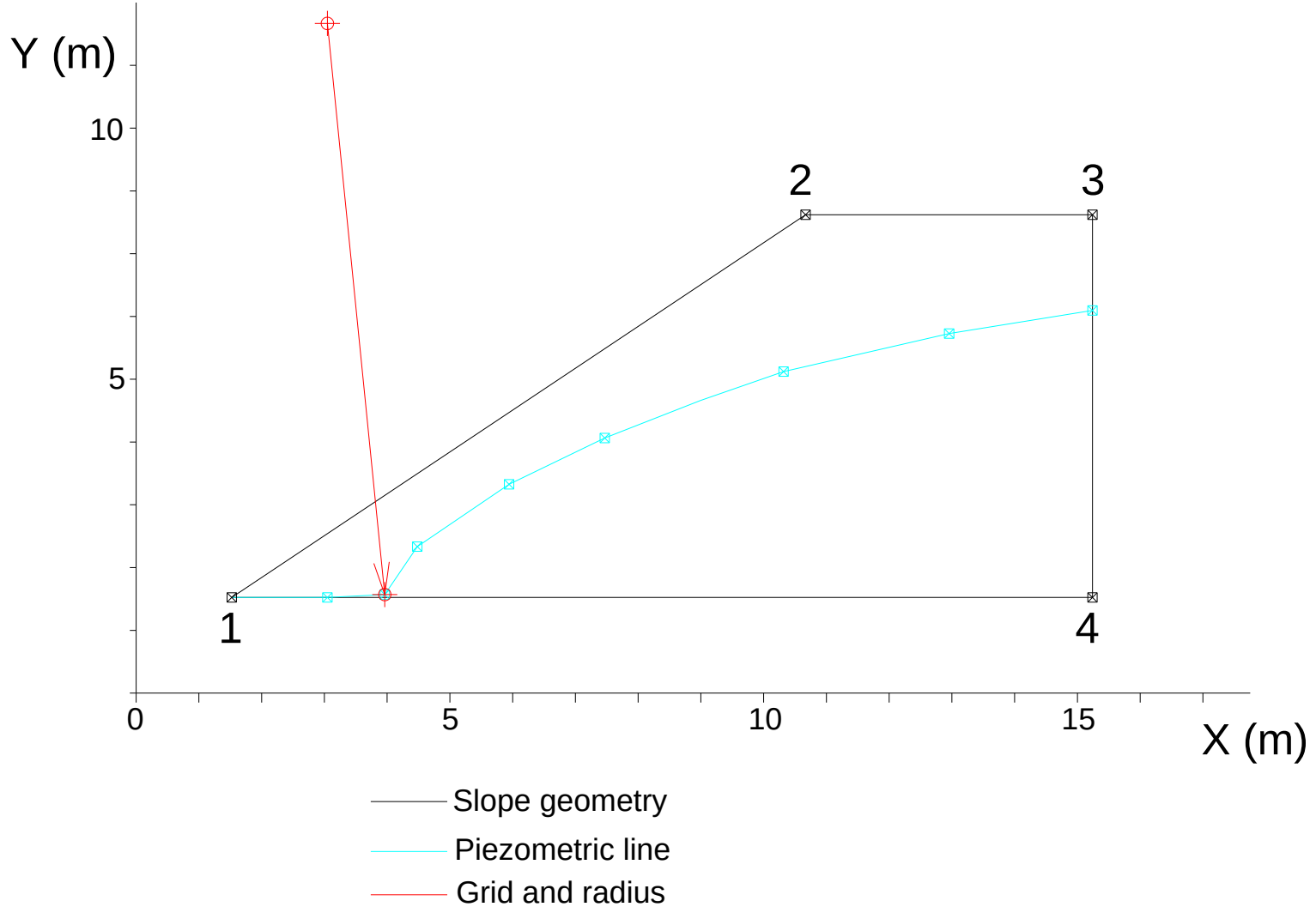

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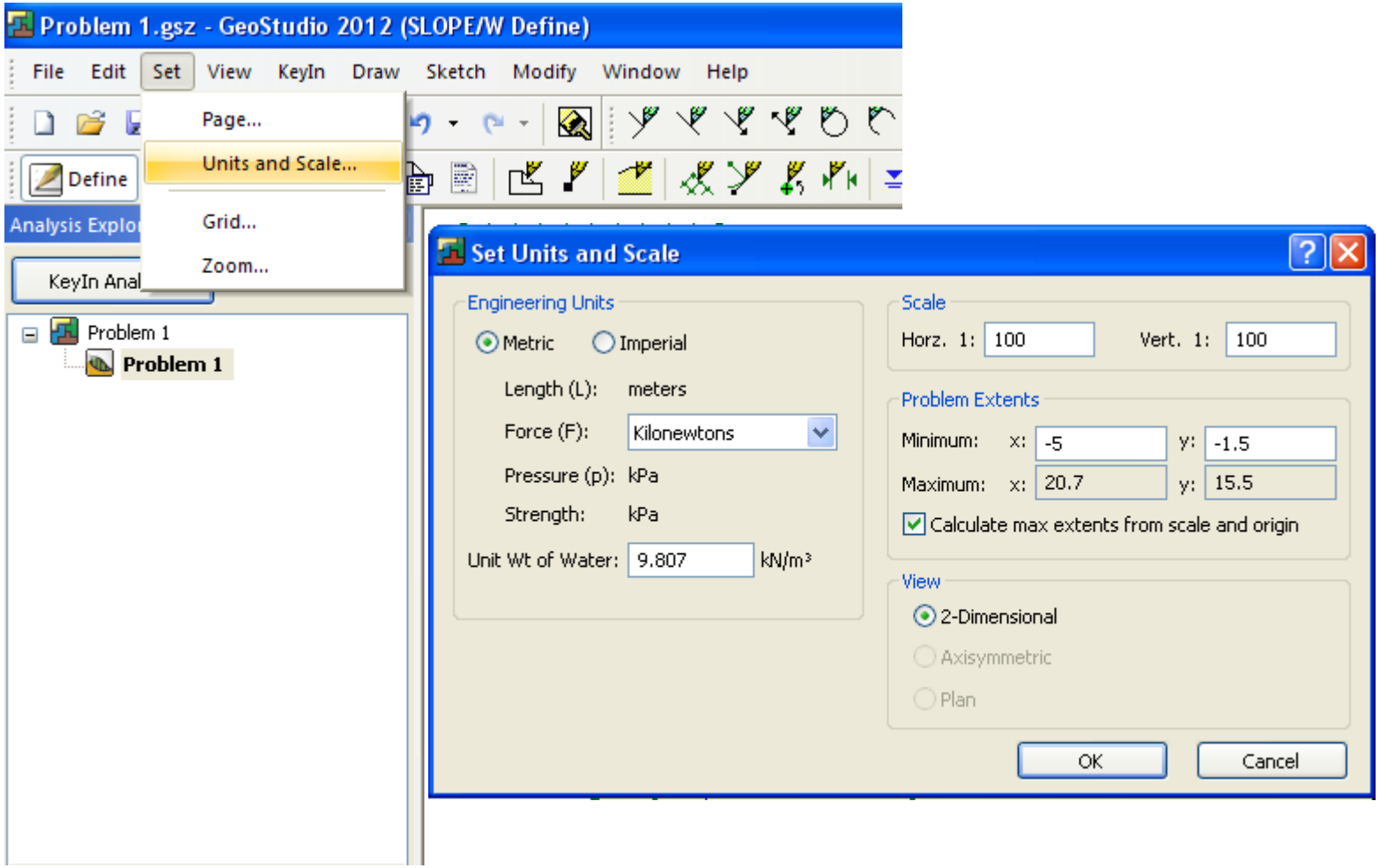

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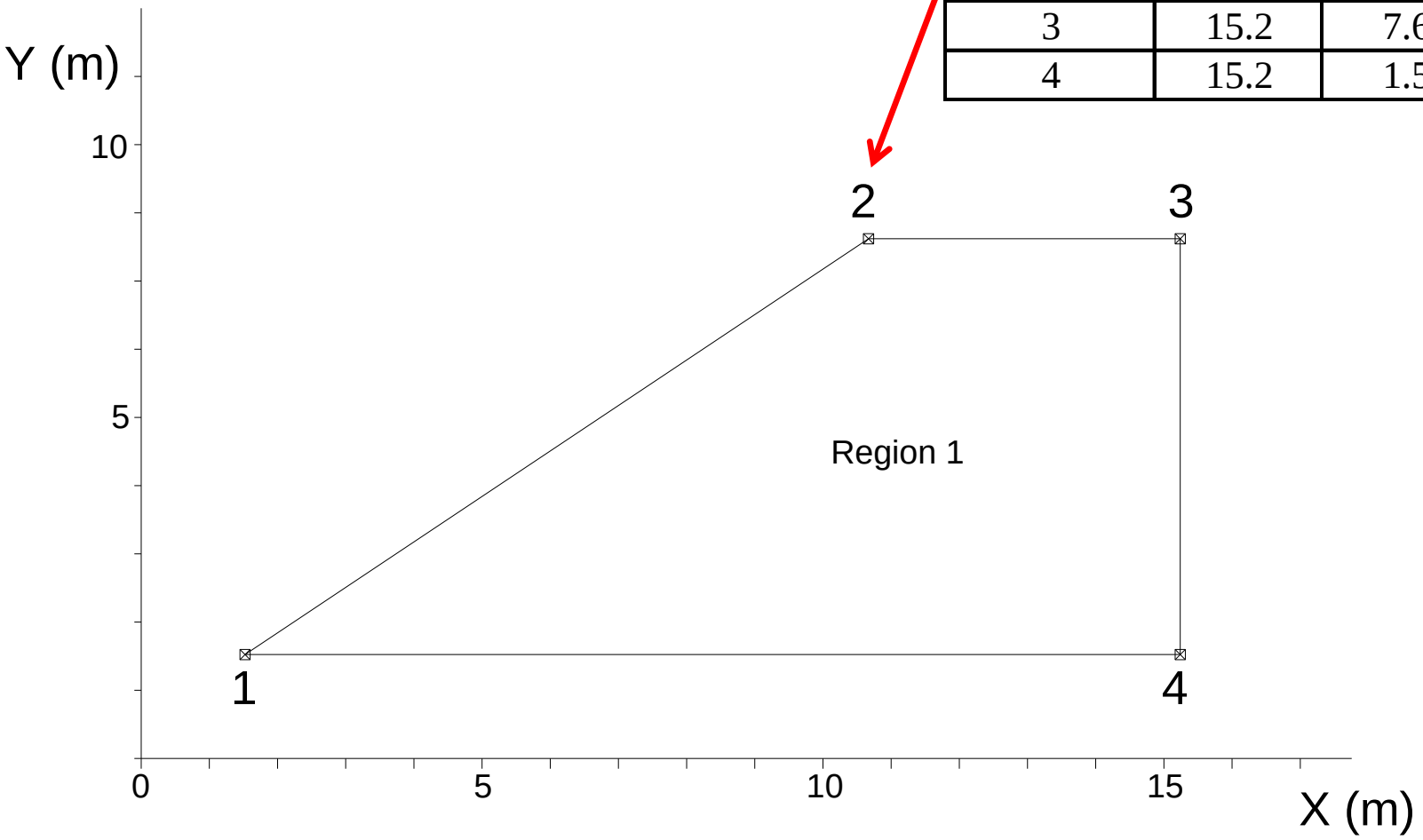


Draw Points (KeyIn – Points)

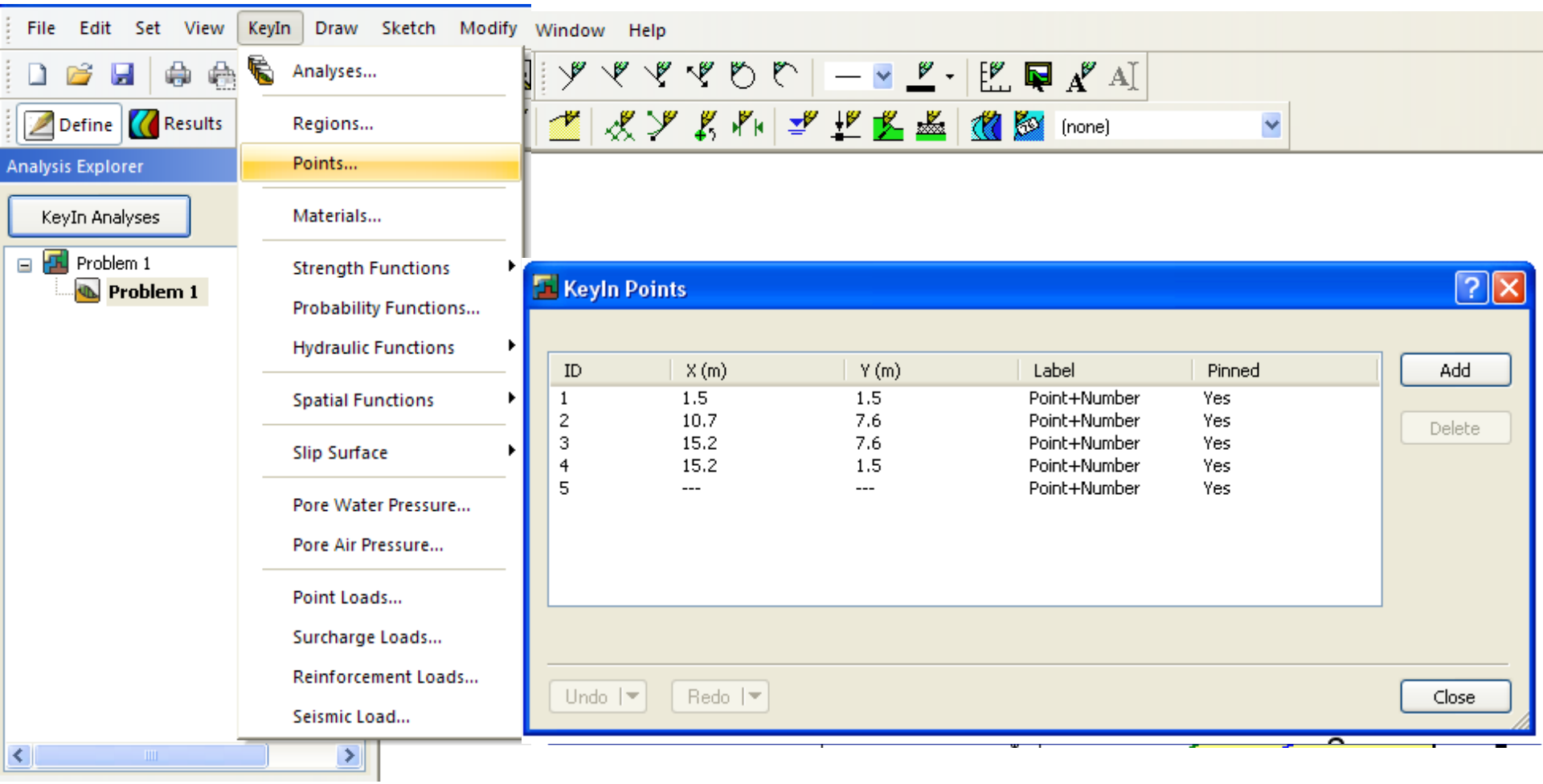
- Input the point coordinate one-by one or
- Paste the coordinate data

Draw Points (Draw – Points)

- To draw a point: left click in the model area.
- To edit a point: left click in the existing point.

PROBLEM 1

Draw Points



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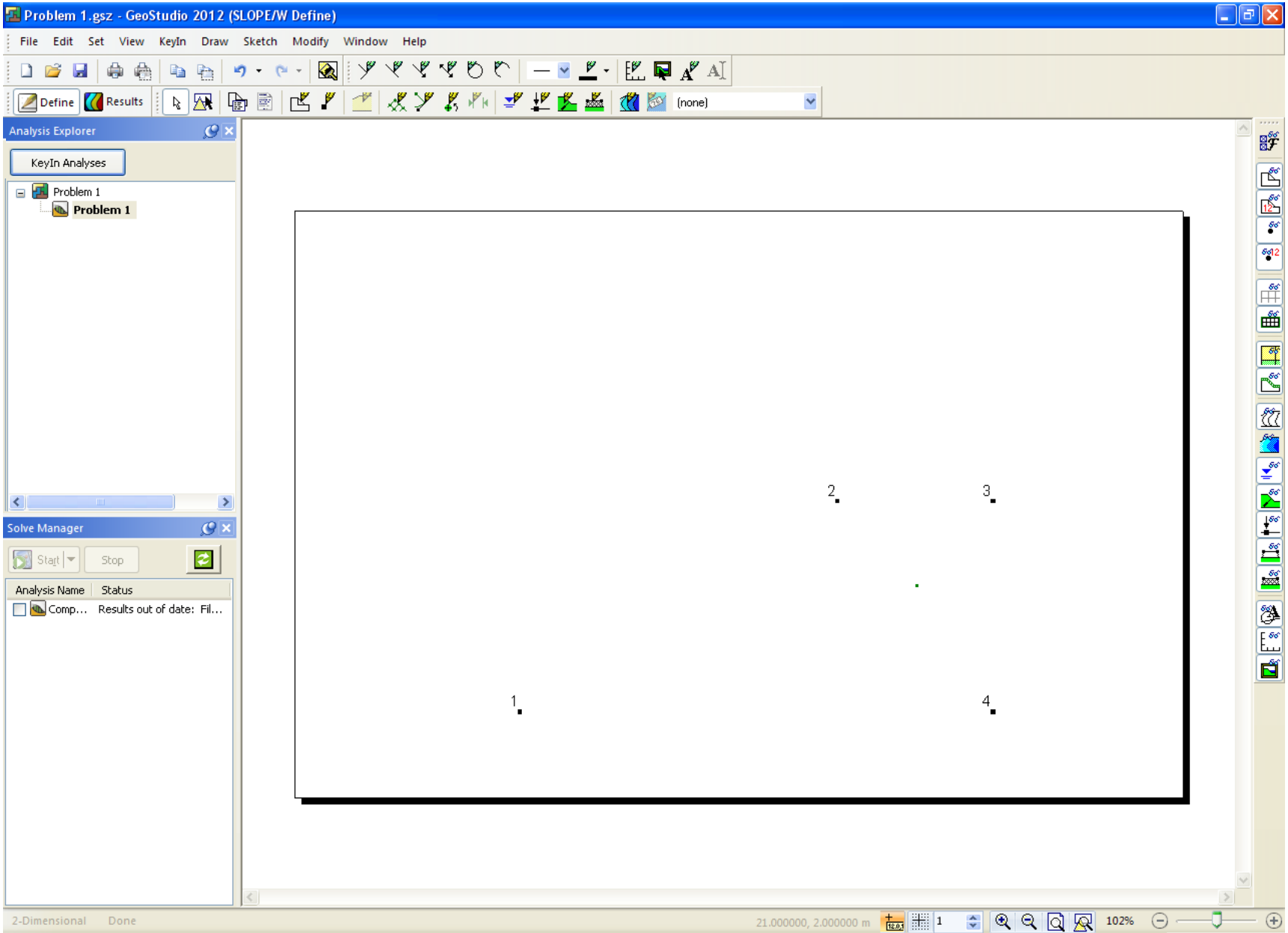

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Draw Regions (KeyIn – Regions)

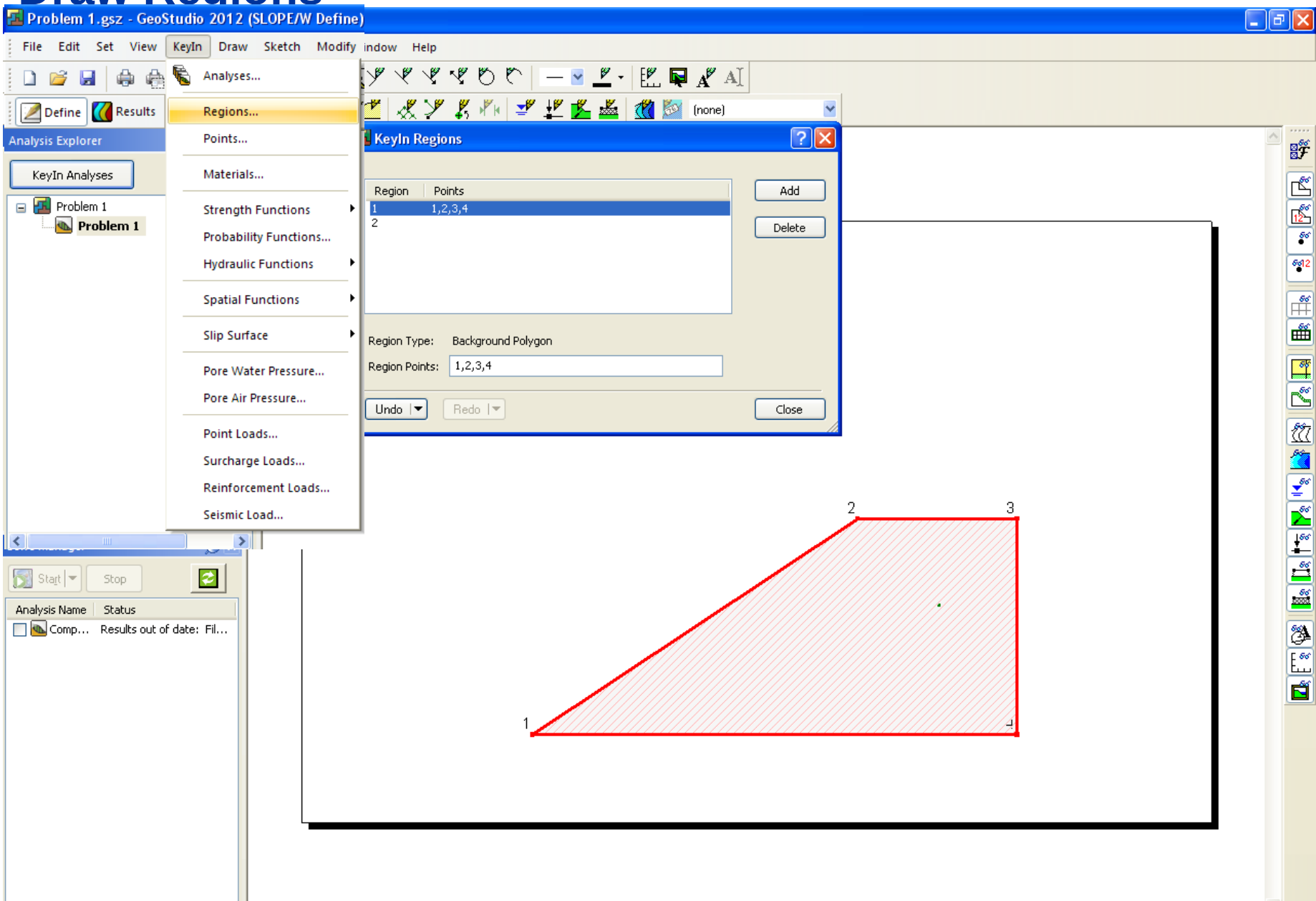
- Input the point numbers of each coordinate separated by commas.
- Point numbers should be in sequence of clockwise or counter-clockwise direction of each region.
- Draw each region one-by one.

Draw Regions (Draw – Regions)

- To draw a region: click in the model area.
- To edit a region: click on one region.

