Appendix no. 4

Appendix 4.1 General Information about Landslides

Appendix 4.2 Software Package GeoStudio Software

Appendix 4.3 Selected photos

Appendix 4.1 General Information about Landslides

The first sign of an imminent landslide is the appearance of surface cracks in the upper part of the slope, perpendicular to the direction of the movement. These cracks may gradually fill with water, which weakens the soil and increases the horizontal force which initiates the slide. Frequently, inclined shear cracks can also be observed on both sides of the slide, as well as a slight bulge at the toe of the slope.

Landslides are primarily caused by gravitational forces but occasionally seismic forces can be a contributing factor. A landslide is primarily the result of a shear failure along the boundary of the moving mass of soil or rock. Failure is generally assumed to occur when the average shear stress along the sliding or slip surface is equal to the shear strength of the soil or rock as evaluated by field or laboratory tests.

The geologist regard landslides as one of the many natural processes which act on the surface of the earth as part of the general geological cycle. However, the engineer, on the other hand, tries to determine the maximum angle at which a slope is stable and studies the stability of a slope in terms of a factor of safety.

Landslides may be classified according to the shape of sliding which are falls, rotational slides, translational slides or flow.

4.4.1 Causes of Landslides

The main factors that cause landslides are:

- Construction Operation
- Erosion
- Tectonic Movements
- Earthquakes (Vibrations)
- Rains or Melting Snow
- Frost Action
- Dry Spells
- Rapid Draw Down
- Seepage from Artificial Sources of Water
- Seepage from Artificial Sources of Water

4.4.2 Investigation and Analysis of Landslides

To investigate landslides one should do field studies, laboratory studies and slope stability analysis. It is important that the field and laboratory investigations be supplemented by field measurements so that the behavior of a slope can be checked and corrective measures be taken in times.

The first step in landslides analysis is the collection of available information geological, hydrological, topographical, and soil maps.

4.4.3 Methods of Correcting Landslides

Several methods are available for correcting landslides as follows:

1- Geometrical Methods to increase slope stability (factor of safety form analysis) including:

- Flattening of slope
- Excavation at top of slope
- Fill at toe of slope

2- Hydrological Methods are aimed to drainage of surface water and lowering of ground water level. Methods may include:

- Surface drains
- Drain holes
- Sand drains
- Inverted filters

3- Mechanical Methods to increase the shear strength of the soil to resist the forces causing sliding or inserting reinforcing technique to increase slope instability. These methods include:

- Compaction
- Freezing
- Grouting
- Rock Bolts
- Piles
- Retaining Walls, Sheet Pile Walls, and Toe Walls.

Appendix 4.2 Software Package GeoStudio Software

GeoStudio
One Model. One Tool. Many Analyses.

Overview

GeoStudio 2004 is a suite of applications for geotechnical and geo-environmental modeling. It includes the following software products:

SLOPE/W for slope stability analysis

SEEP/W for groundwater seepage analysis

SIGMA/W for stress and deformation analysis

QUAKE/W for dynamic earthquake analysis

TEMP/W for thermal analysis

CTRAN/W for contaminant transport analysis

VADOSE/W for vadose zone and soil cover analysis

With GeoStudio 2004, you can analyze almost any problem you encounter in your geotechnical, geo-environmental, civil and mining engineering projects.

Seven Integrated Applications

GeoStudio applications are integrated, allowing you to use the analysis results from one product in another one. This unique and powerful feature greatly expands the types of problems you can analyze. For example, use SIGMA/W to establish initial static stress conditions for a QUAKE dynamic earthquake analysis. Then use SEEP/W to dissipate the excess pore-water pressures calculated by QUAKE/W. Finally, use the resulting pore-water pressure and stress distributions in a SLOPE/W stability analysis.

Integration between the Packages

The power of GeoStudio is in the tight integration between each of its applications.

Pore-water pressures computed by SEEP/W, SIGMA/W or QUAKE/W can be used in a SLOPE/W analysis.

SIGMA/W static stresses or QUAKE/W dynamic stresses can be used in a SLOPE/W stability analysis.

SEEP/W pore-water pressures can be used in a SIGMA/W consolidation analysis.

SEEP/W pore-water pressures can be used in a CTRAN/W density-dependent contaminant transport analysis.

Excess pore-water pressures computed by QUAKE/W can be dissipated over time in a SEEP/W transient seepage analysis.

Static stress conditions computed by SIGMA/W can be specified as the initial stresses in a QUAKE/W dynamic analysis.

Typical Applications

GeoStudio applications can be used to model almost any geotechnical problem, including:

- Slope stability problems involving earth and rock slopes, including sloping excavations, embankments, anchors, soil nails and geofabrics
- Seepage affected by infiltration, drains, and injection wells
- Deformation resulting from staged loading, excavations, and fill placement or removal
- Earthquake-induced deformation and pore-water pressure generation
- Contaminant transport problems
- Thermal conduction and transient freeze-thaw problems
- Unsaturated soil behavior

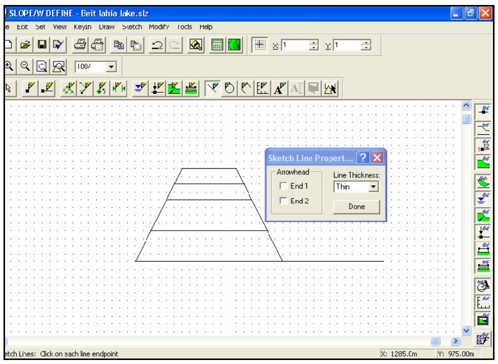
Features

- The common look and feel of each GeoStudio application means you can quickly learn how to use each product.
- Define and modify the problem geometry using CAD-like tools.
- Interactively specify material properties and boundary conditions.
- Use general data-point functions for material properties.
- Import background pictures or DXF files.
- View results as contours, x-y plots, vectors, or tables of data that can be exported to other applications.
- Solve the analysis with iterative or direct equation solvers.