PROBLEM 1

Draw Regions



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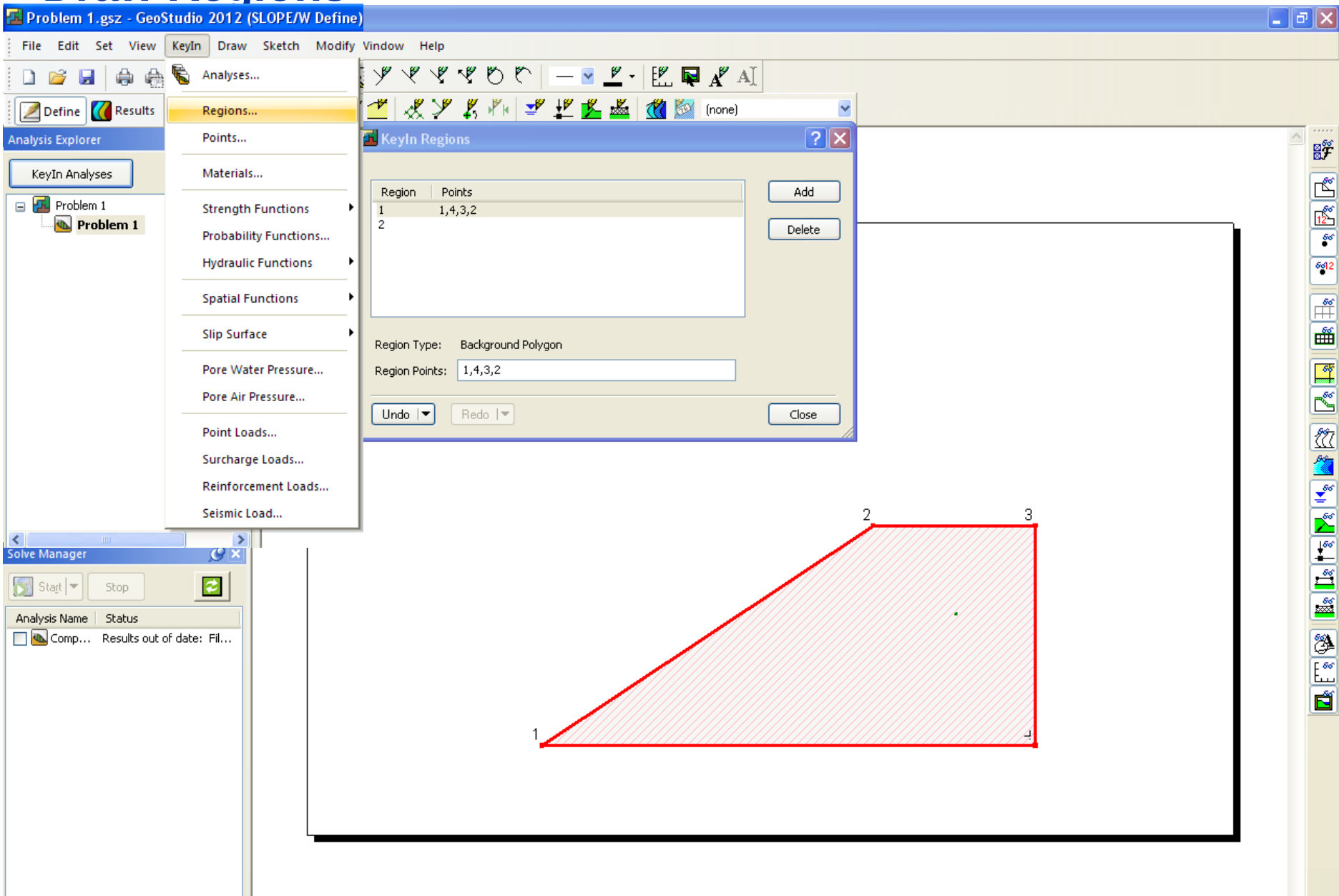

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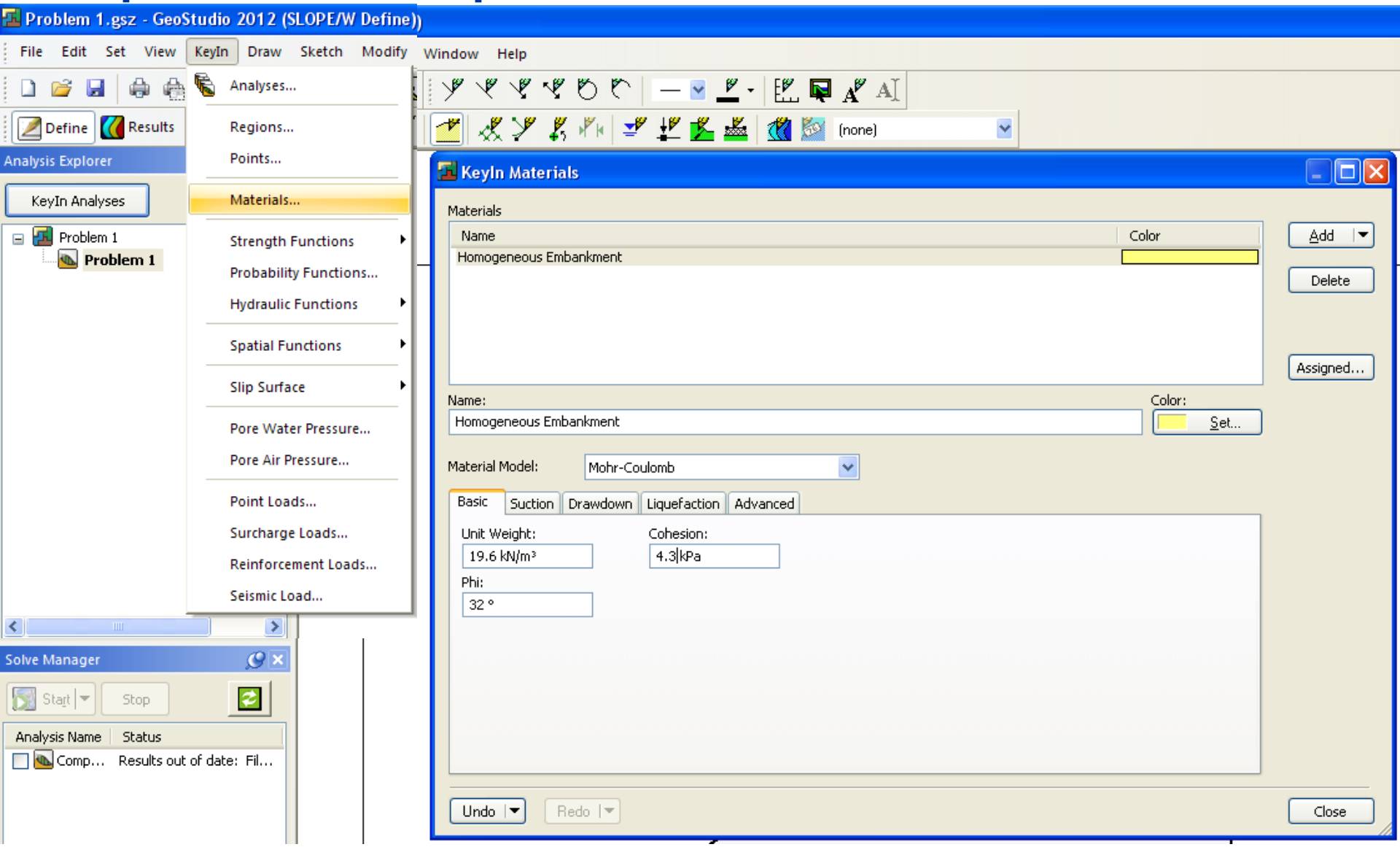
Input Material Properties Data



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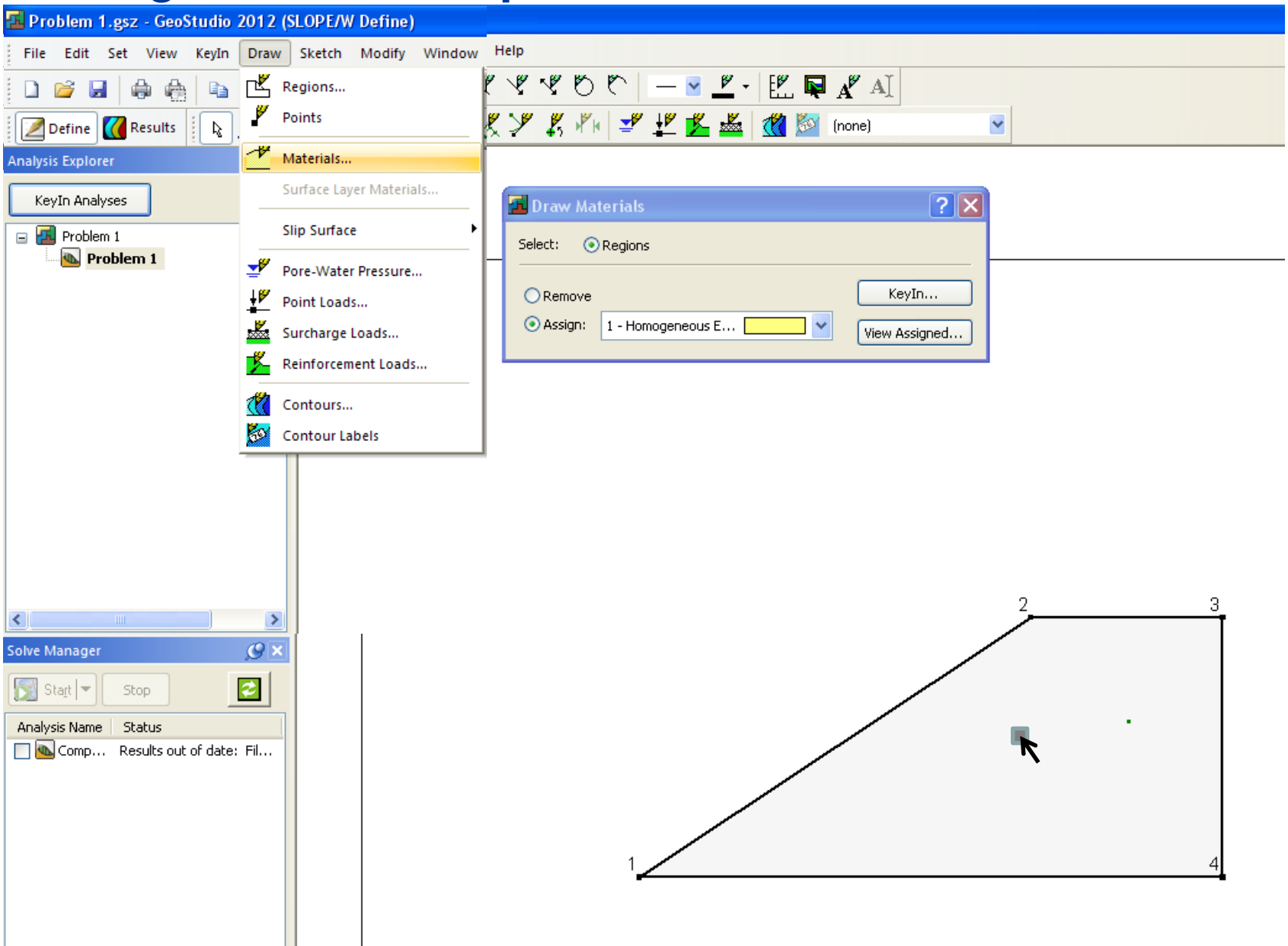

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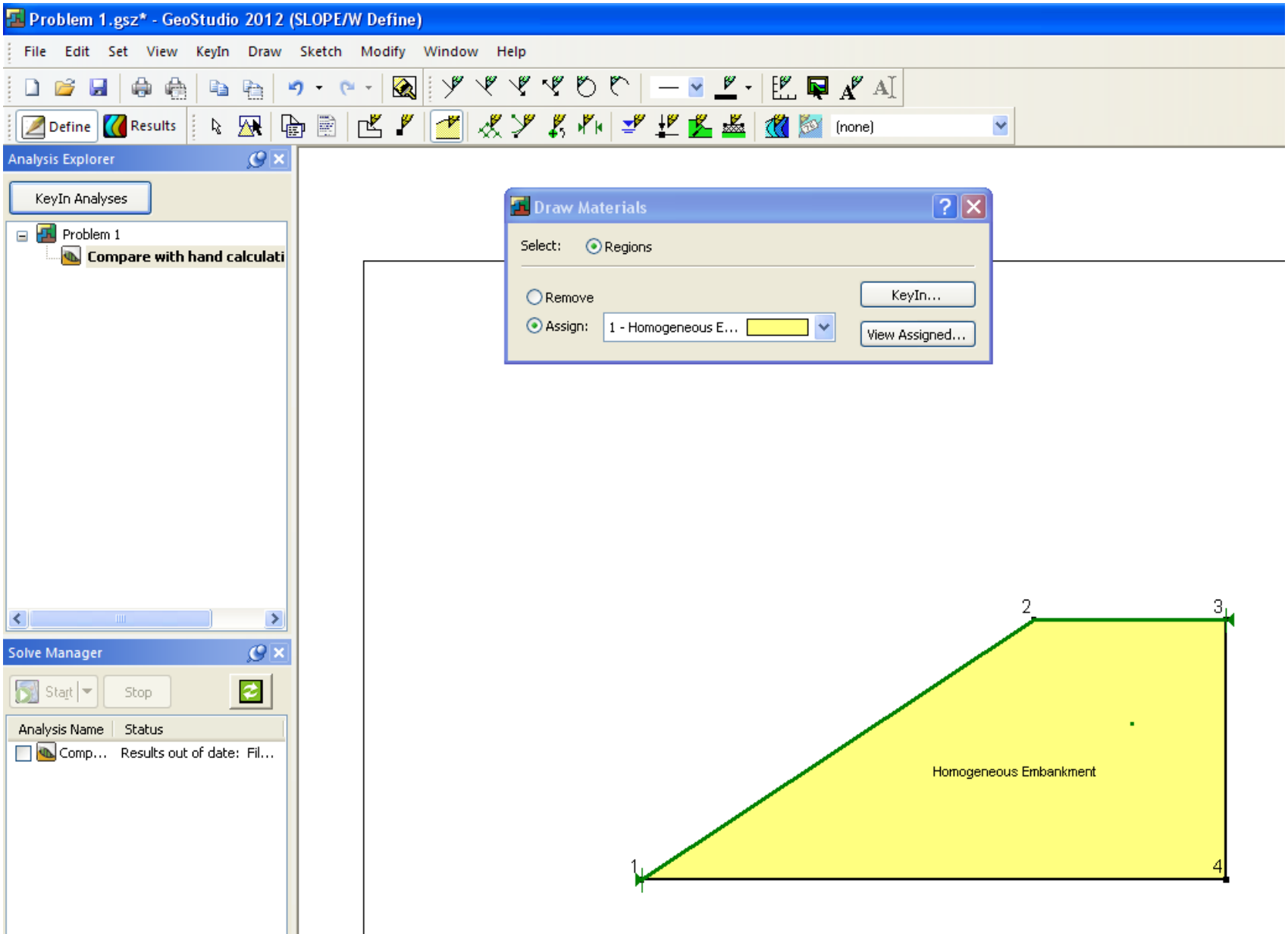

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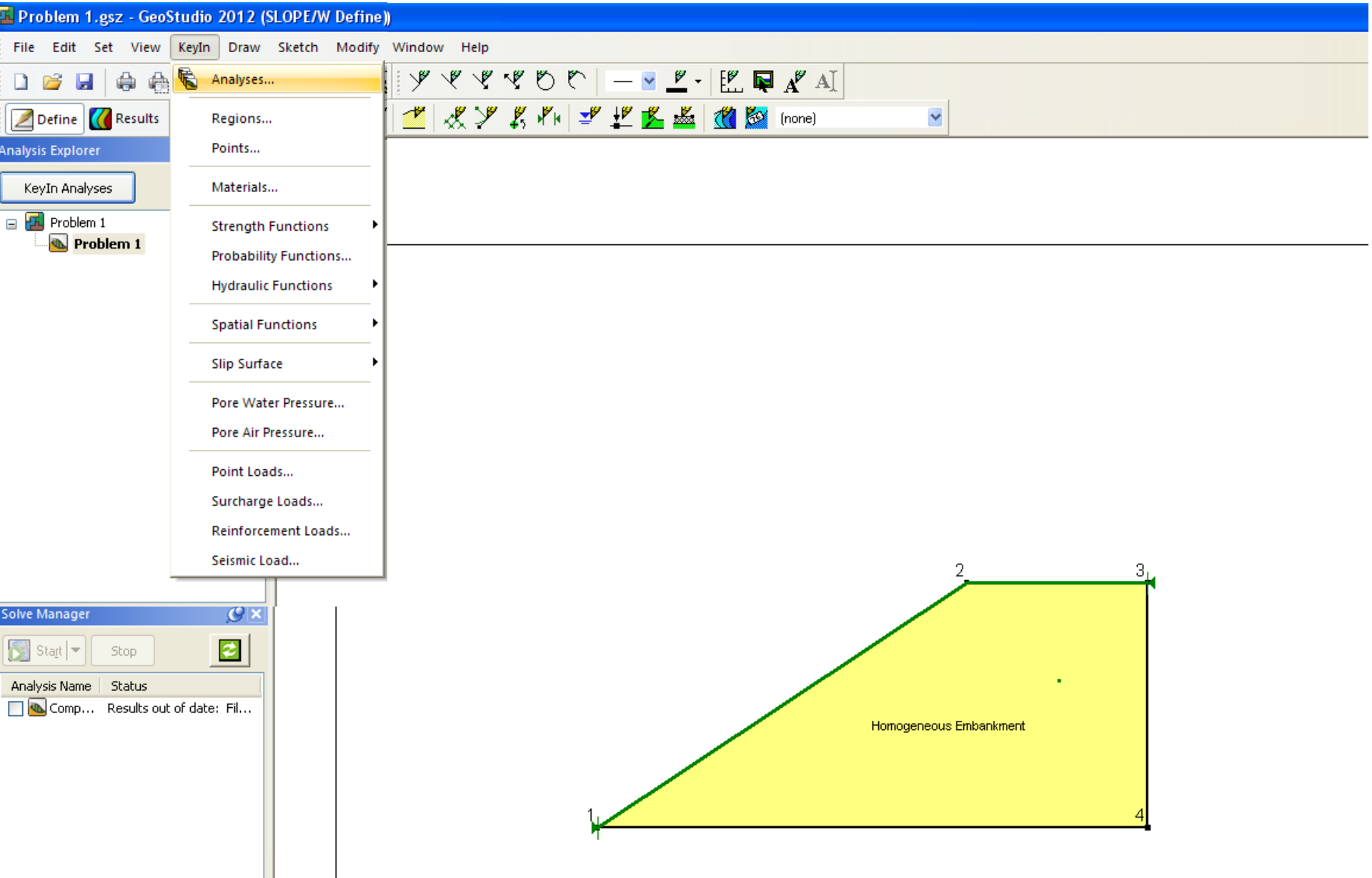
Choose the Method of Analyses



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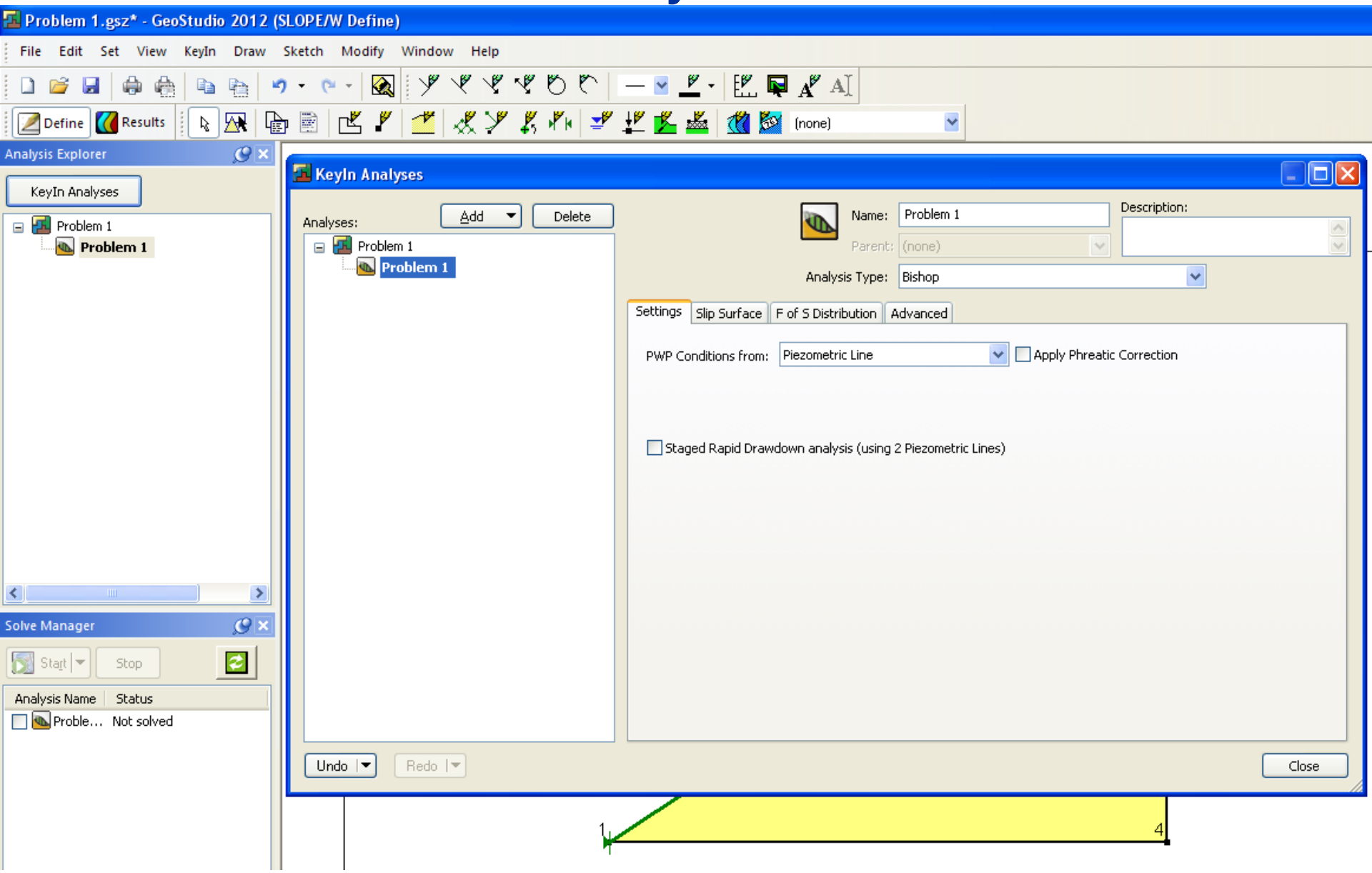

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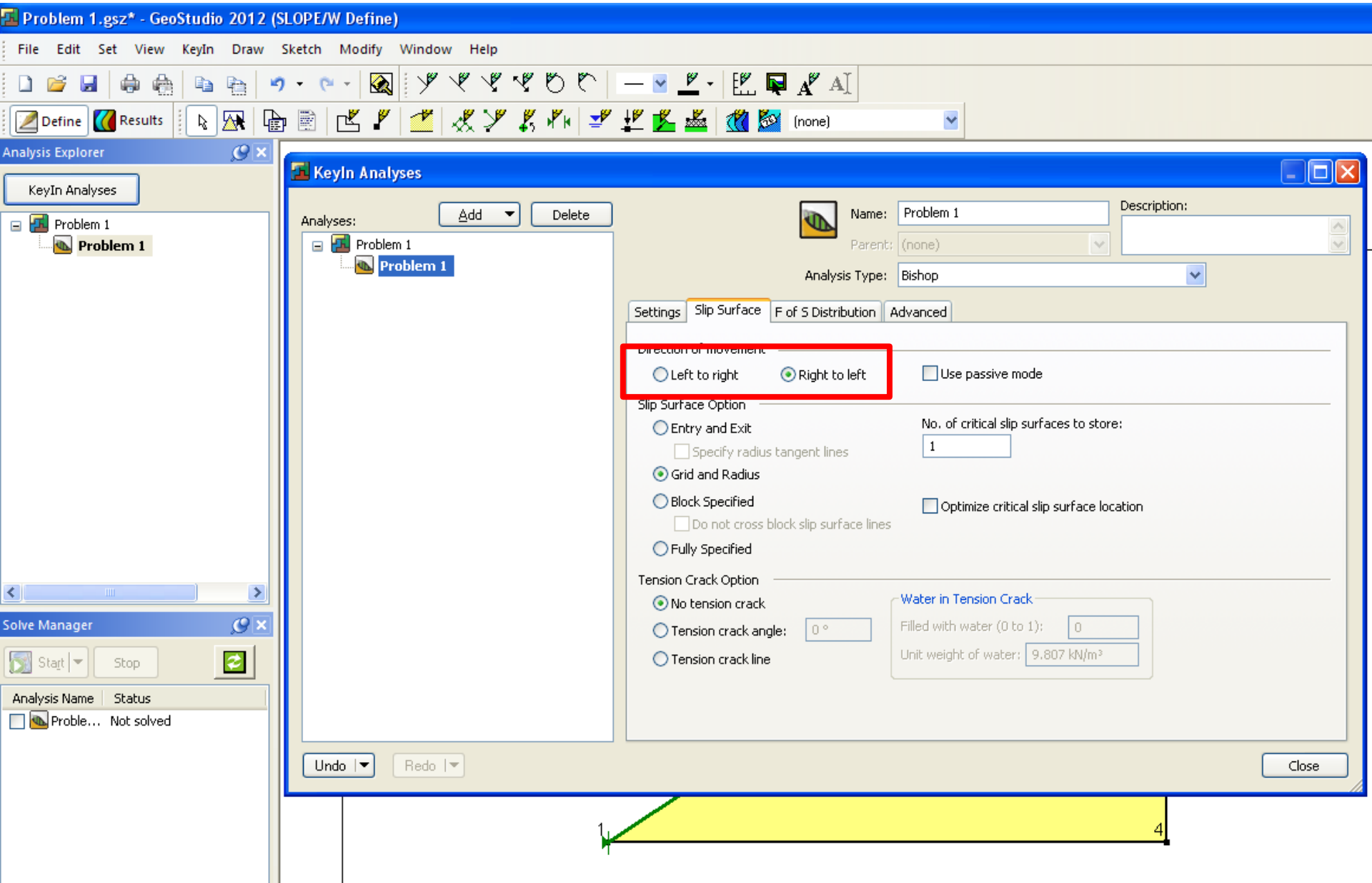

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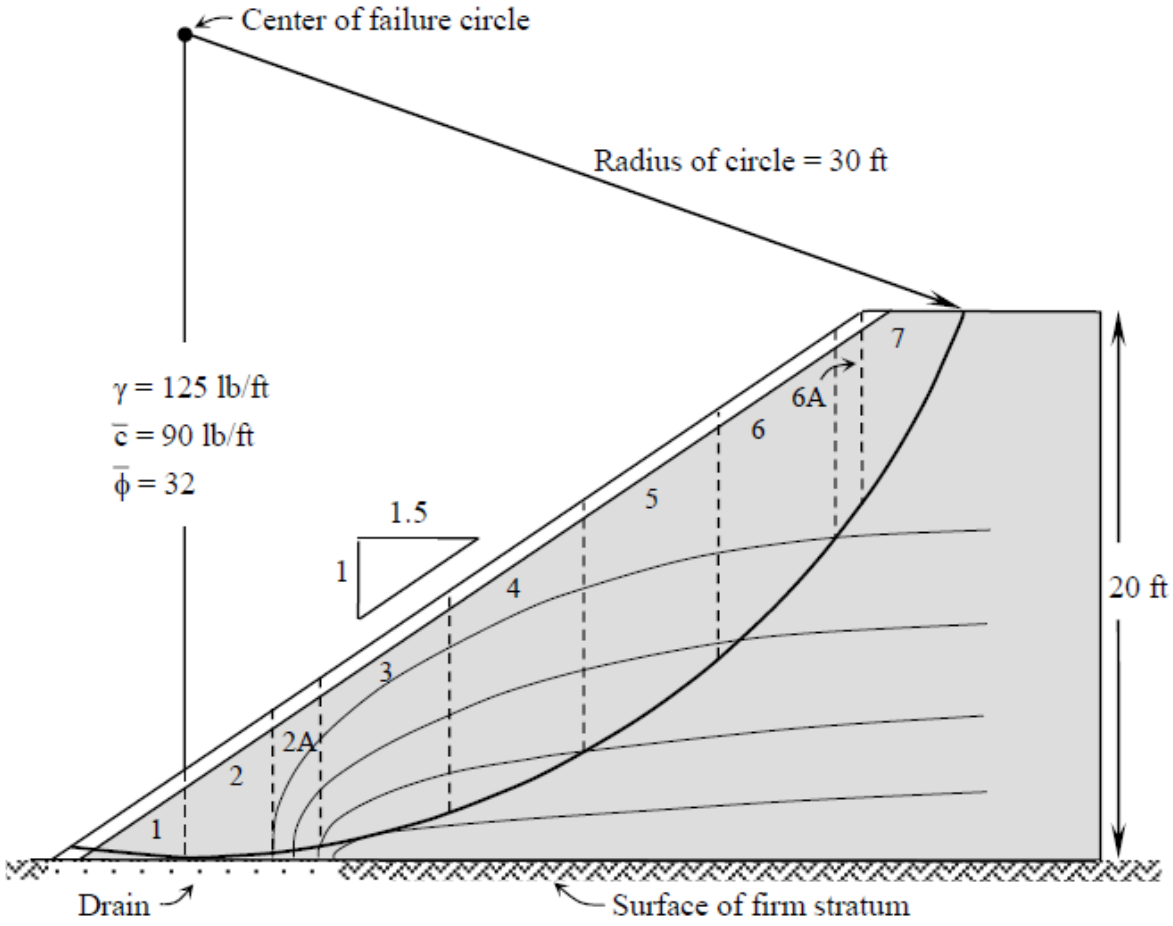
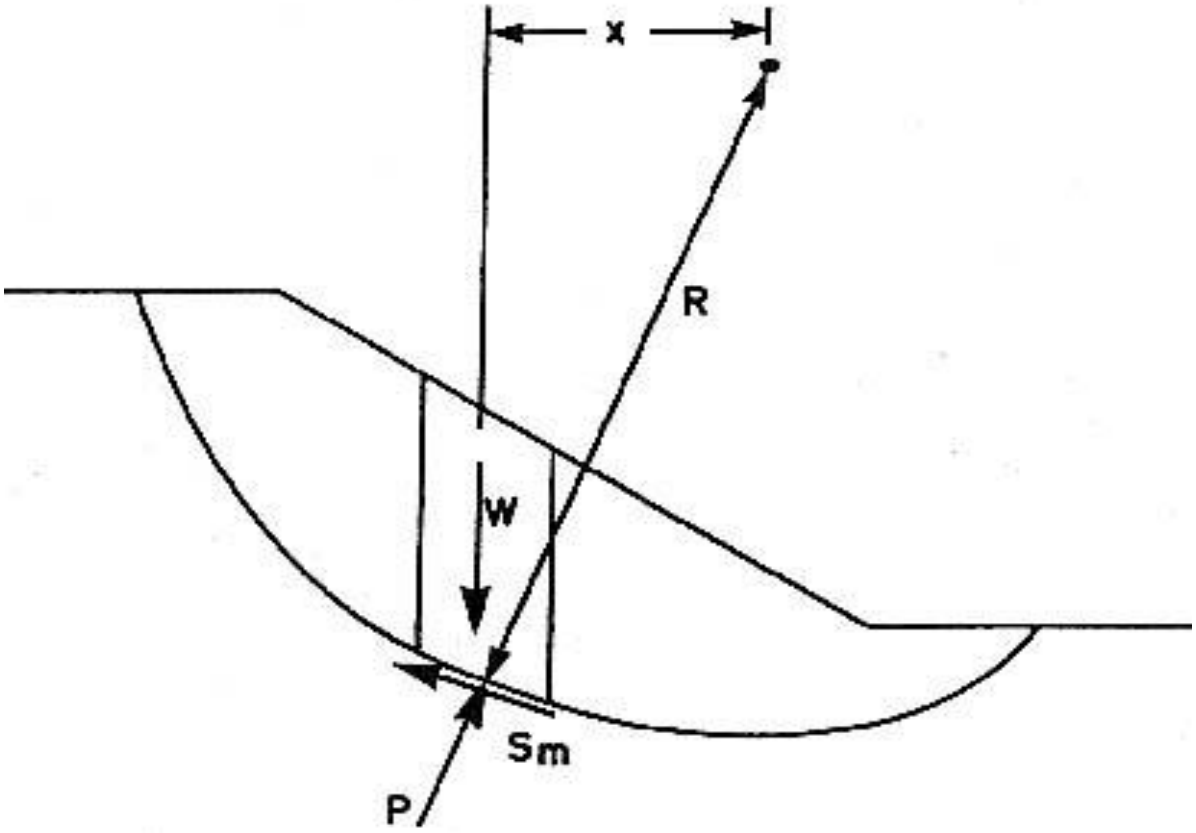


Figure 1 Stability of slope with an underdrain (after Lambe and Whitman)

Direction of movement: right to left

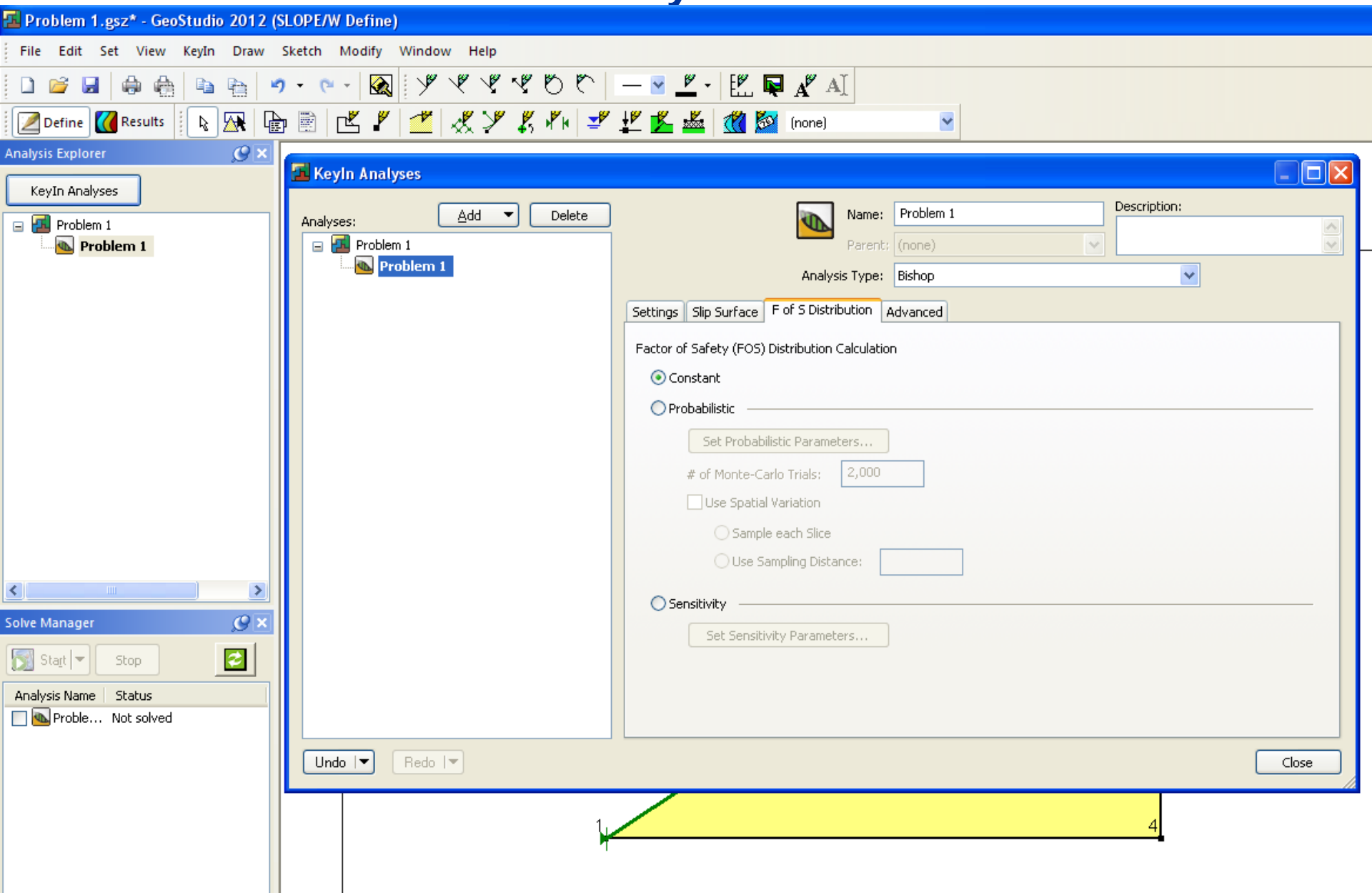
PROBLEM 1



Direction of movement: left to right

PROBLEM 1

Choose the Method of Analyses



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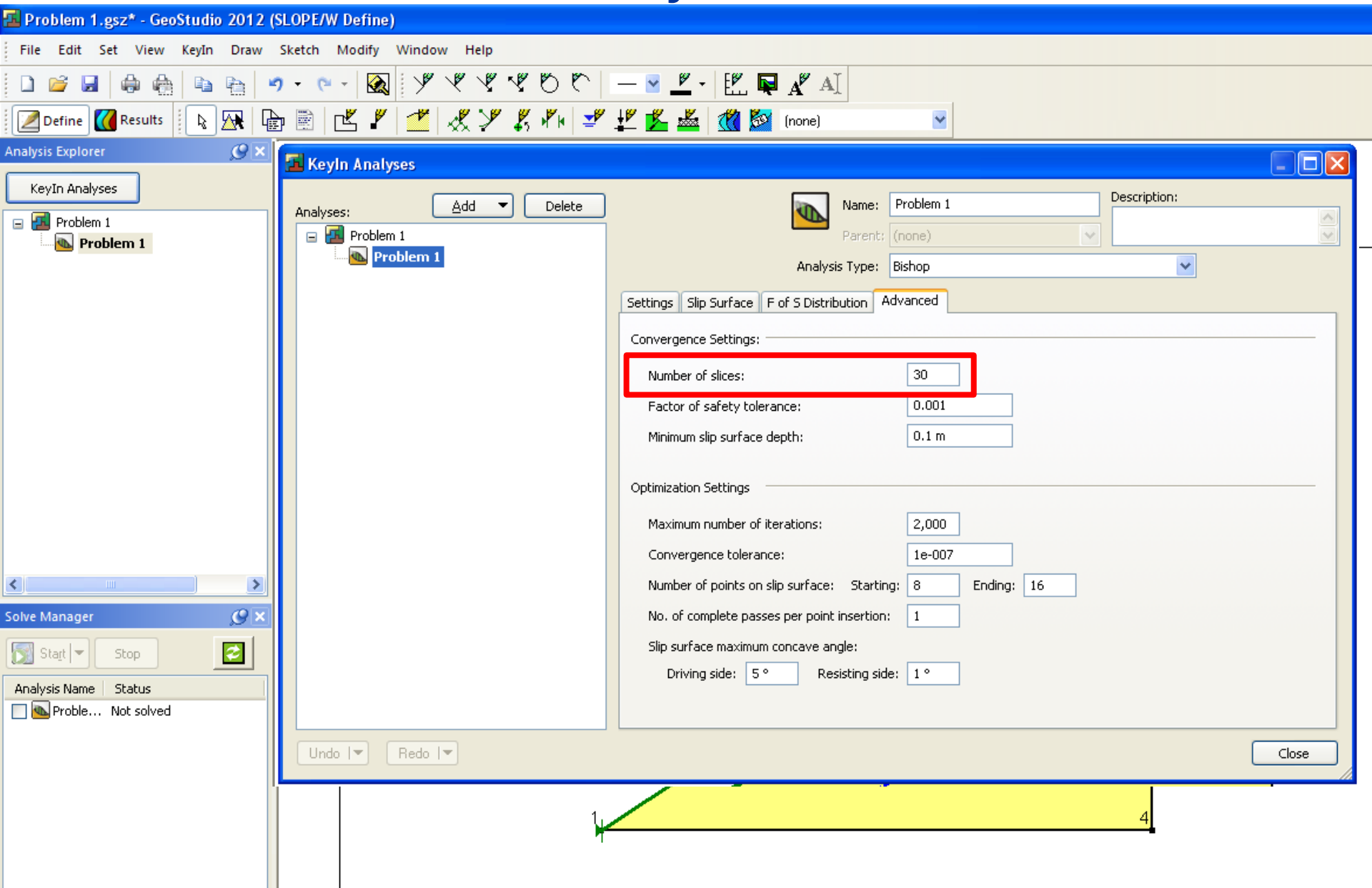

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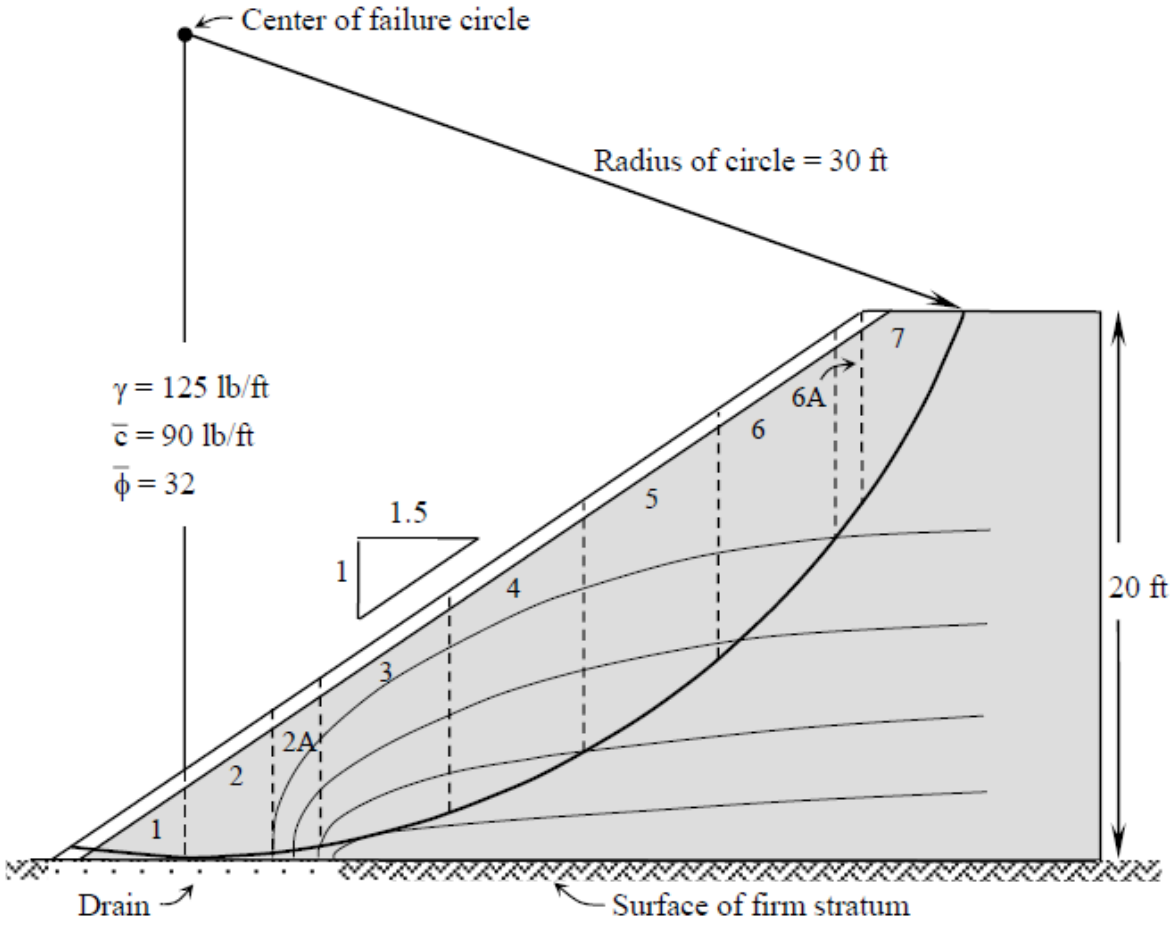

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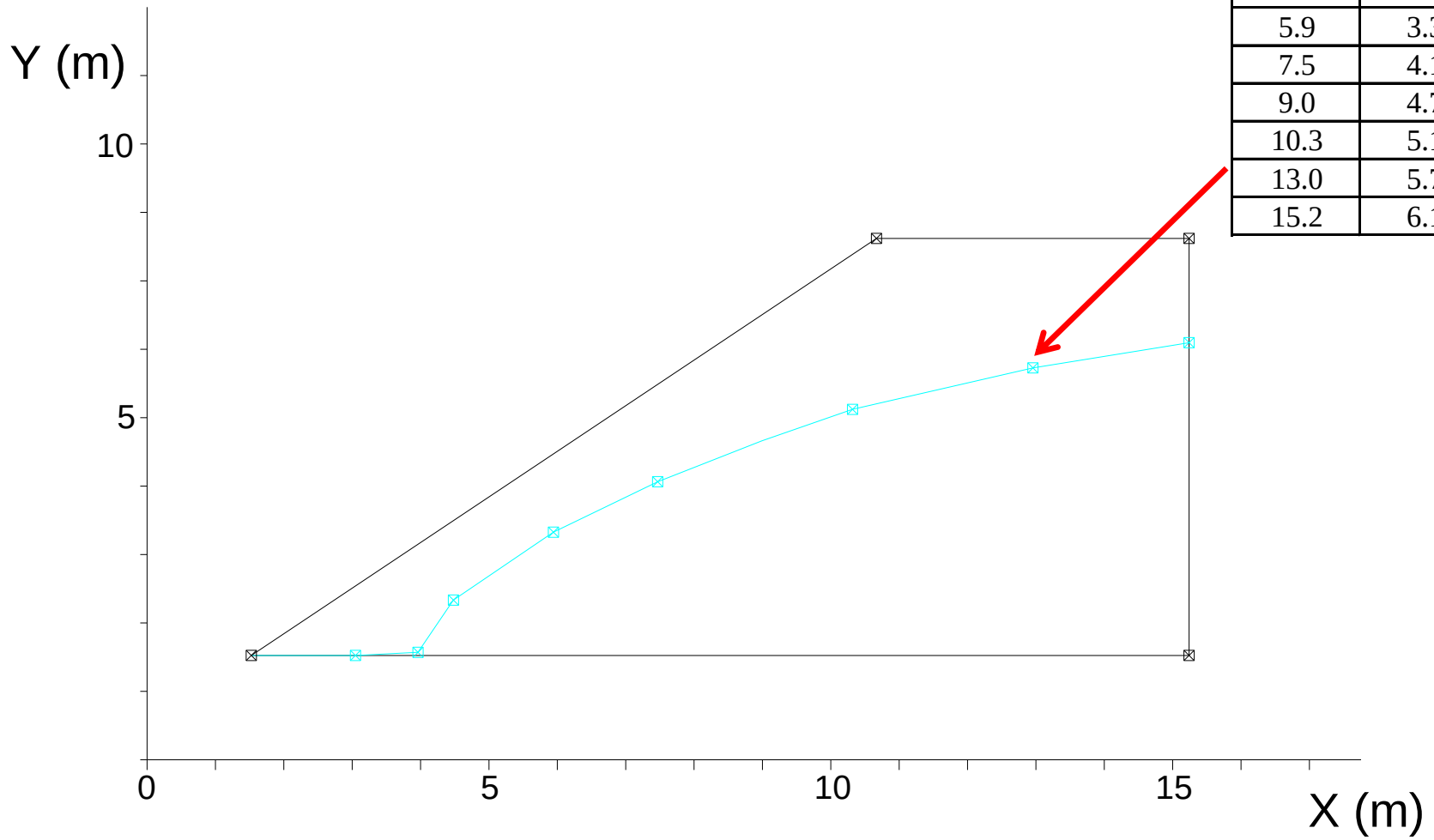
PROBLEM 1

Piezometric Line

X (m)	Y (m)
1.5	1.5
3.0	1.5
4.0	1.6
4.5	2.3
5.9	3.3
7.5	4.1
9.0	4.7
10.3	5.1
13.0	5.7
15.2	6.1

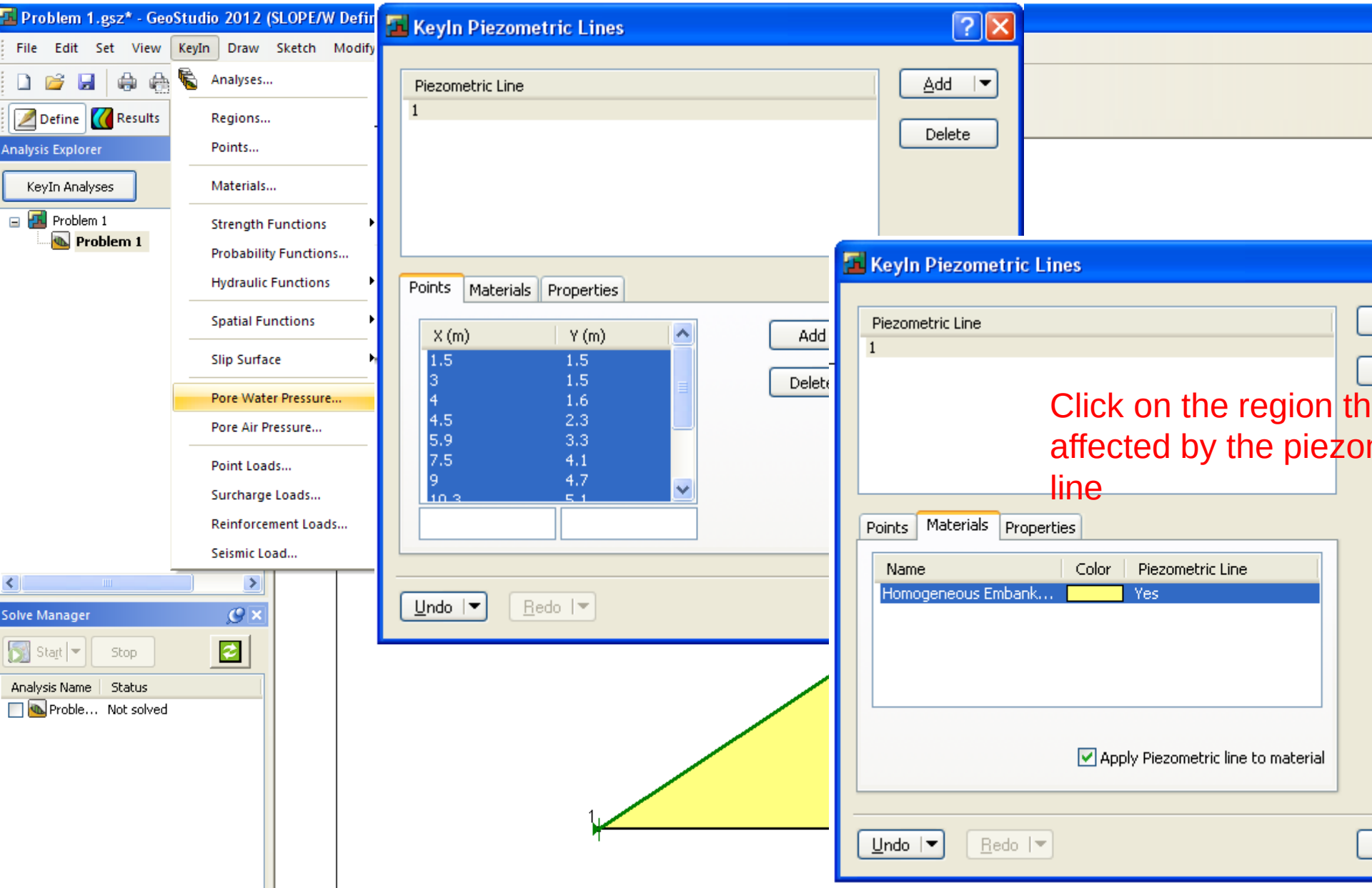


Draw Piezometric lines
(KeyIn – Piezometric Lines)

- Input the point coordinate one-by one or
- Paste the coordinate data

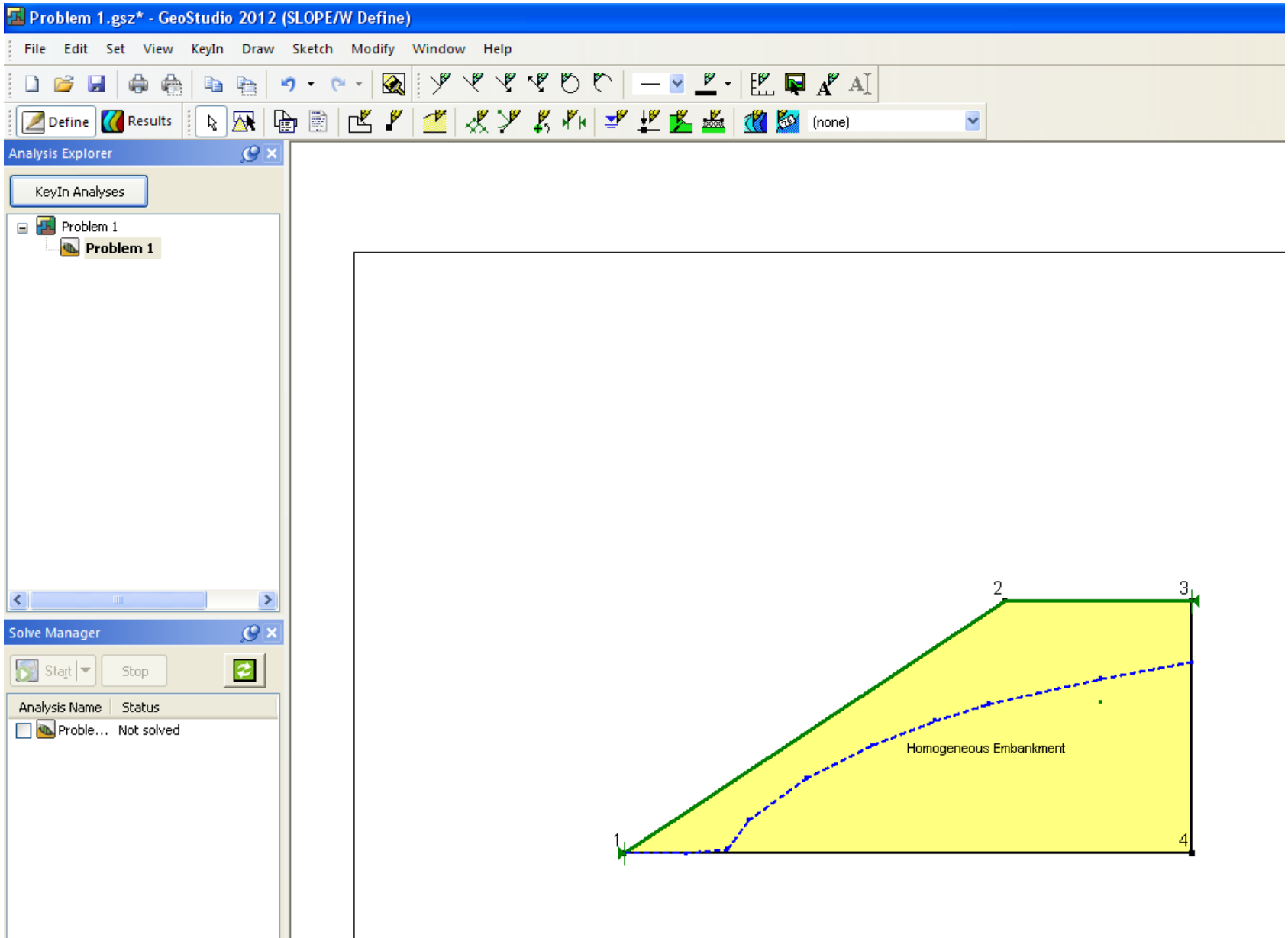
PROBLEM 1

Draw Piezometric Line



PROBLEM 1

Draw Piezometric Line

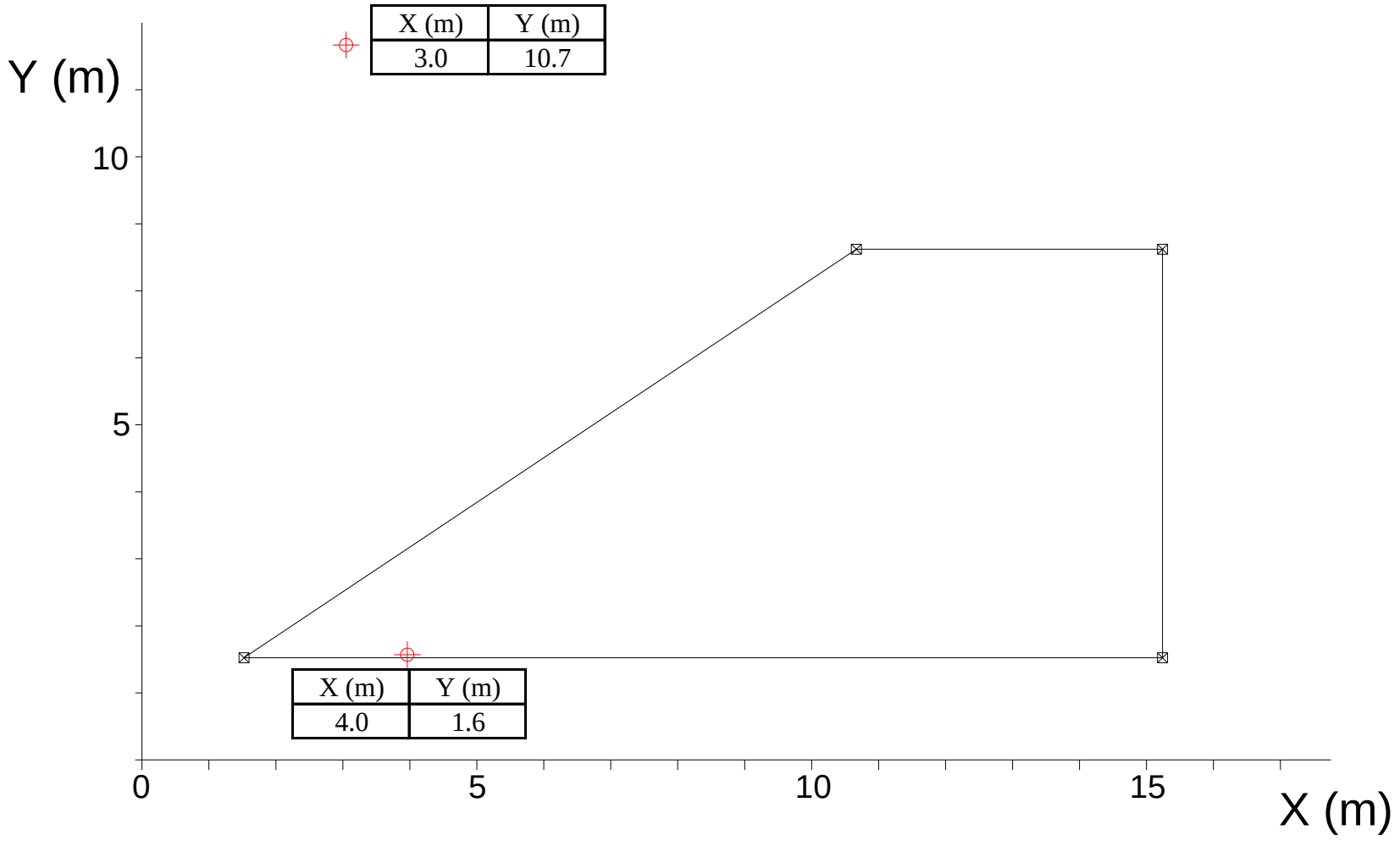


Suggested sequence of analysis using SLOPE/W:

- Geometry: sketch the geometry
- Set page size, unit and scale
- Geometry:
  - Draw points
  - Draw regions
- Material properties:
  - Input material properties data
  - Assign material properties
- Choose the method of analyses
- Draw piezometric lines
- Draw and assign loadings
- Choose the method to draw slip surfaces
- Execute the analysis
- Post processing (output)

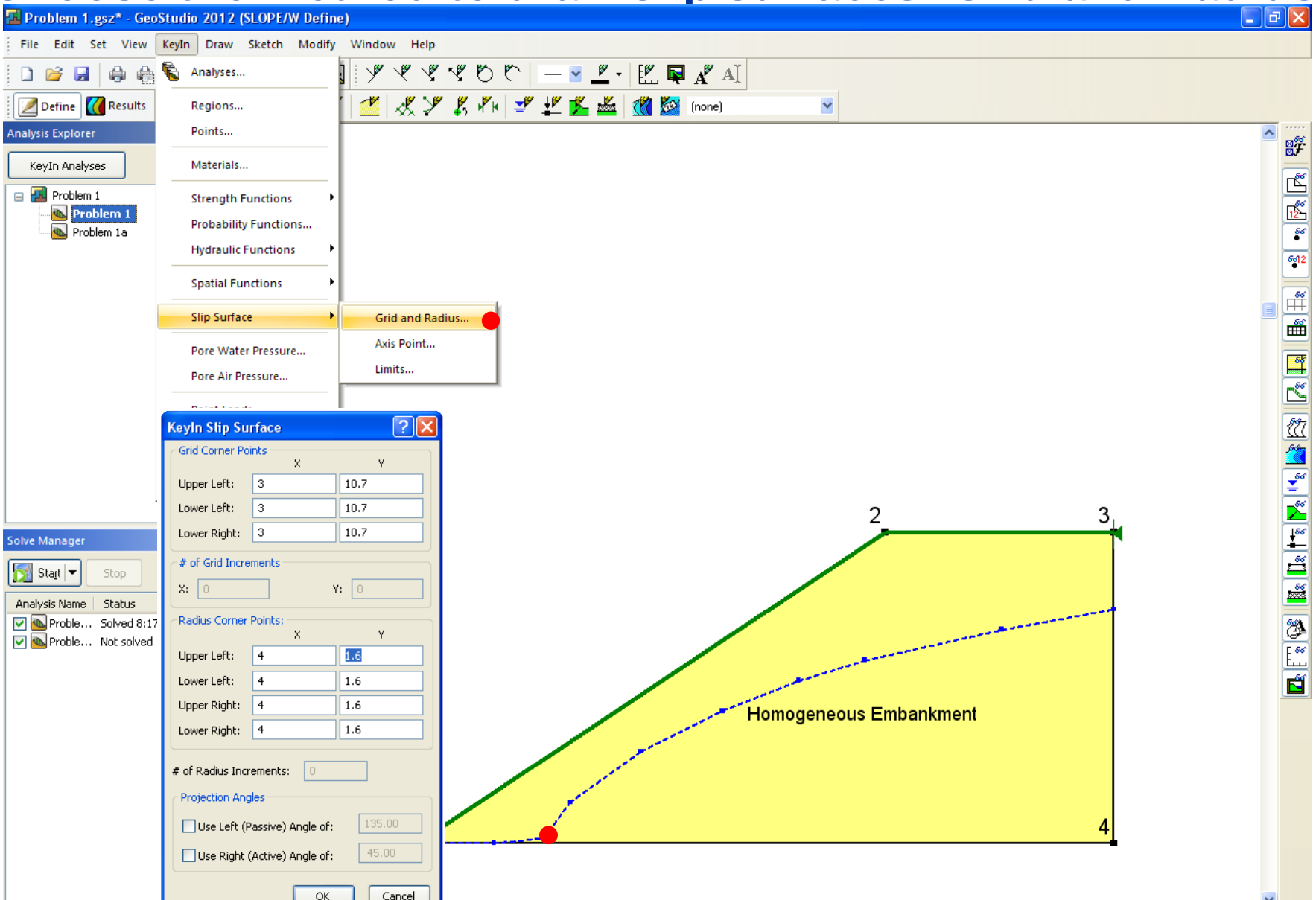
PROBLEM 1

Grid and Radius



PROBLEM 1

Choose the method to draw slip surfaces: Grid and Radius

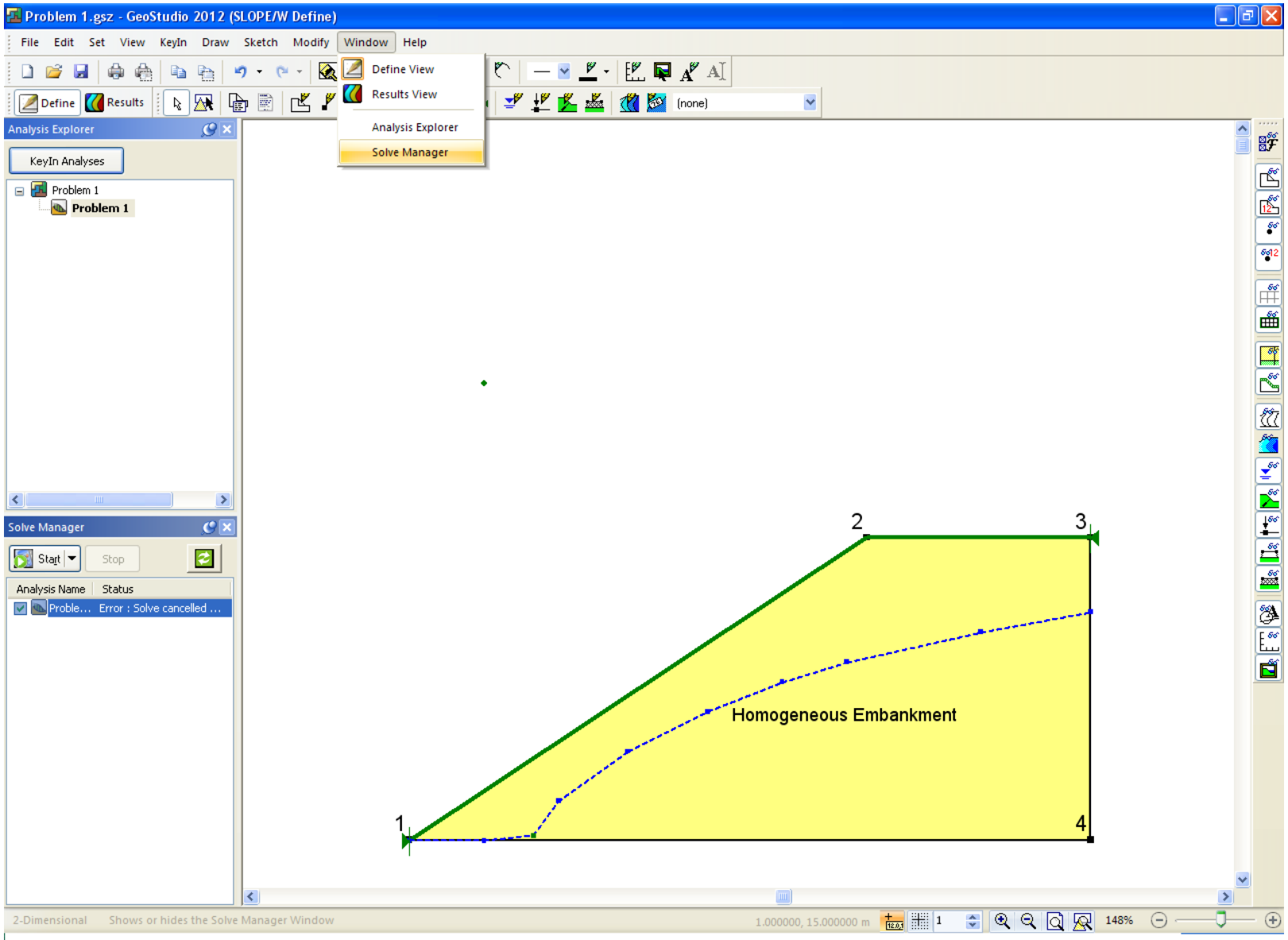


Suggested sequence of analysis using SLOPE/W:

- Geometry: sketch the geometry
- Set page size, unit and scale
- Geometry:
  - Draw points
  - Draw regions
- Material properties:
  - Input material properties data
  - Assign material properties
- Choose the method of analyses
- Draw piezometric lines
- Draw and assign loadings
- Choose the method to draw slip surfaces
- Execute the analysis
- Post processing (output)

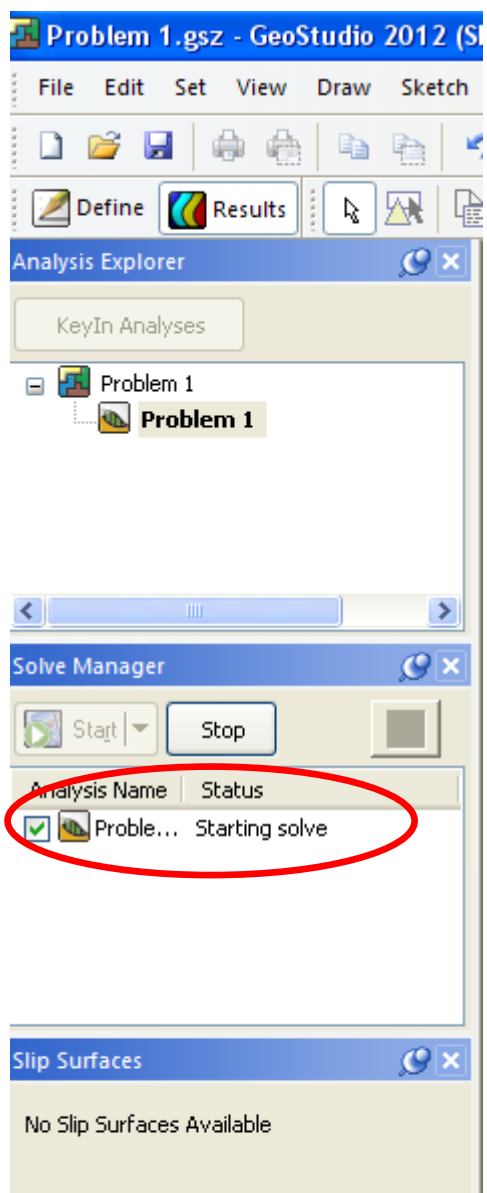
PROBLEM 1

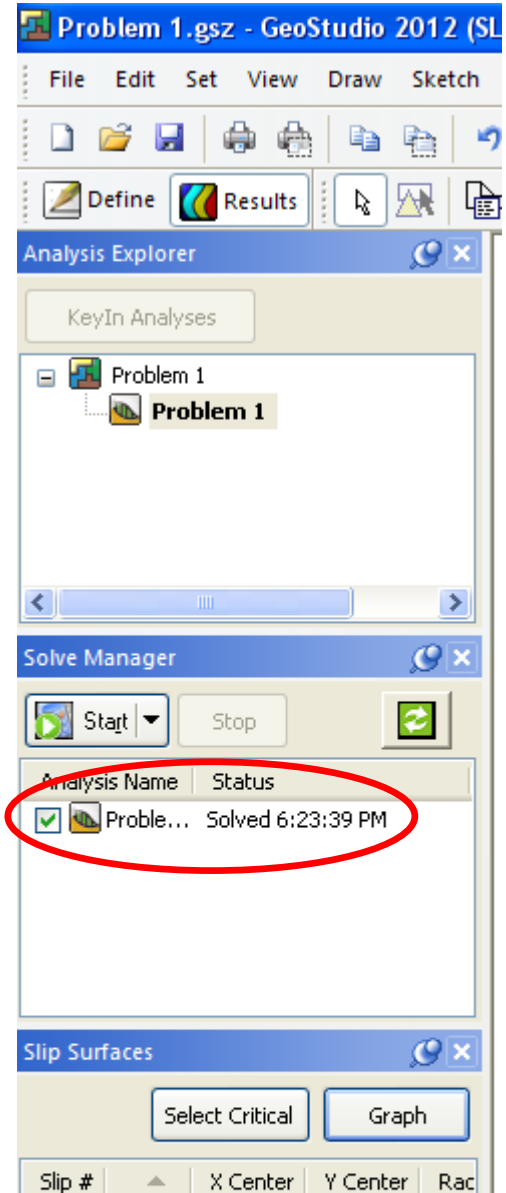
Execute the Analysis



PROBLEM 1

Execute the Analysis



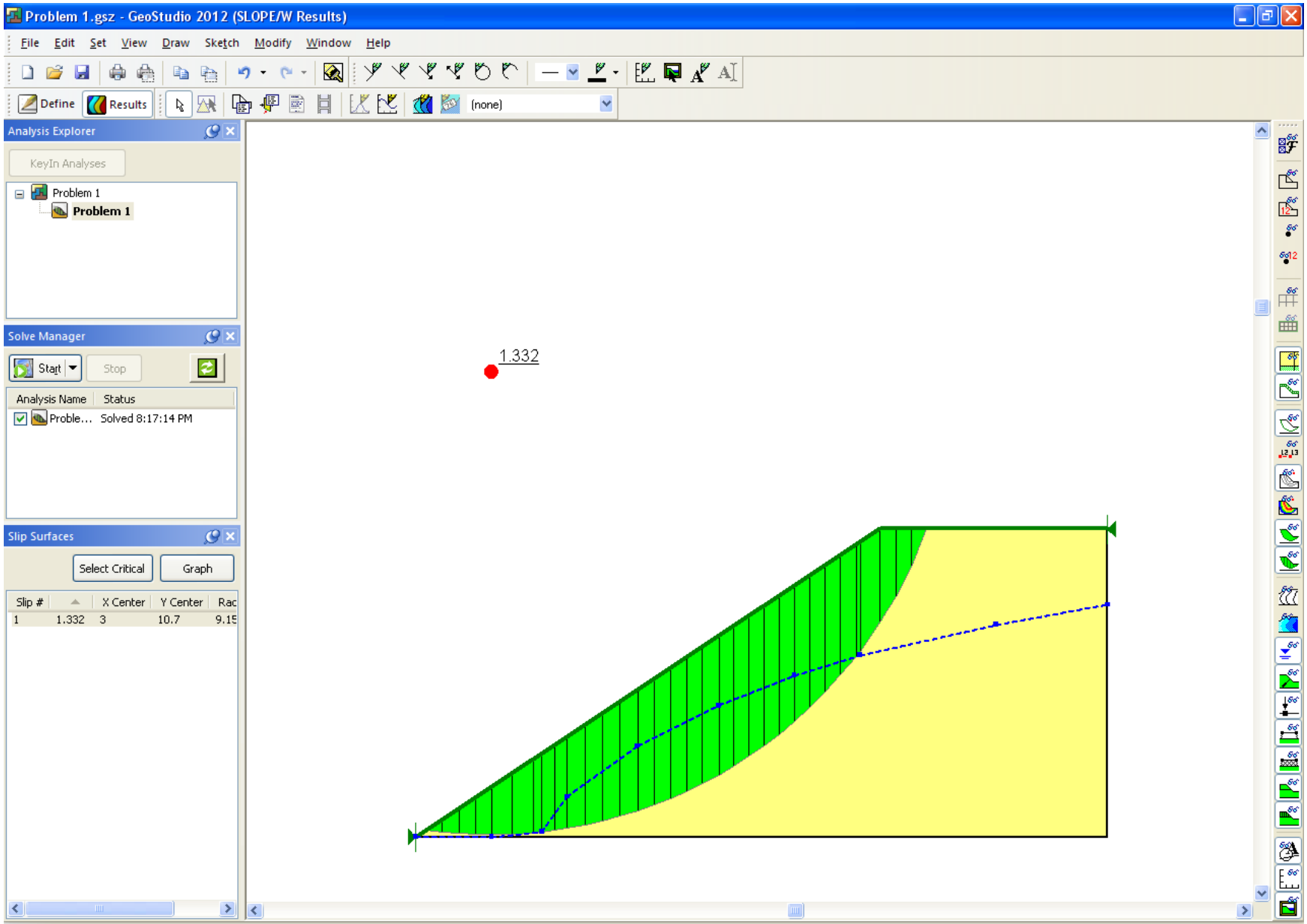


Suggested sequence of analysis using SLOPE/W:

- Geometry: sketch the geometry
- Set page size, unit and scale
- Geometry:
  - Draw points
  - Draw regions
- Material properties:
  - Input material properties data
  - Assign material properties
- Choose the method of analyses
- Draw piezometric lines
- Draw and assign loadings
- Choose the method to draw slip surfaces
- Execute the analysis
- Post processing (output)

PROBLEM 1

Output of FoS



Problem 1 – Comparison with Hand Calculation

Table 3 Lambe and Whitman calculation of the Bishop Simplified factor of safety

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)		(9)	
Slice	Δx (ft)	cΔxi (kips)	uiΔxi (kips)	Wi - uiΔxi (kips)	(5)tan ϕ (kips)	(3)+(6) (kips)	Mi		(7) + (8)	
							F = 1.25	F = 1.35	F = 1.25	F = 1.35
1	4.5	0.40	0	0.9	055	0.95	0.97	0.97	1.0	1.0
2	3.2	0.29	0	1.7	1.05	1.35	1.02	1.02	1.3	1.3
2A	1.8	0.16	0.05	1.25	1.80	1.95	1.06	1.05	0.9	0.9
3	5.0	0.45	1.05	3.55	2.25	2.70	1.09	1.08	2.5	2.5
4	5.0	0.45	1.45	4.15	2.55	3.00	1.12	1.10	2.7	2.75
5	5.0	0.45	1.25	4.55	2.7	3.15	1.10	1.08	3.85	2.9
6	4.4	0.40	0.50	4.1	2.63	3.05	1.05	1.02	2.9	2.95
6a	0.6	0.05	0	0.5	2.30	0.35	0.98	0.95	0.35	0.4
7	3.2	0.29	0	1.5	2.95	1.25	0.93	0.92	1.3	1.35
									15.8	16.05

For assumed F = 1.25 $$F = \frac{15.8}{12.3} = 1.29$$

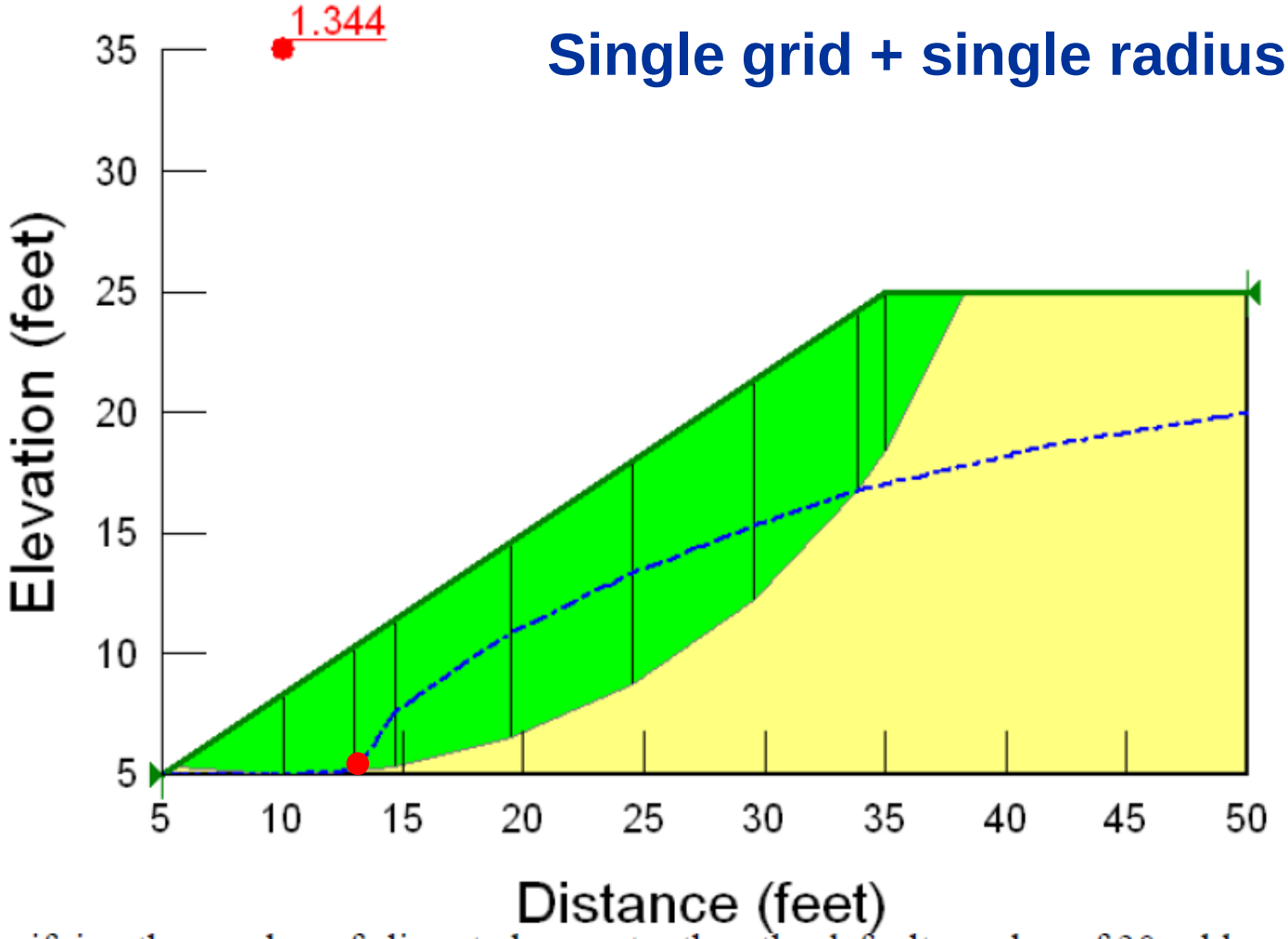
F = 1.35 $$F = \frac{16.05}{12.3} = 1.31$$

FoS = 1.25 – 1.35

As shown in the above calculations, a trial factor of safety of 1.25 results in a computed factor of safety of 1.29, and a trial factor of safety of 1.35 results in a computed value of 1.31. Since the trial value of 1.25 is too low and the trial value of 1.35 is too high, the correct value using the Bishop Simplified method is between 1.25 and 1.35.

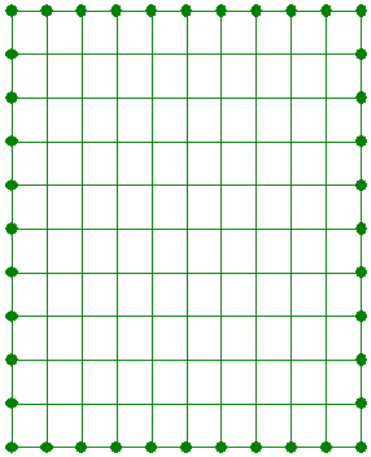
PROBLEM 1

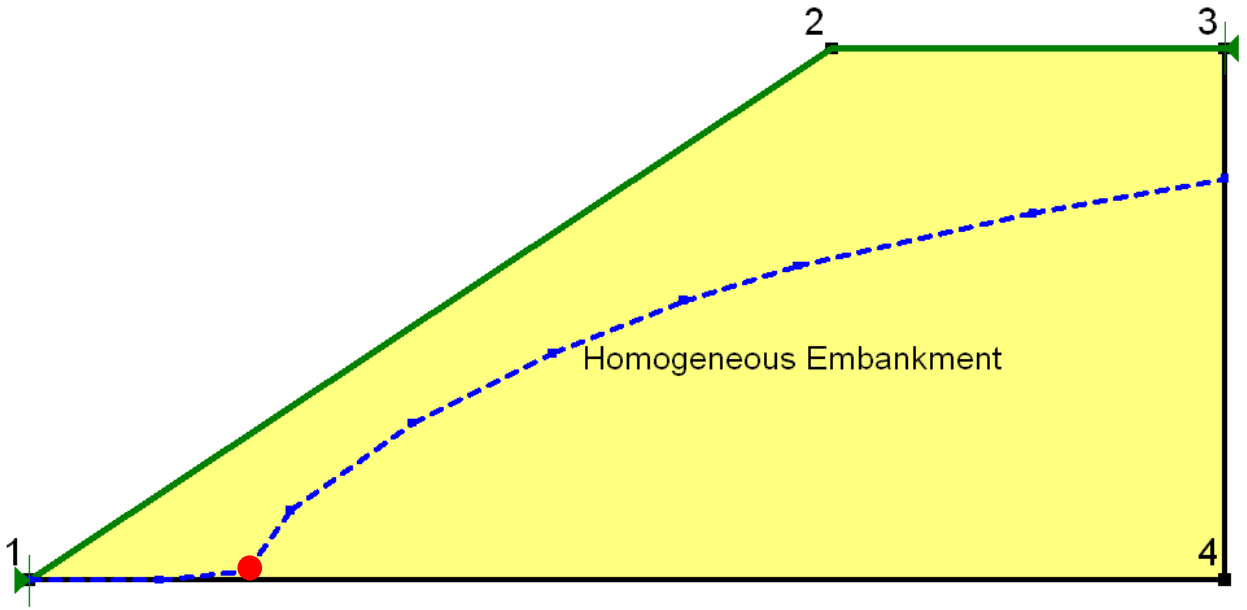
Single grid + single radius point



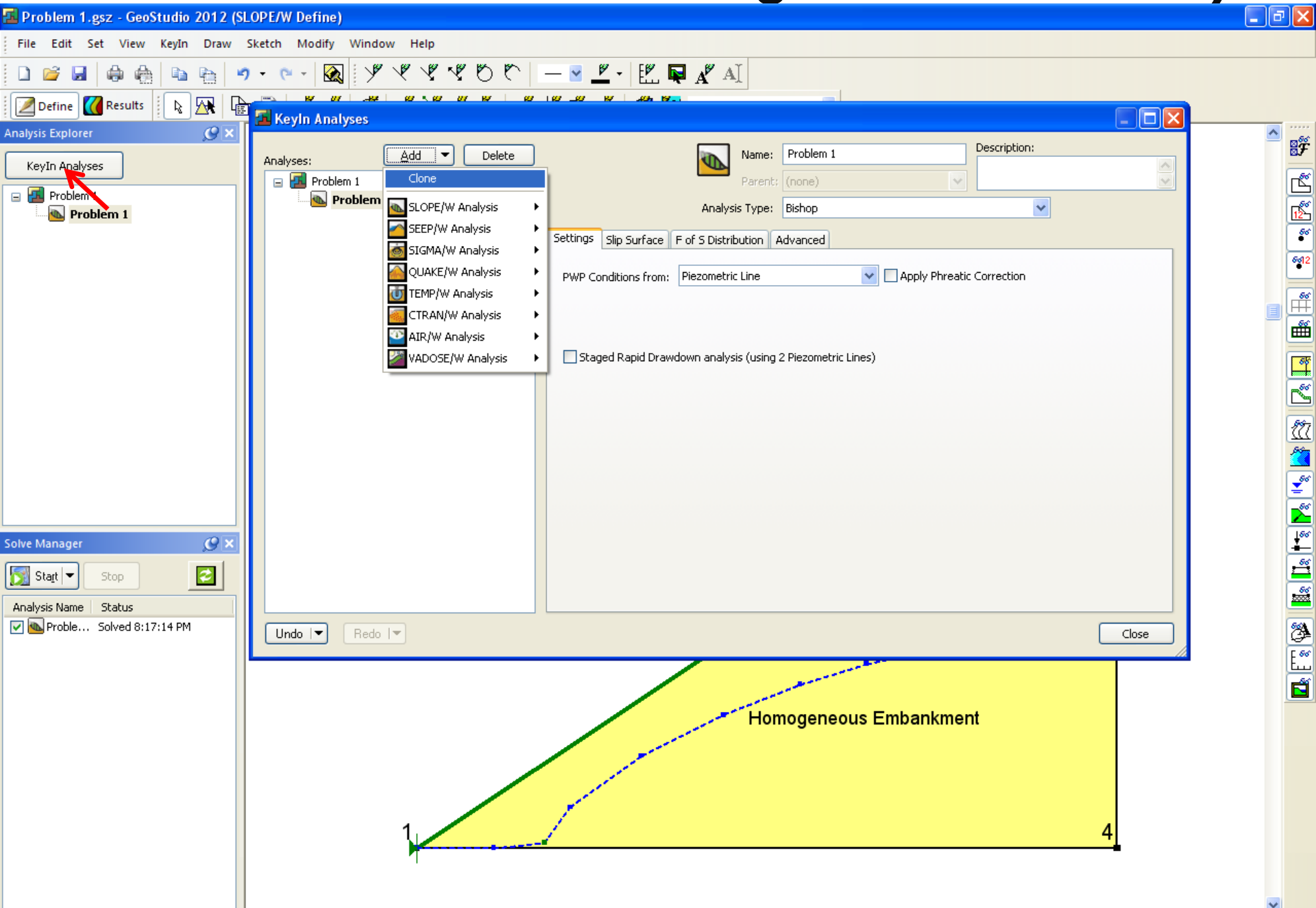
of slices. Specifying the number of slices to be greater than the default number of 30 seldom alters the factor of safety significantly. Specifying the number of slices lower than the default value of 30 is not recommended unless you want to investigate a specific issue like, for example, comparing the SLOPE/W results with hand calculations. Making the number of slices too high simply creates an excessive amount of unnecessary data without a significant improvement in safety factor accuracy. Figure 5-9 shows the

PROBLEM 1a (Grid + Single Point Radius)

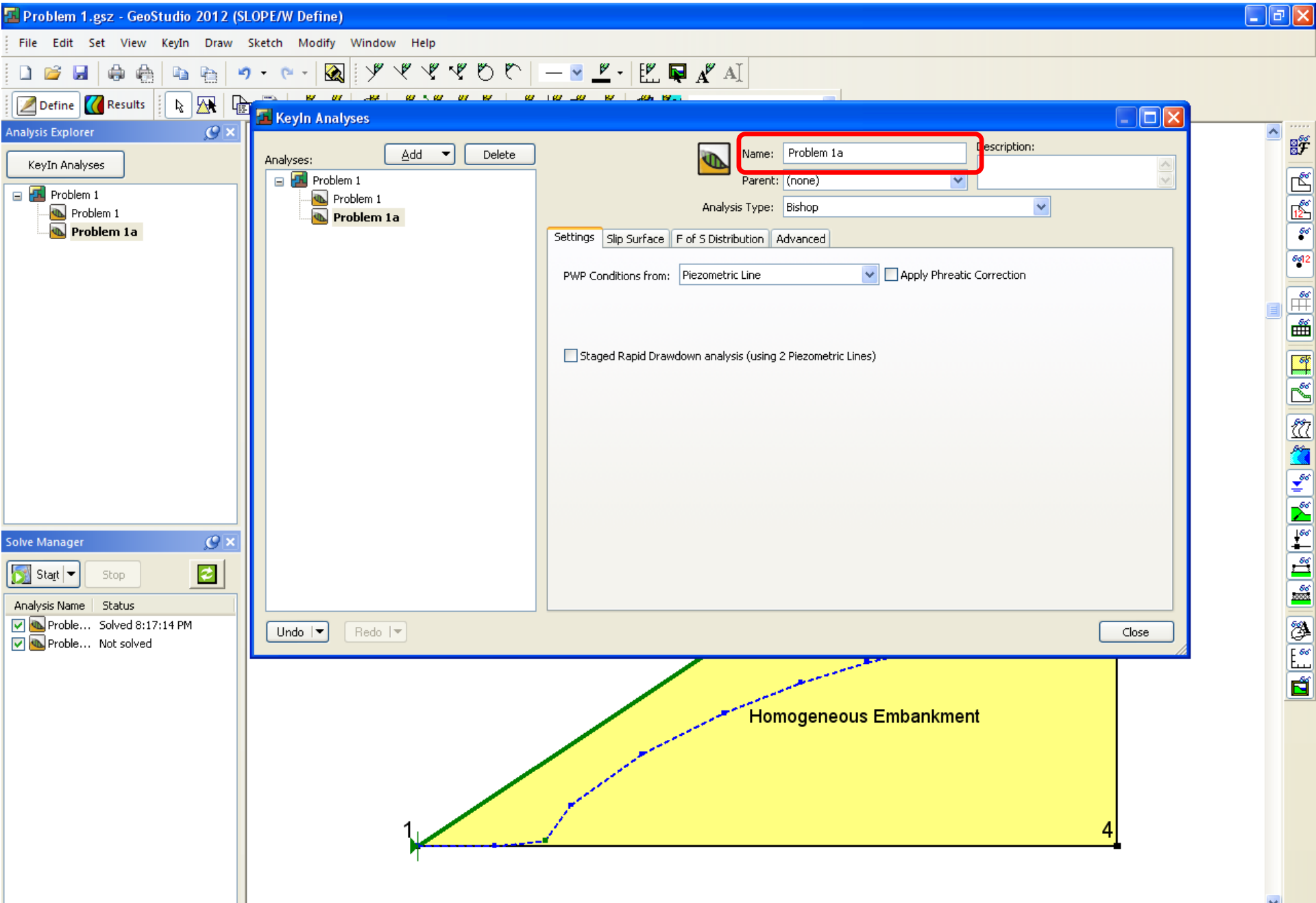




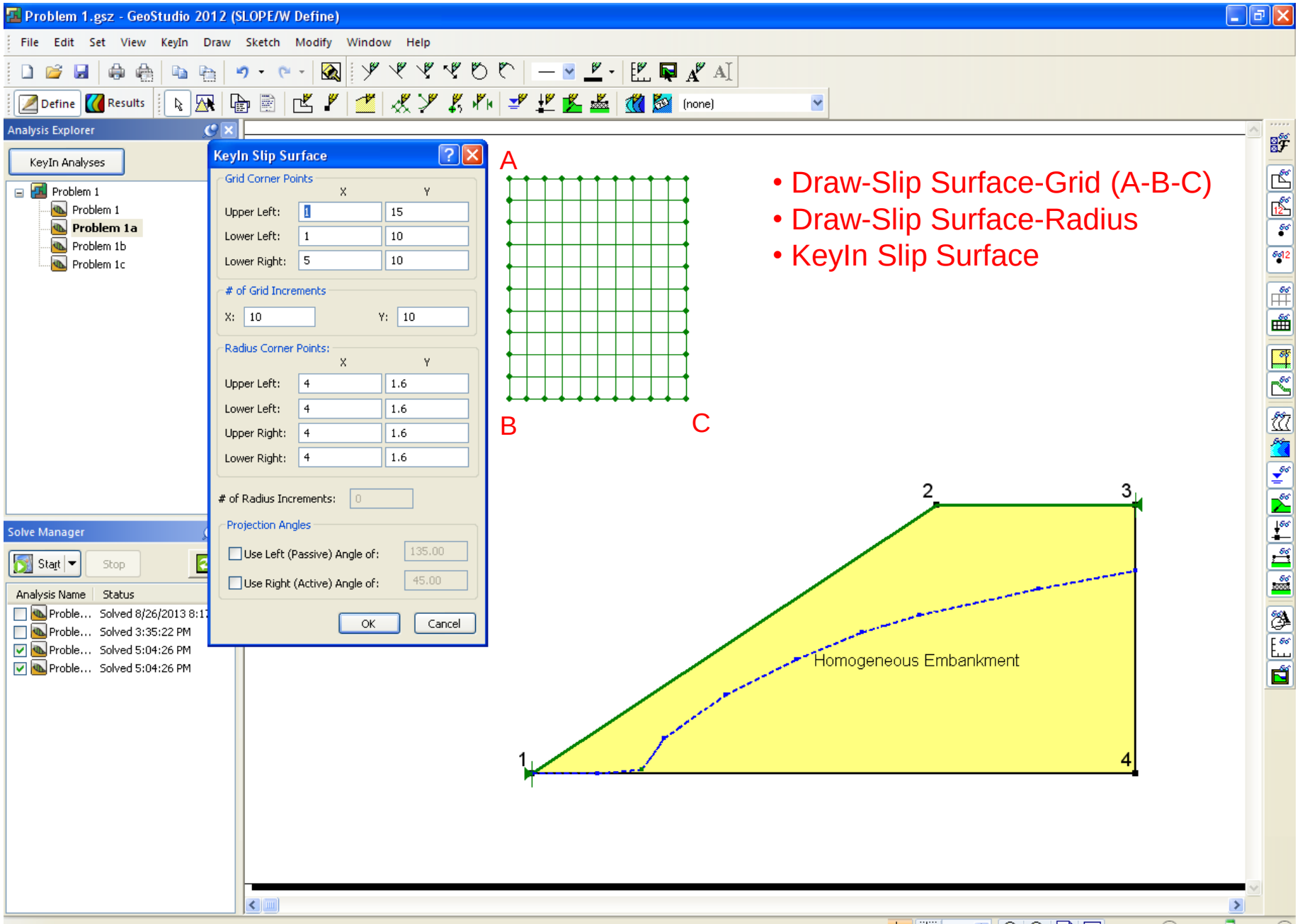
PROBLEM 1a Grid + Single Point Radius)



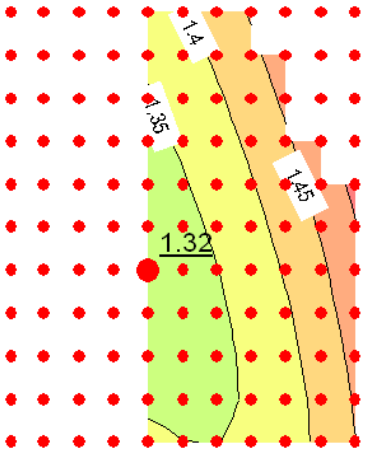
PROBLEM 1a (Grid + Single Point Radius)

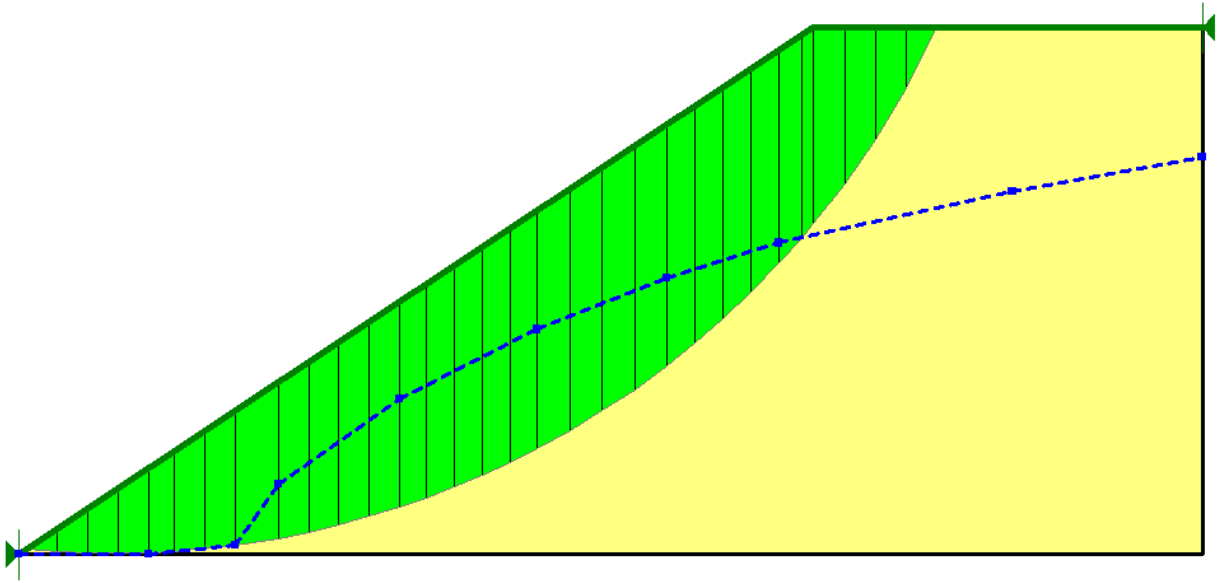


PROBLEM 1a (Grid + Single Point Radius)

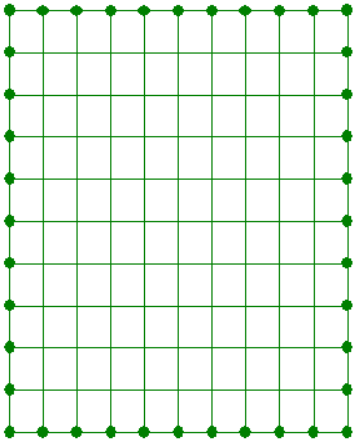


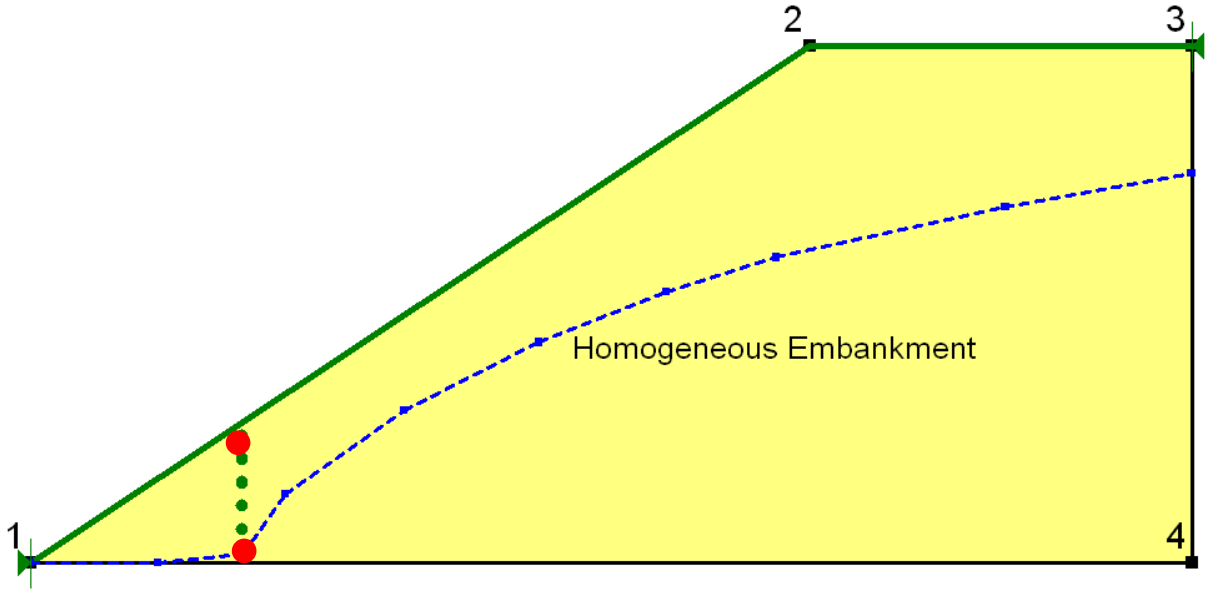
PROBLEM 1a (Grid + Single Point Radius)





PROBLEM 1b (Grid + Two Points Radius)





PROBLEM 1b (Grid + Two Points Radius)

Problem 1.gsz - GeoStudio 2012 (SLOPE/W Define)

File Edit Set View KeyIn Draw Sketch Modify Window Help

Define Results (none)

Analysis Explorer

KeyIn Analyses

- Problem 1
  - Problem 1
  - Problem 1a
  - **Problem 1b**
  - Problem 1c

Solve Manager

Start Stop

Analysis Name	Status
Proble...	Solved 8/26/2013 8:17:
Proble...	Solved 5:21:43 PM
Proble...	Solved 5:22:07 PM
Proble...	Solved 5:04:26 PM

KeyIn Slip Surface

Grid Corner Points

	X	Y
Upper Left:	1	15
Lower Left:	1	10
Lower Right:	5	10

# of Grid Increments

X: 10 Y: 10

Radius Corner Points:

	X	Y
Upper Left:	4	3
Lower Left:	4	1.6
Upper Right:	4	3
Lower Right:	4	1.6

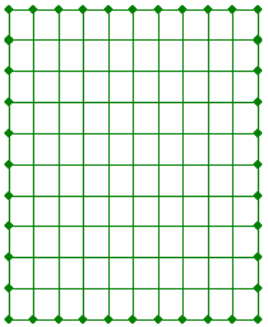
# of Radius Increments: 5

Projection Angles

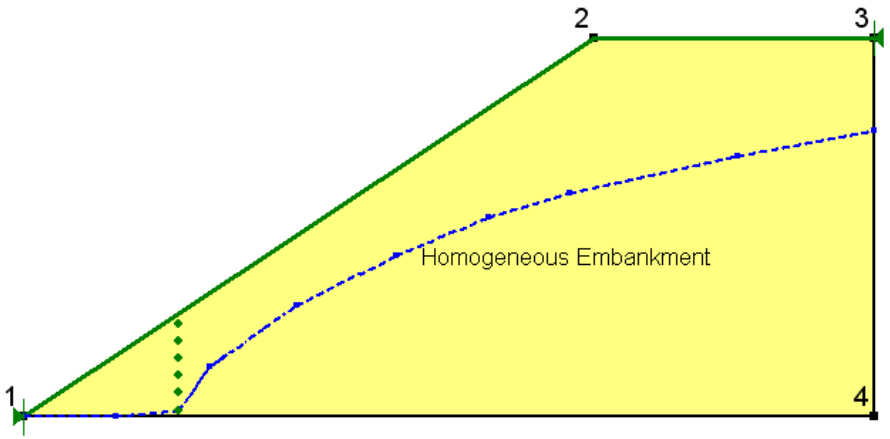
Use Left (Passive) Angle of: 135.00

Use Right (Active) Angle of: 45.00

OK Cancel

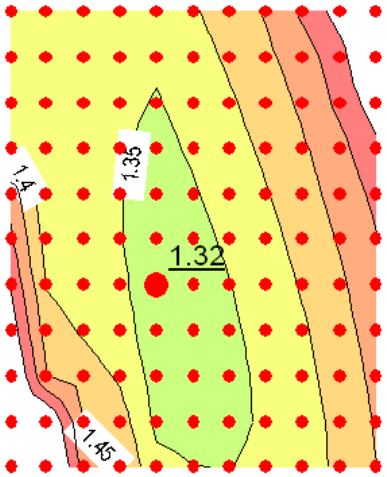


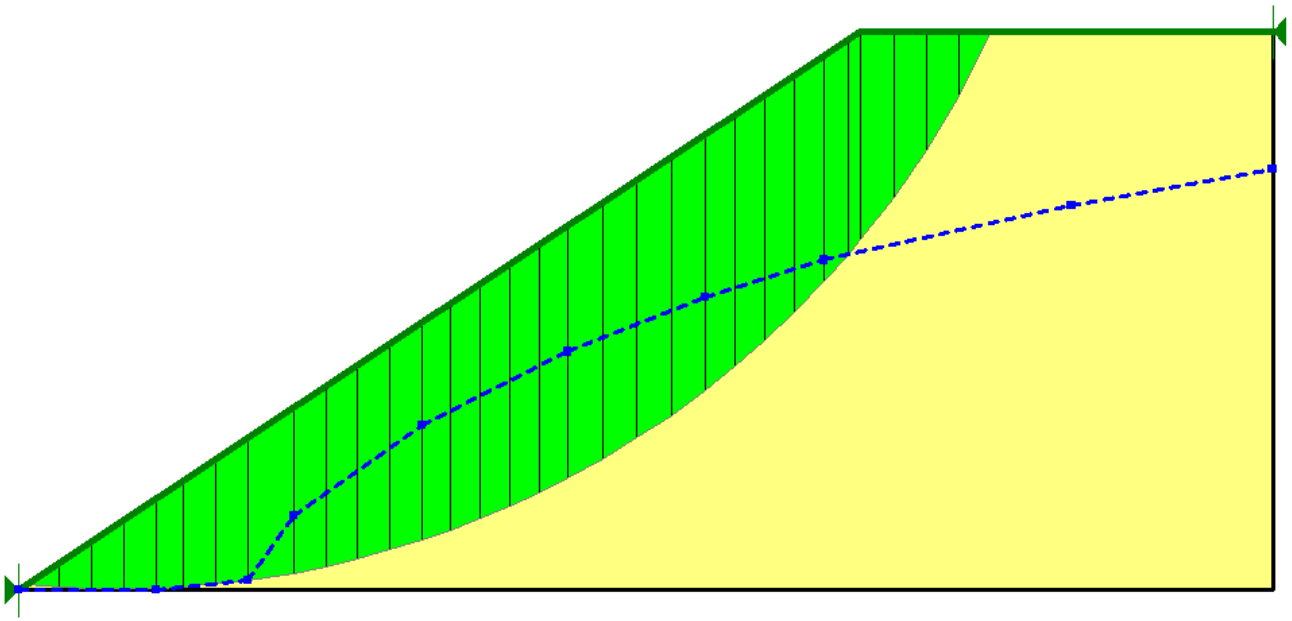
- Draw-Slip Surface-Grid
- Draw-Slip Surface-Radius
- KeyIn Slip Surface



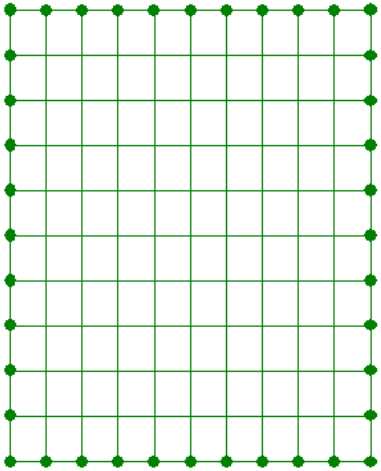
2-Dimensional For Help, press F1 -4.000000, 15.000000 m 130%

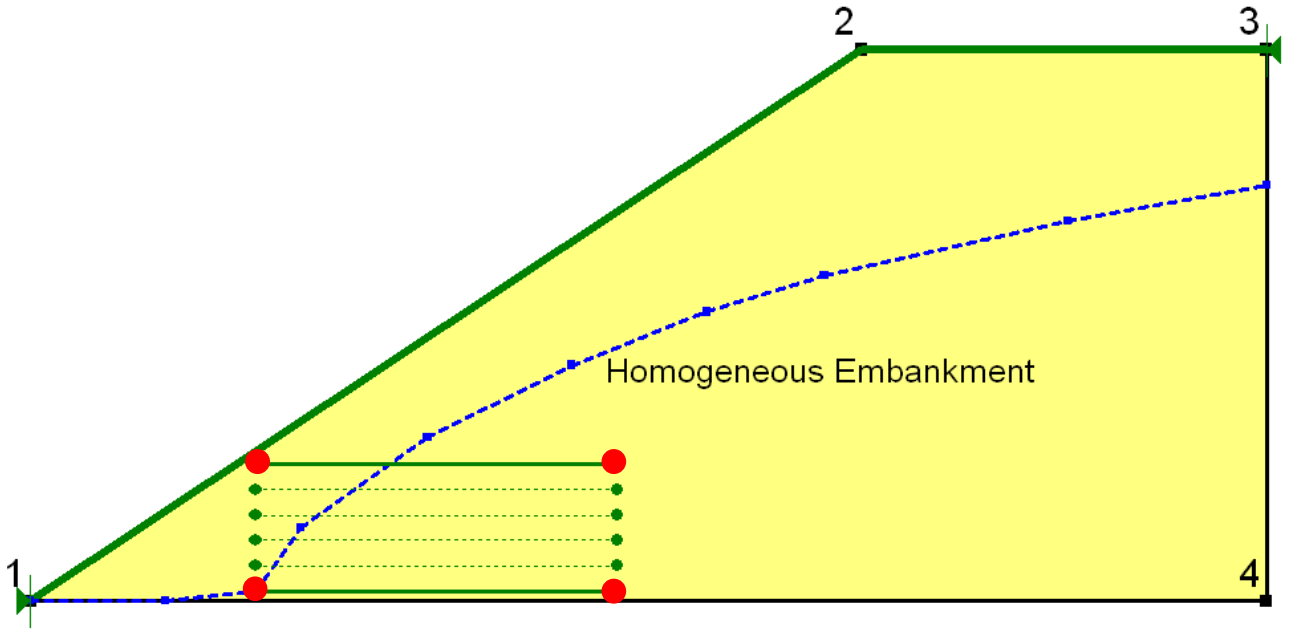
PROBLEM 1b (Grid + Two Points Radius)





PROBLEM 1c (Grid + Four Point Radius)





PROBLEM 1c (Grid + Four Point Radius)

Problem 1.gsz* - GeoStudio 2012 (SLOPE/W Define)

File Edit Set View KeyIn Draw Sketch Modify Window Help

Define Results (none)

Analysis Explorer

KeyIn Analyses

- Problem 1
  - Problem 1
  - Problem 1a
  - Problem 1b
  - **Problem 1c**

Solve Manager

Start Stop

Analysis Name	Status
Proble...	Solved 8/26/2013 8:1
Proble...	Solved 5:21:43 PM
Proble...	Solved 5:22:07 PM
Proble...	Solved 5:04:26 PM

KeyIn Slip Surface

Grid Corner Points

	X	Y
Upper Left:	1	15
Lower Left:	1	10
Lower Right:	5	10

# of Grid Increments

X: 10 Y: 10

Radius Corner Points:

	X	Y
Upper Left:	4	3
Lower Left:	4	1.6
Upper Right:	8	3
Lower Right:	8	1.6

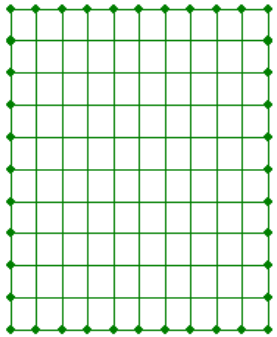
# of Radius Increments: 5

Projection Angles

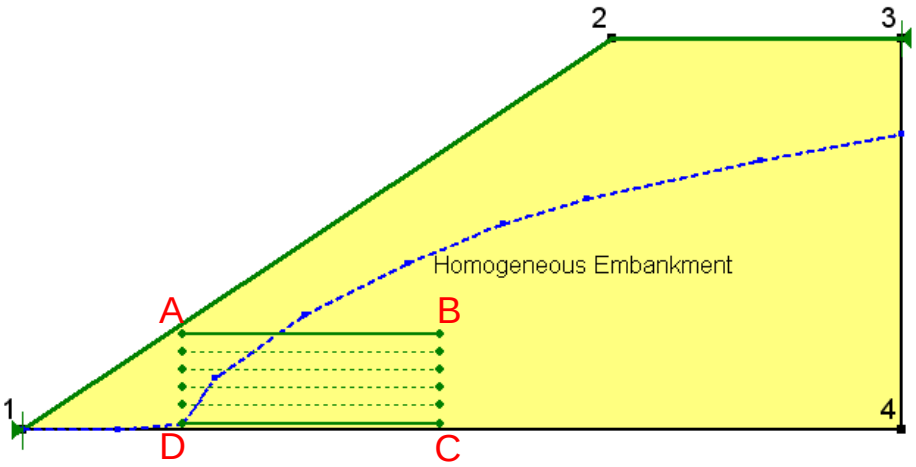
Use Left (Passive) Angle of: 135.00

Use Right (Active) Angle of: 45.00

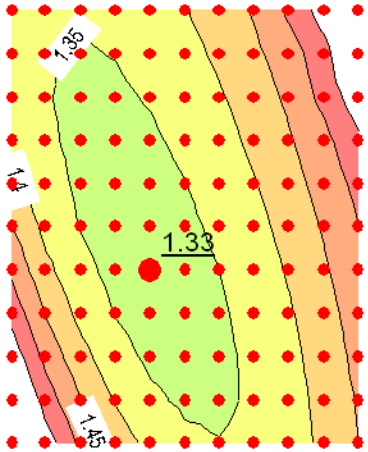
OK Cancel

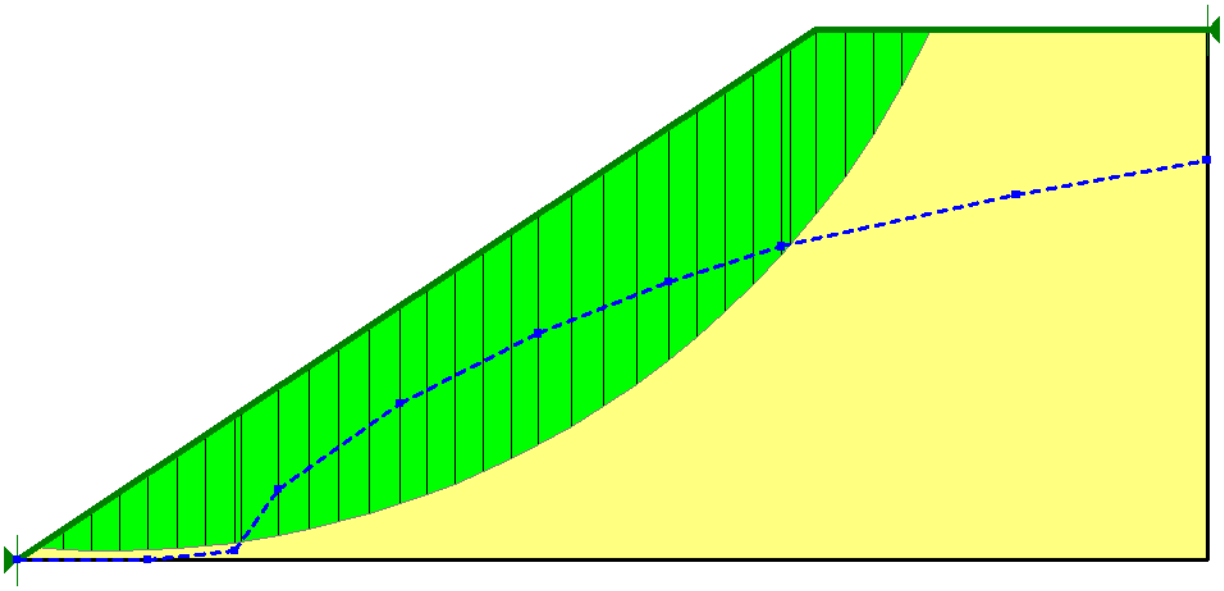


- Draw-Slip Surface-Grid
- Draw-Slip Surface-Radius (A-B-C-D)
- KeyIn Slip Surface

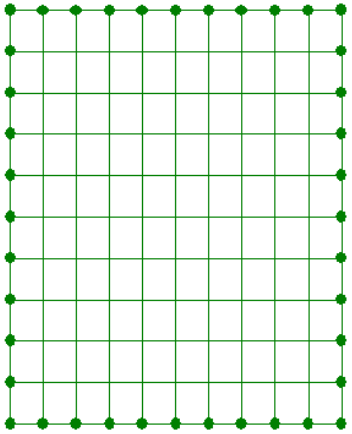


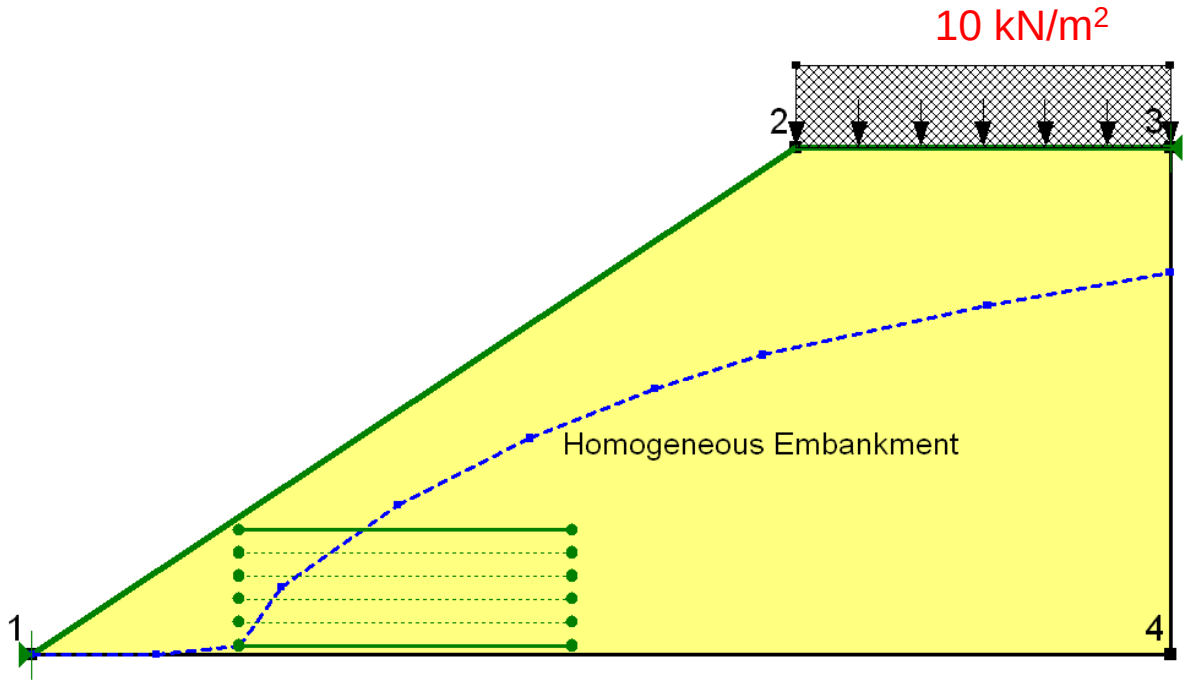
PROBLEM 1c (Grid + Four Point Radius)





PROBLEM 1d
(Grid + Four Points Radius + Surcharge Load)





Draw and Assign a Distributed Load

Assign Surcharge Unit Weight (KeyIn – Surcharge Loads – Points)

- Input only the top points of the surcharge region
- The point coordinate one-by one or paste the coordinate data

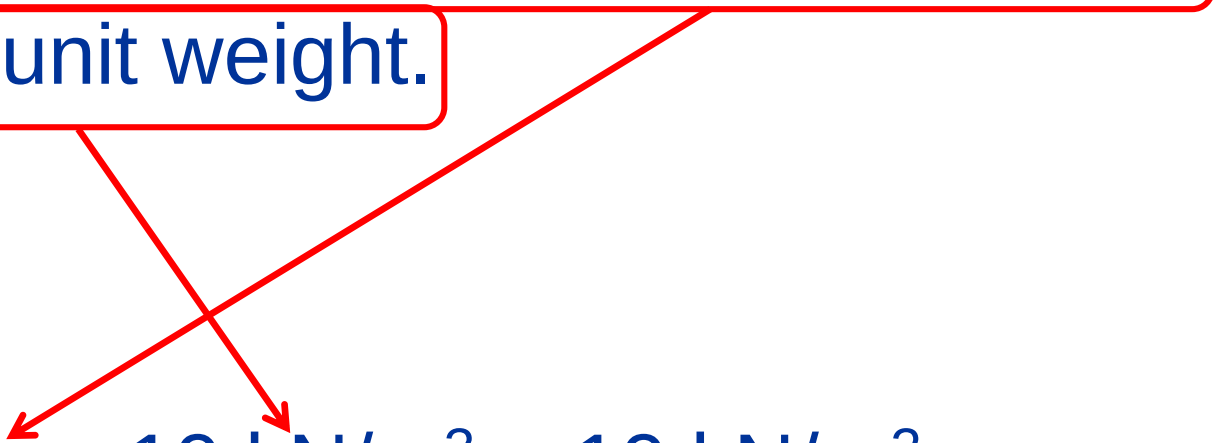
Draw and Assign a Distributed Load

Assign Surcharge Unit Weight (KeyIn – Surcharge Loads – Properties)

- Surcharge unit weight can be vertical or normal to a surface.
- Positif vertical means downward loading.
- Positif normal unit weight mean load towards the surface.

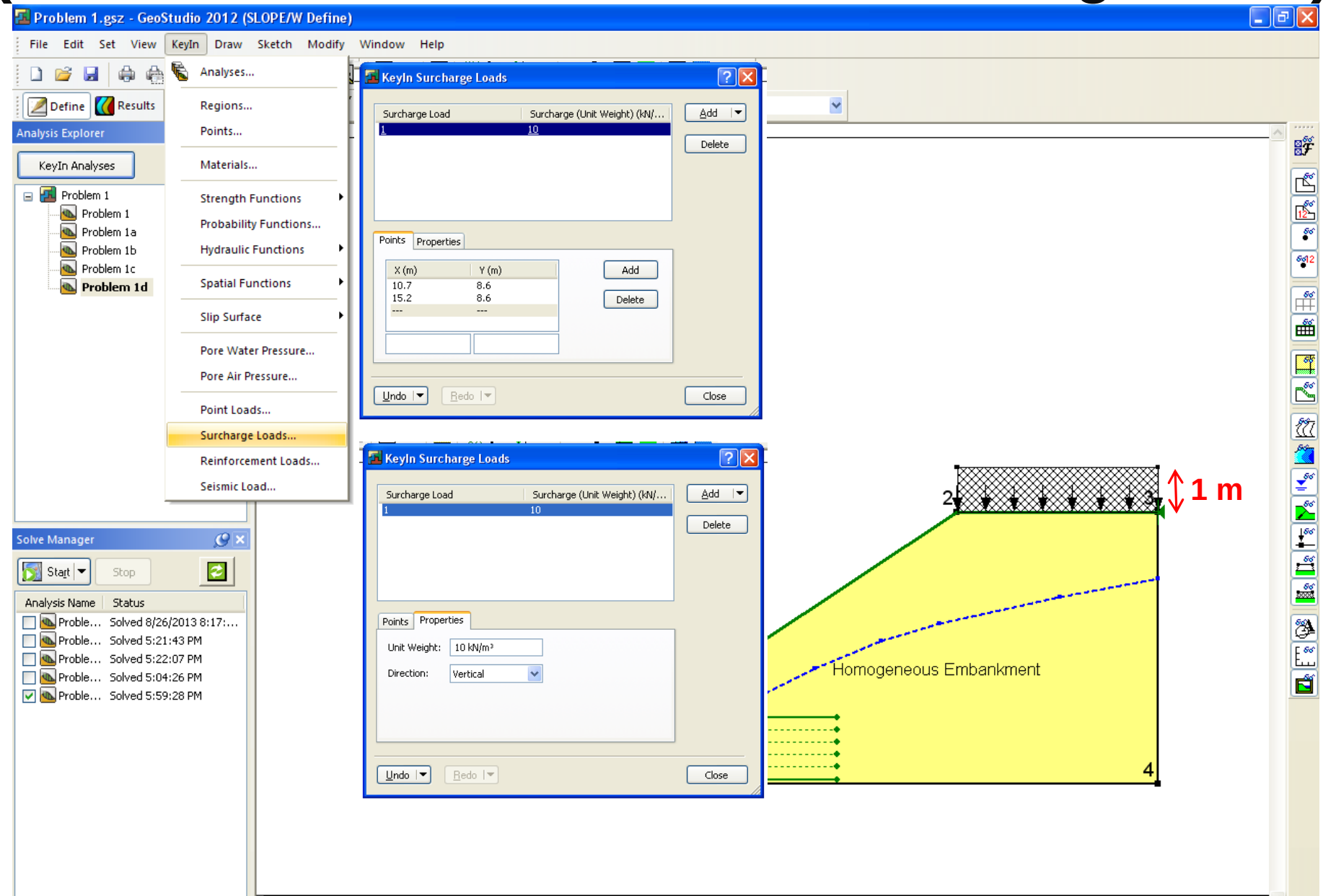
Draw and Assign a Distributed Load

- The actual amount of the distributed load is equal to the height of the surcharge load regions times surcharge unit weight.

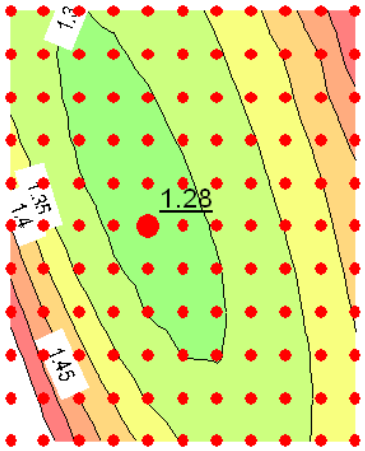


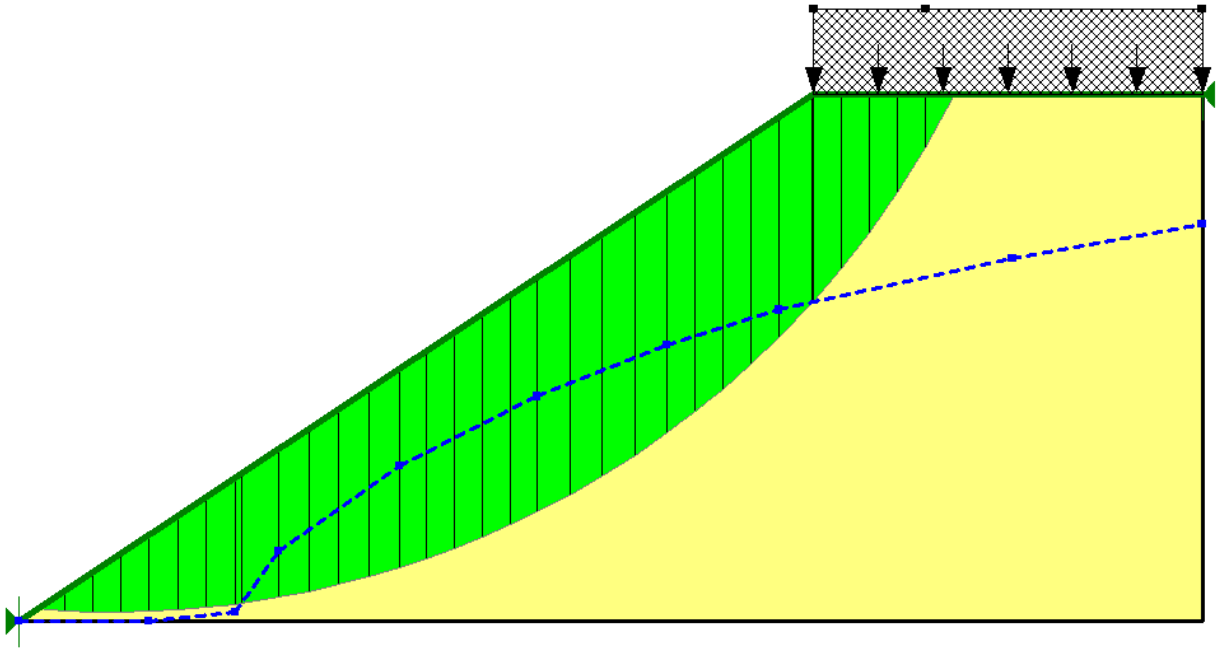
Example: $q = 1\ m \times 10\ kN/m^3 = 10\ kN/m^2$

PROBLEM 1d
(Grid + Four Points Radius + Surcharge Load)



PROBLEM 1d
(Grid + Four Points Radius + Surcharge Load)



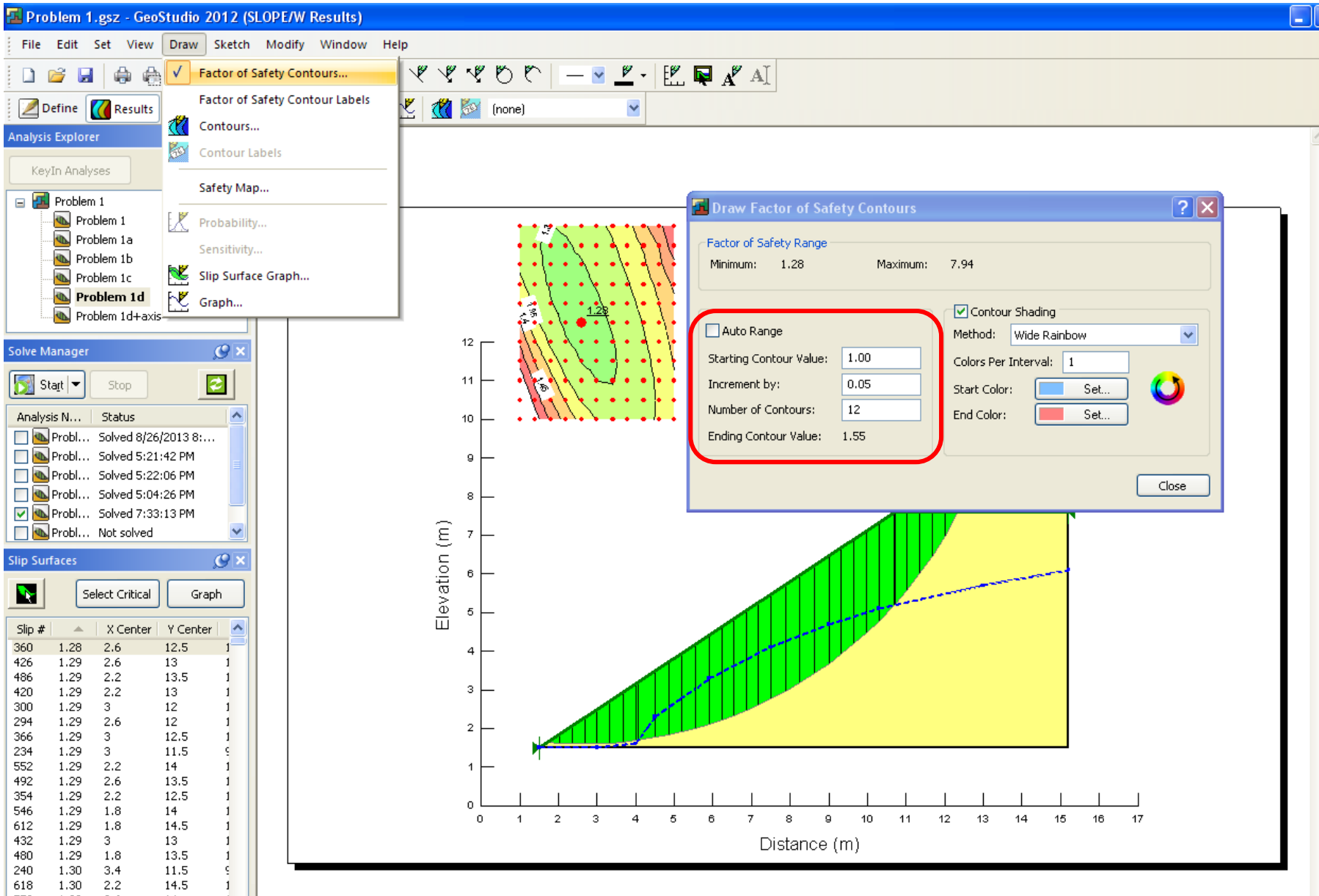


Two components of the Software:

- DEFINE → Input the geometry, material properties, loading, methods of analyses, and **execution**
- RESULTS → post processing (output)

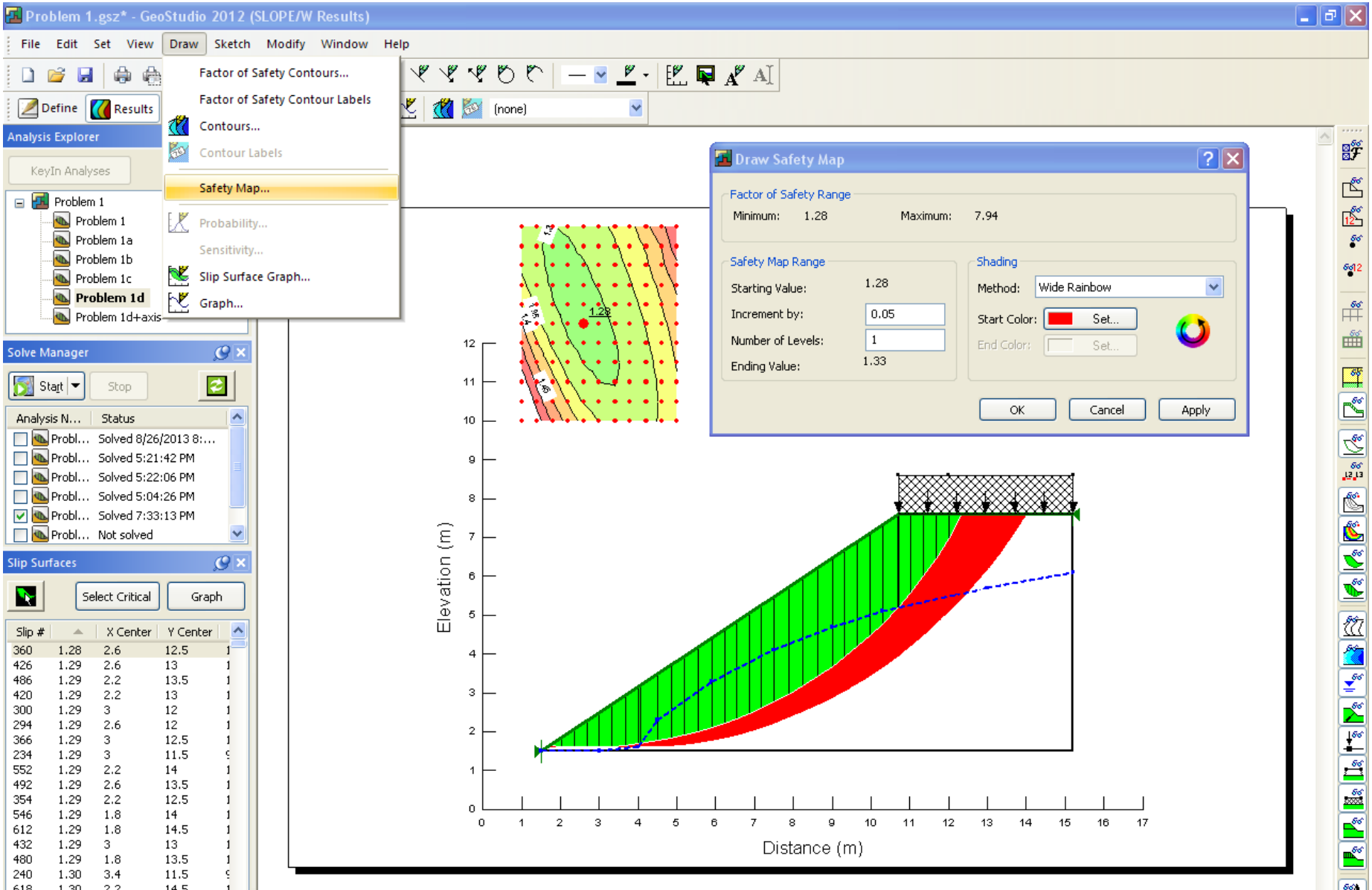
Post Processing (Output)

Draw Contour of FoS



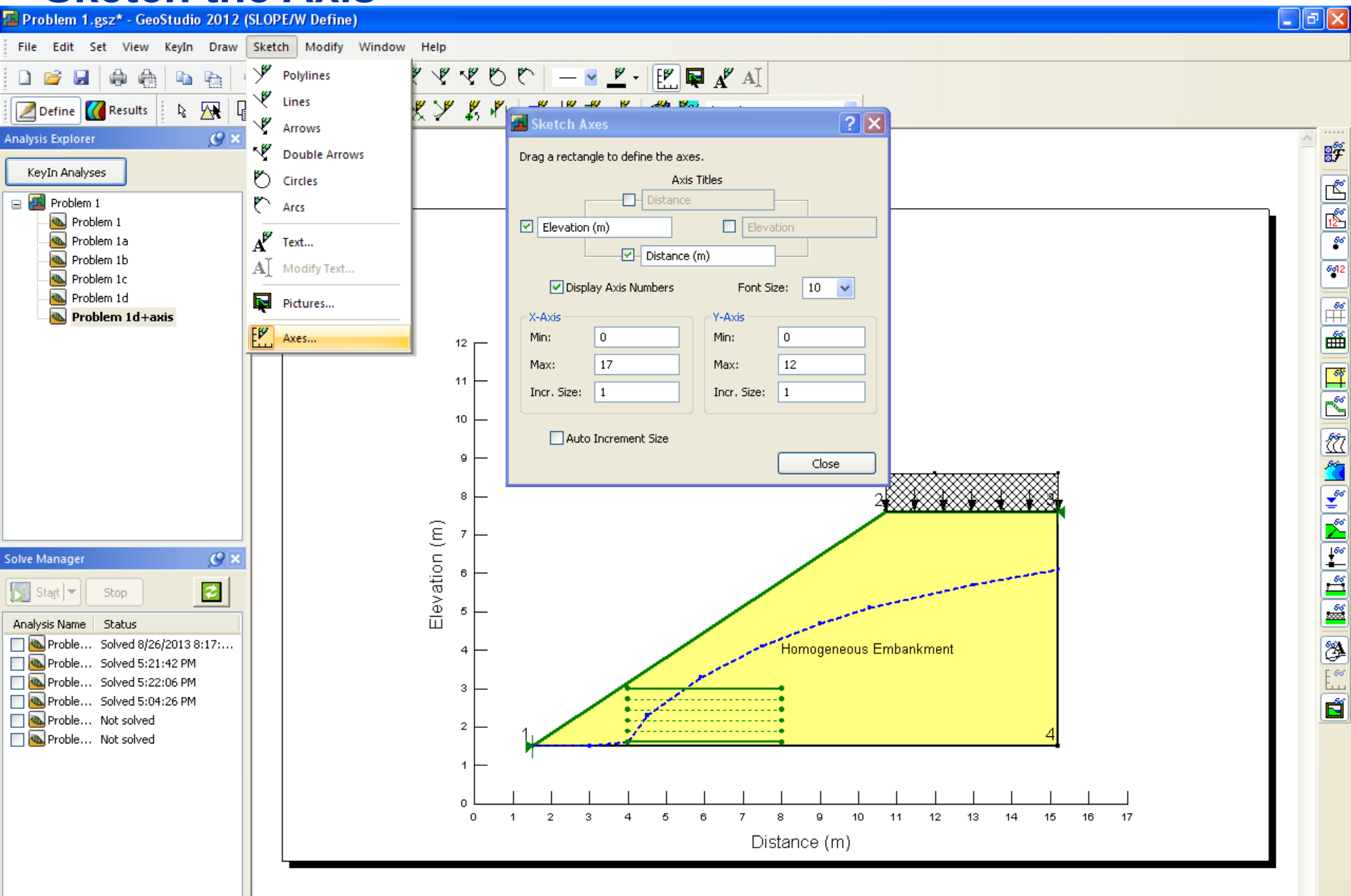
Post Processing (Output)

Draw Safety Map



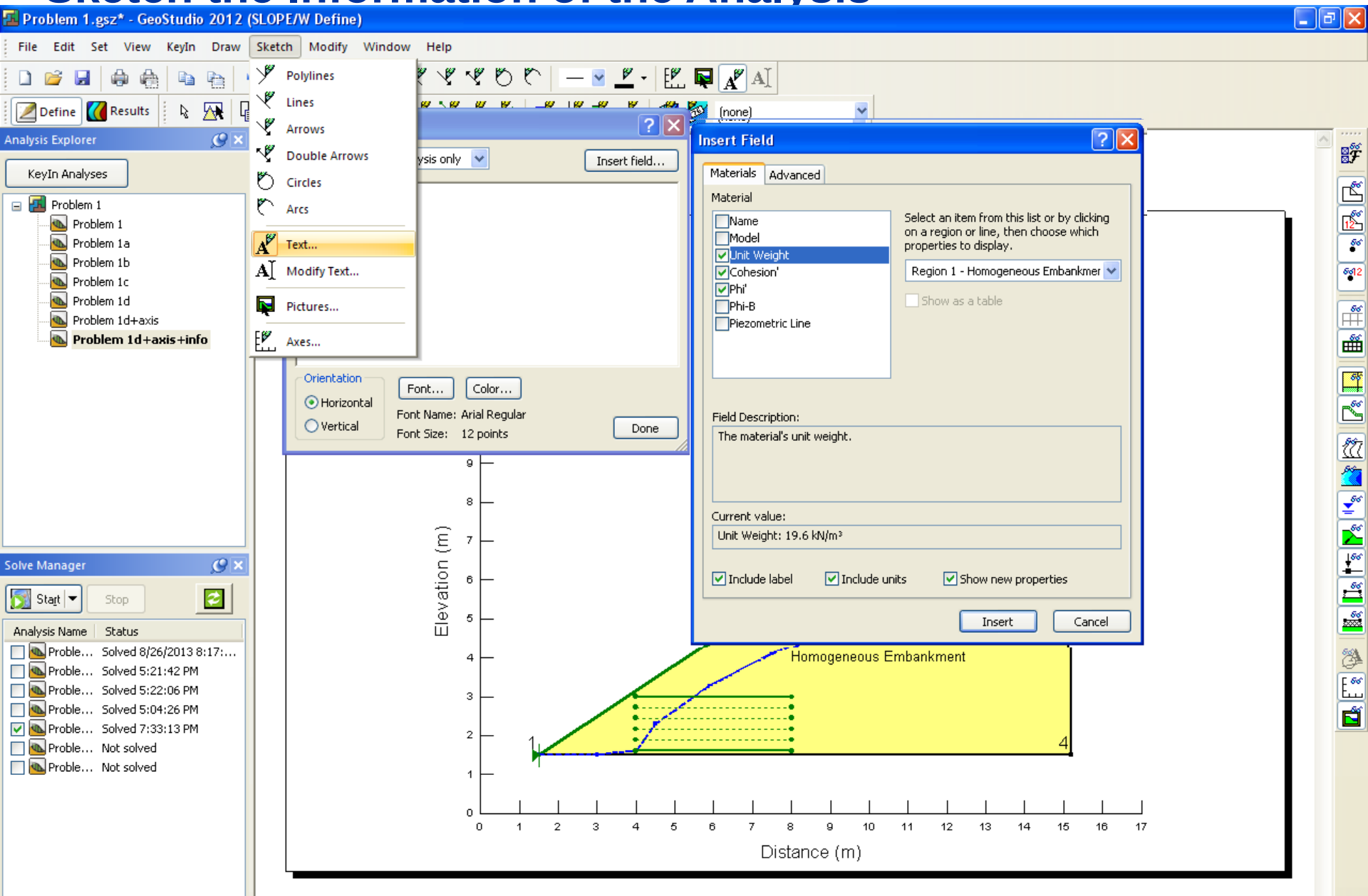
Post Processing (Output)

Sketch the Axis



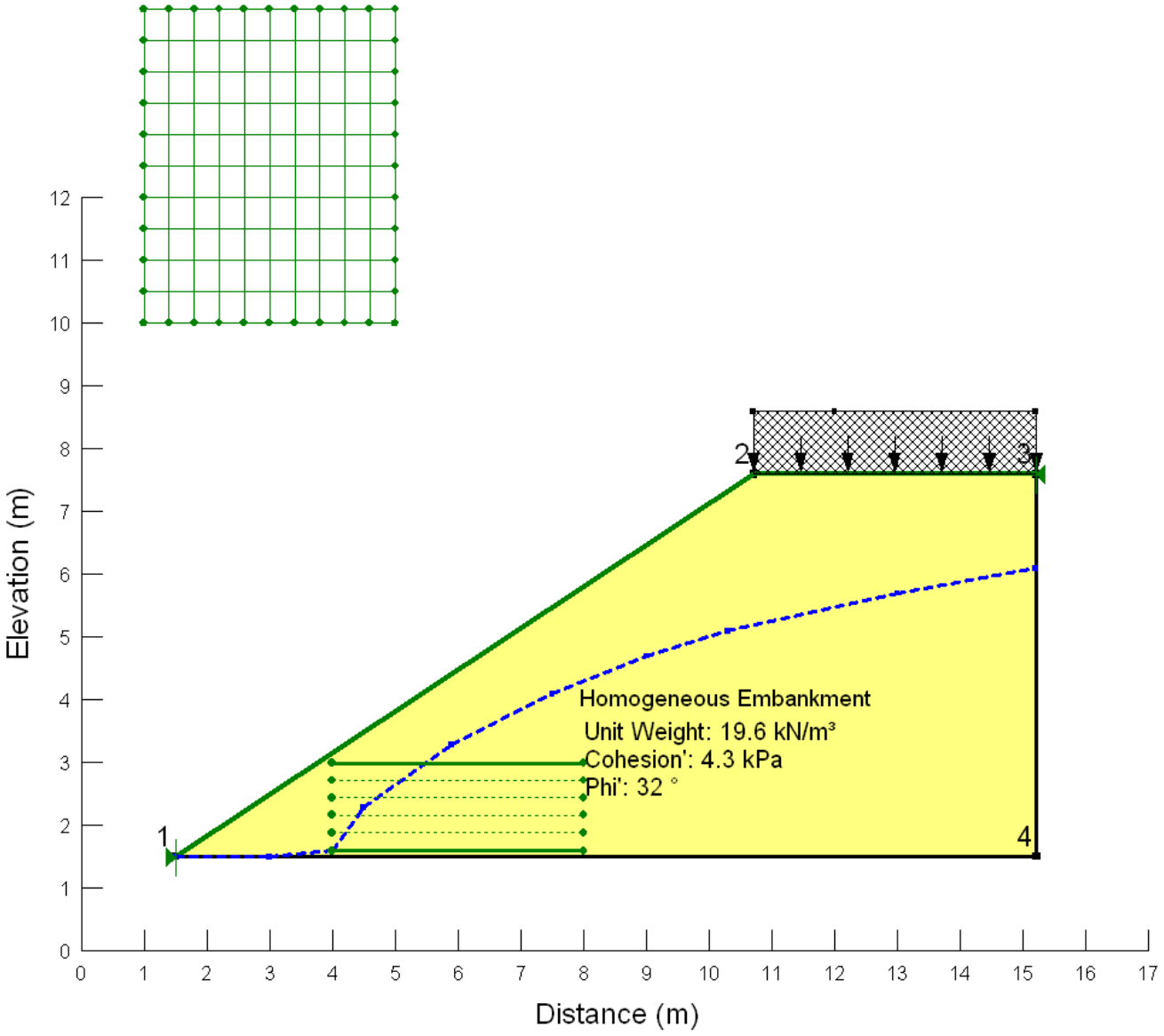
Post Processing (Output)

Sketch the Information of the Analysis

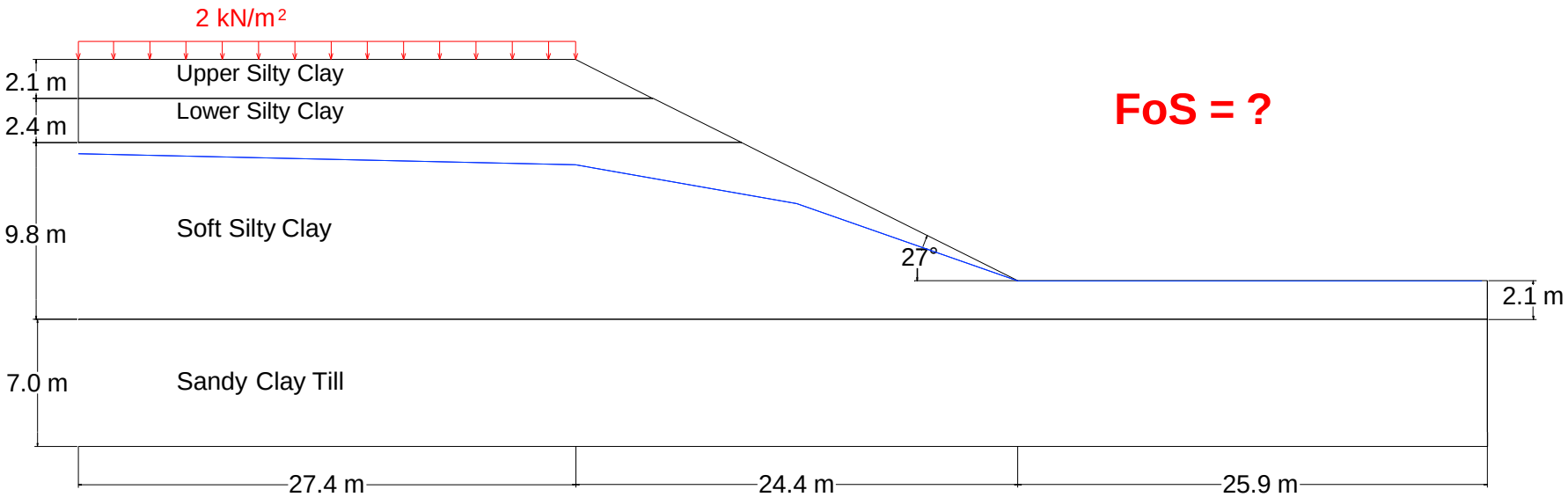


Post Processing (Output)

Sketch the Information of the Analysis



PROBLEM 2



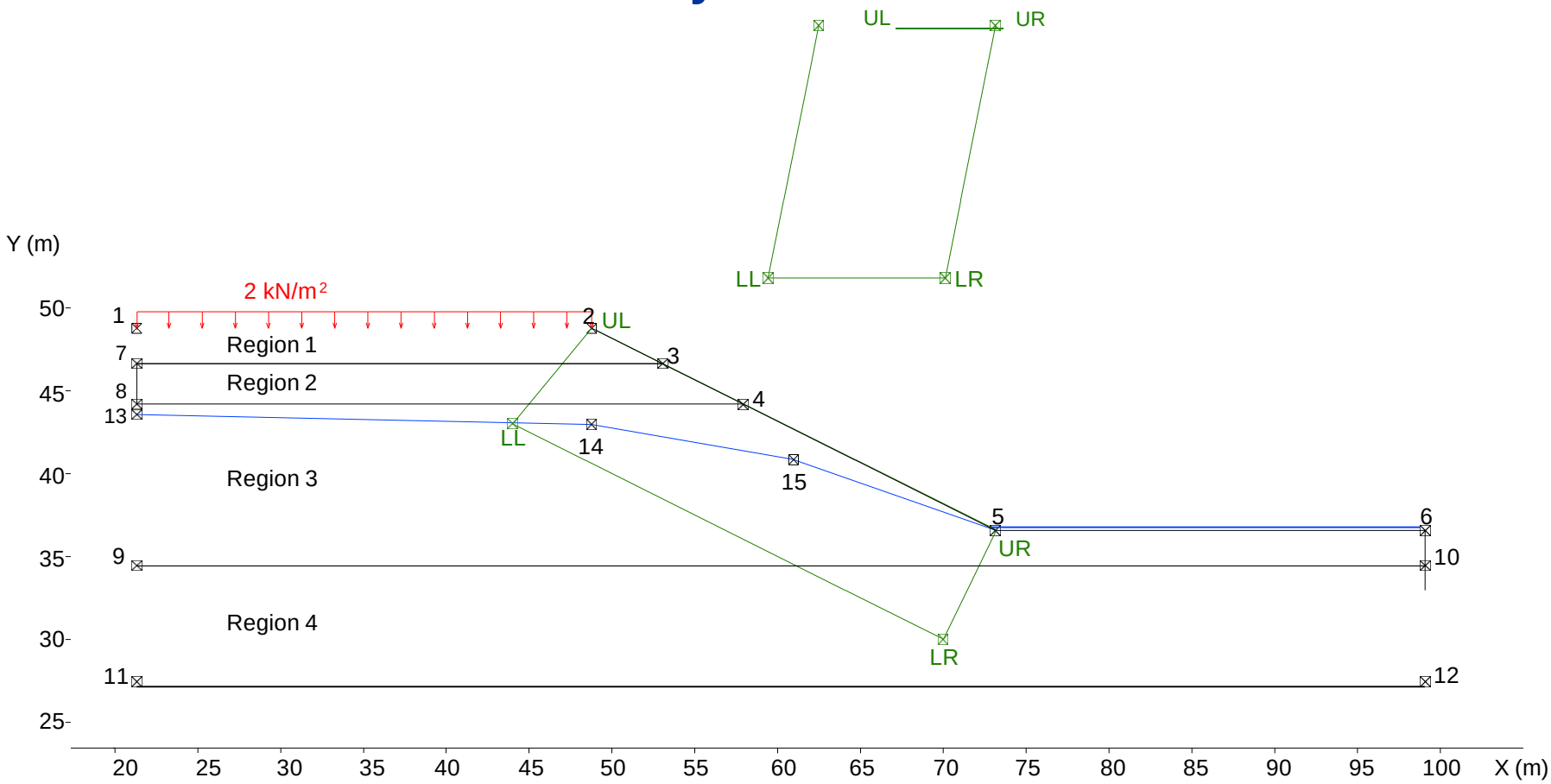
FoS = ?

Soil properties:

Upper Silty Clay	Lower Silty Clay	Soft Silty Clay	Sandy Clay Till
γ = 18.1 kN/m^3	γ = 17.6 kN/m^3	γ = 17.3 kN/m^3	γ = 19.3 kN/m^3
c = 0	c = 28.7 kPa	c = 14.4 kPa	c = 28.7 kPa
ϕ = 30°	ϕ = 21°	ϕ = 20°	ϕ = 27°

PROBLEM 2

Model for Numerical Analysis

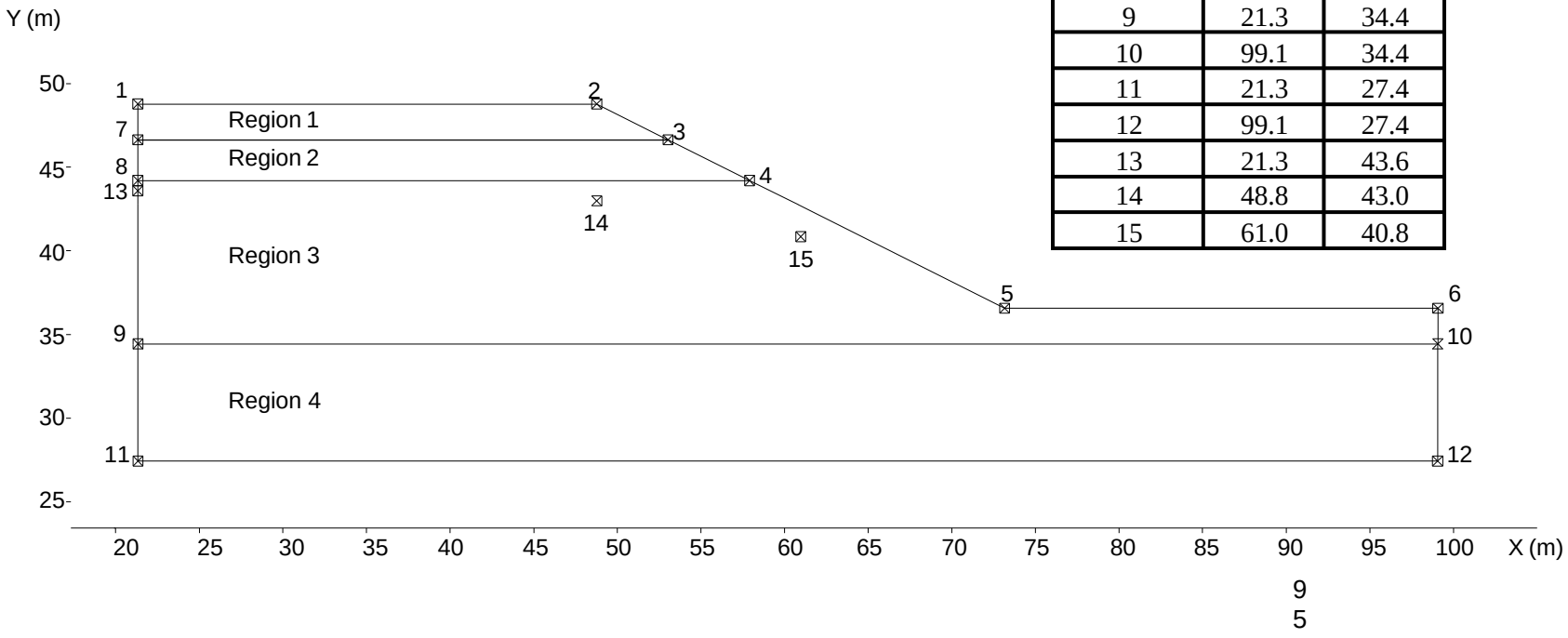


UL = Upper Left LL
= Lower Left
LR = Lower Left
UR = Upper Right

PROBLEM 2

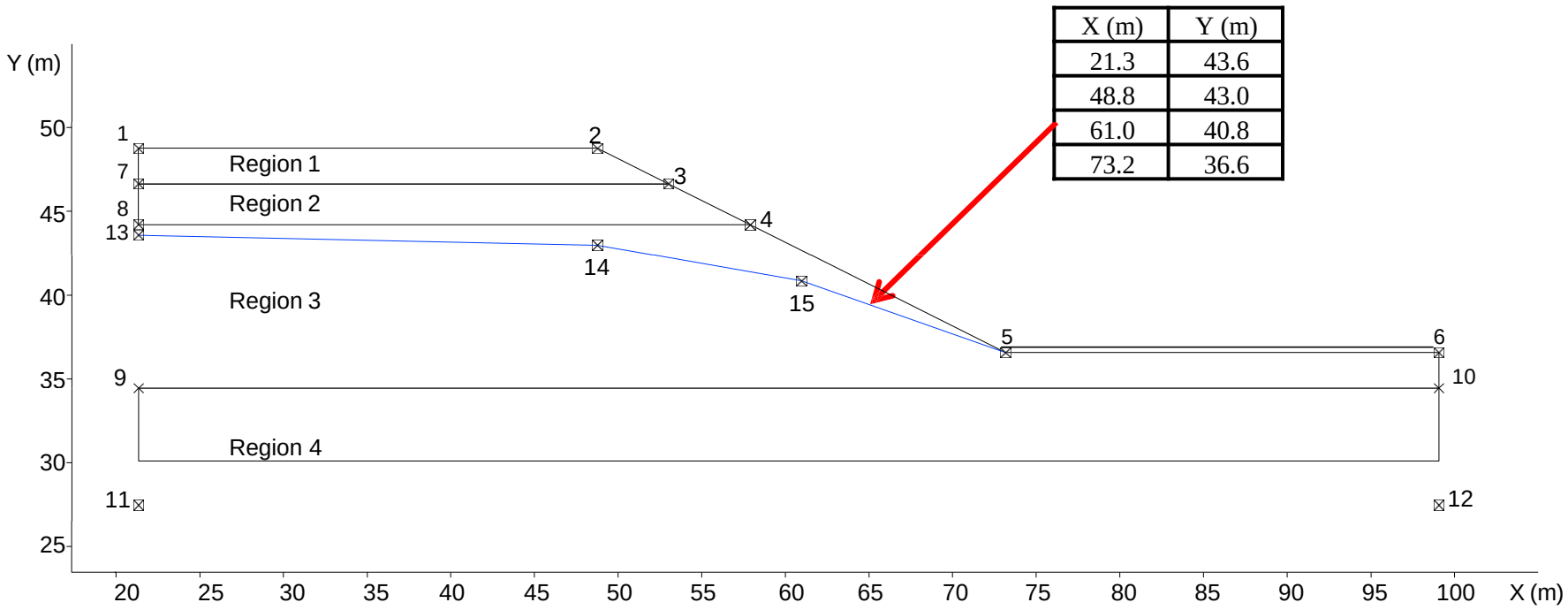
Slope Geometry

POINT ID	X (m)	Y (m)
1	21.3	48.8
2	48.8	48.8
3	53.0	46.6
4	57.9	44.2
5	73.2	36.6
6	99.1	36.6
7	21.3	46.6
8	21.3	44.2
9	21.3	34.4
10	99.1	34.4
11	21.3	27.4
12	99.1	27.4
13	21.3	43.6
14	48.8	43.0
15	61.0	40.8



PROBLEM 2

Piezometric Line

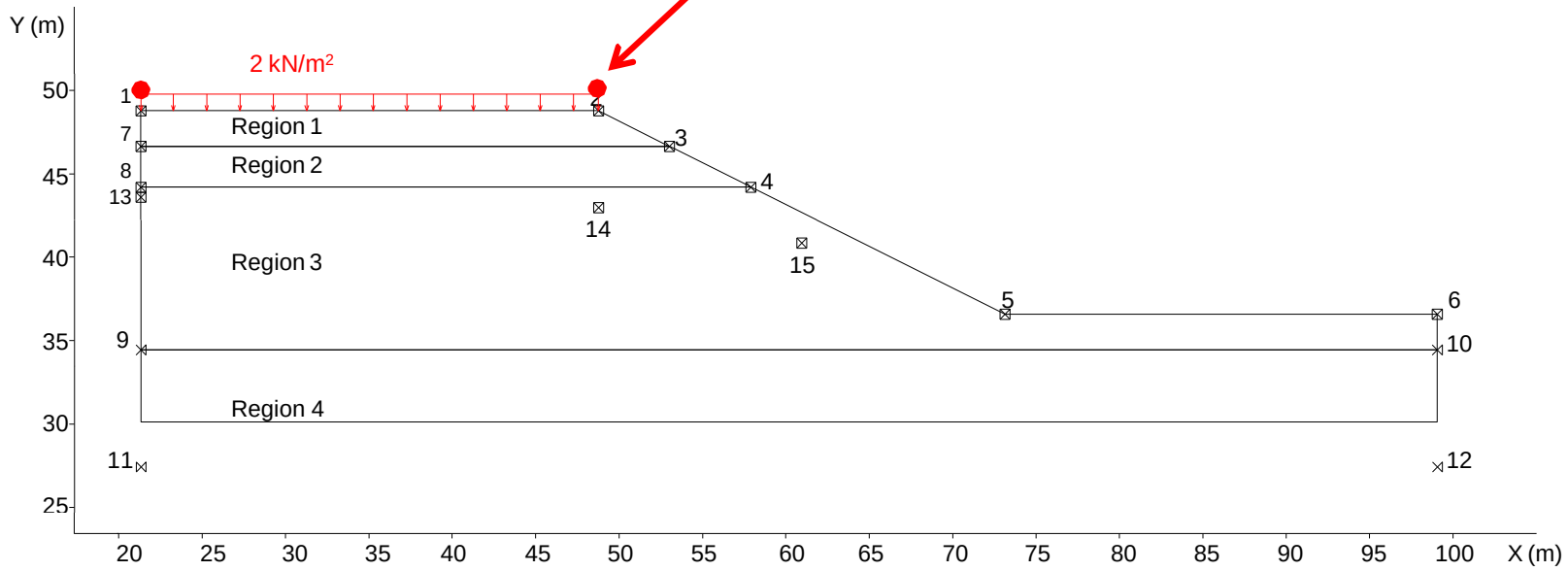


X (m)	Y (m)
21.3	43.6
48.8	43.0
61.0	40.8
73.2	36.6

PROBLEM 2

Surcharge Load

X (m)	Y (m)
21.3	49.8
48.8	49.8



PROBLEM 2

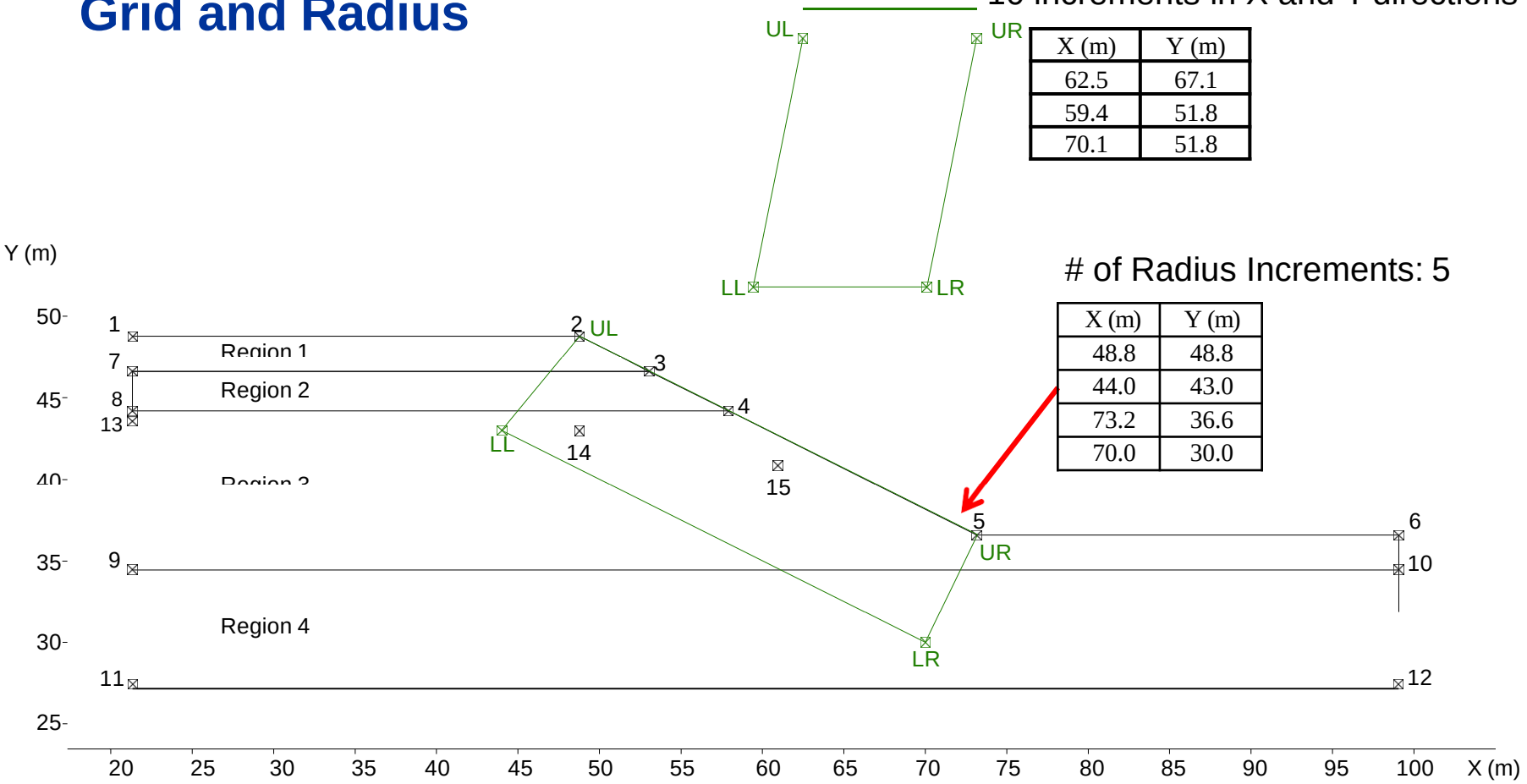
Grid and Radius

of Grid Increments:
10 increments in X and Y directions

X (m)	Y (m)
62.5	67.1
59.4	51.8
70.1	51.8

# of Radius Increments: 5

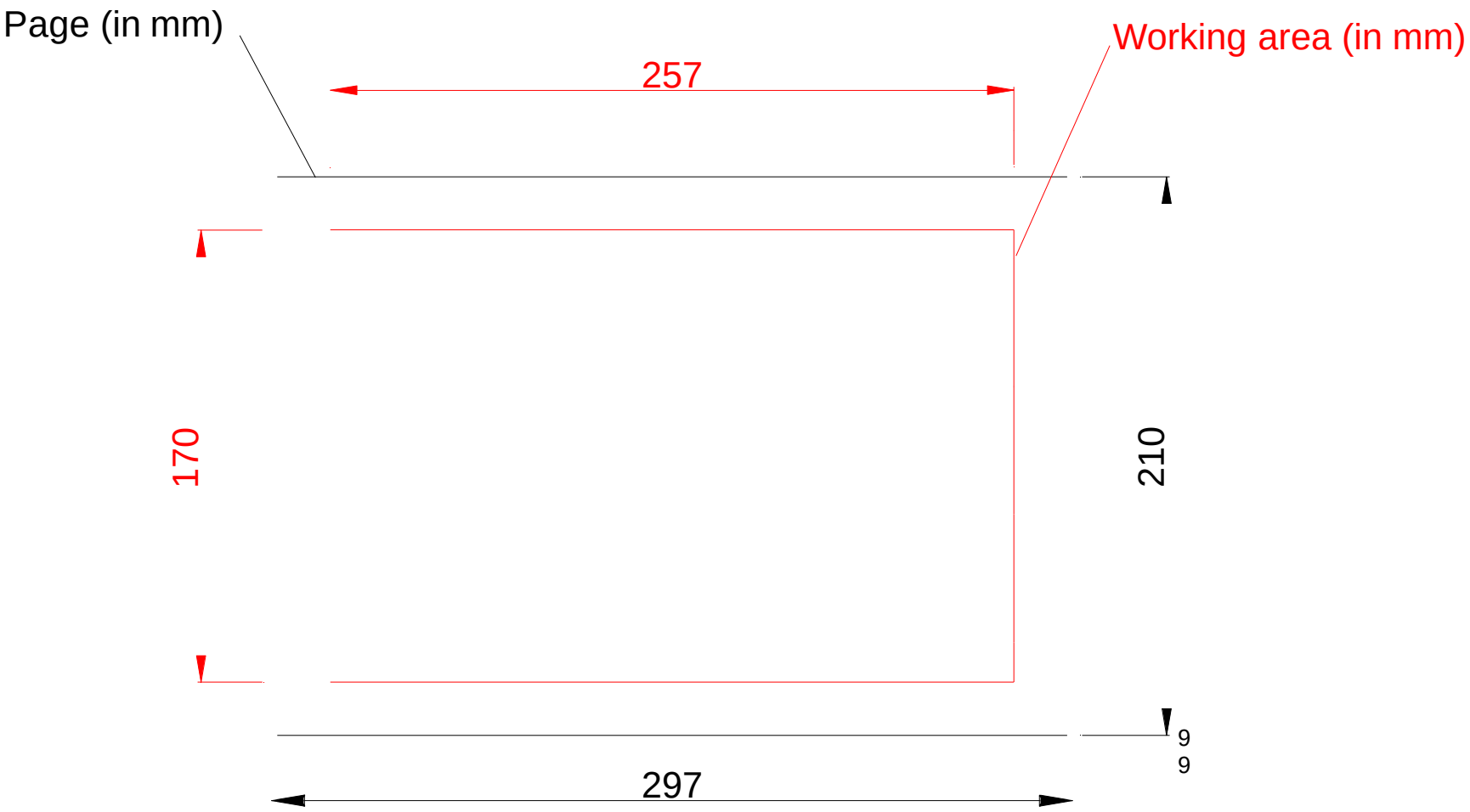
X (m)	Y (m)
48.8	48.8
44.0	43.0
73.2	36.6
70.0	30.0



UL = Upper Left
LL = Lower Left LR = Lower Left UR = Upper Right

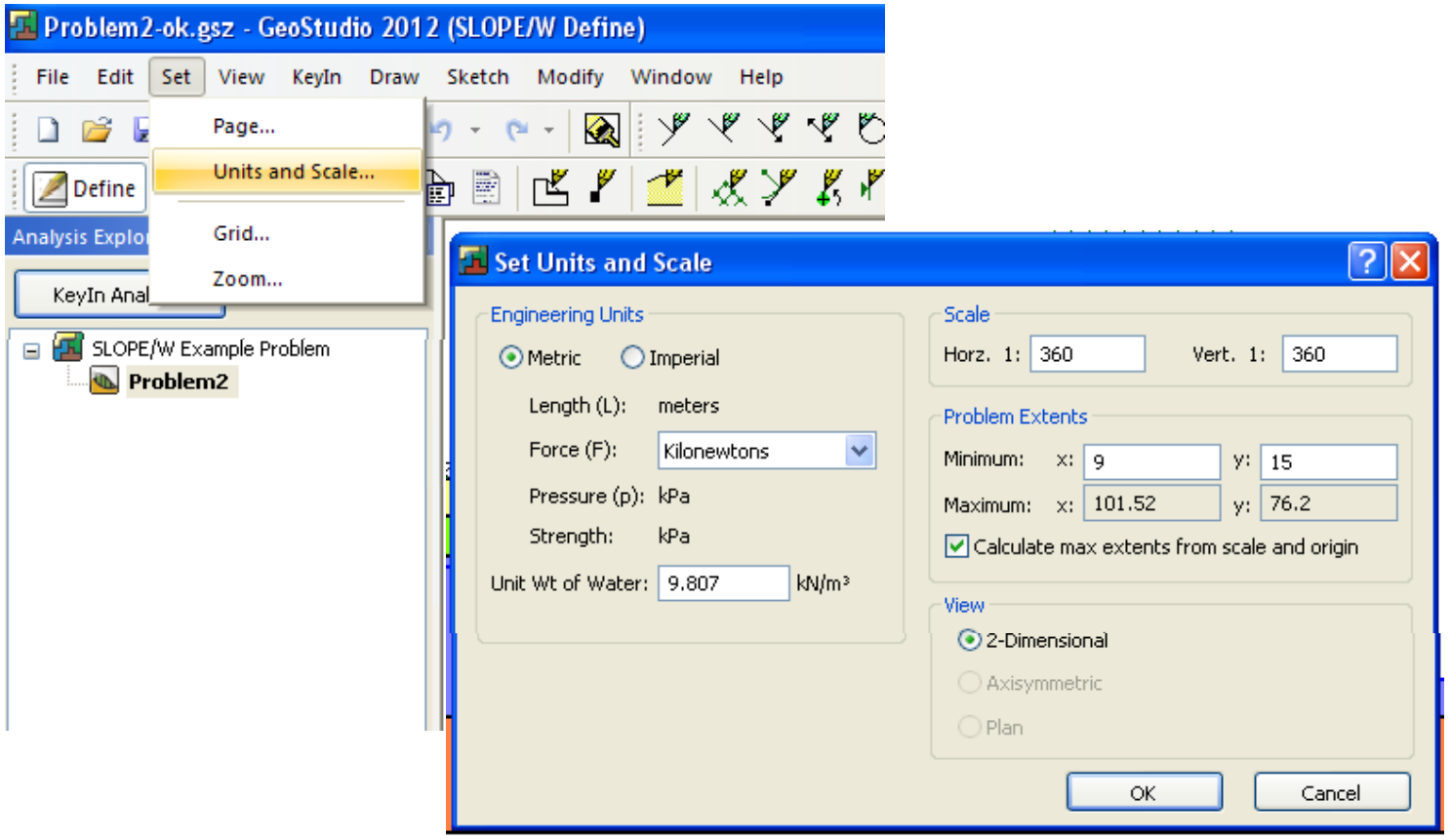
PROBLEM 2

Set Page and Working Area



PROBLEM 2

Set Unit and Scale



PROBLEM 2

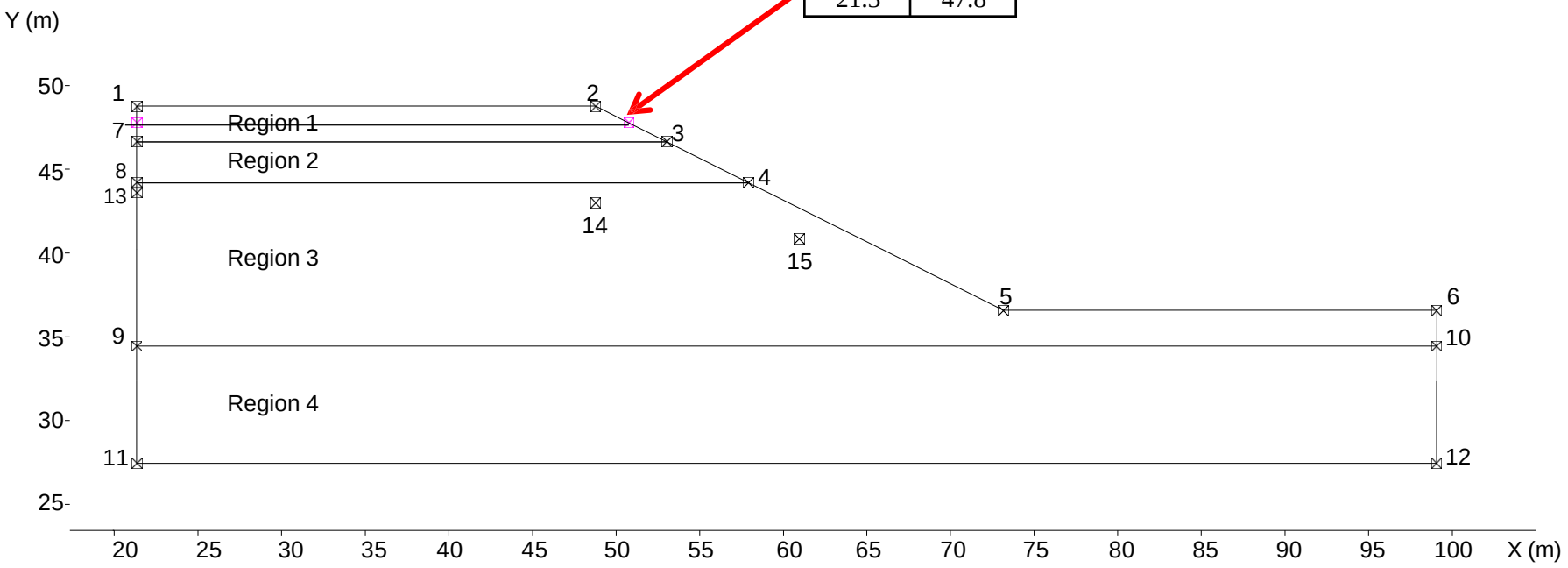
- **Case 2: Calculate FoS by applying phreatic line correction.**
- **Case 3: Calculate FoS incorporating tension cracks: Crack depth: 1 m**

Crack is filled with water

PROBLEM 2

Tension Crack Line

X (m)	Y (m)
50.8	47.8
21.3	47.8



THE END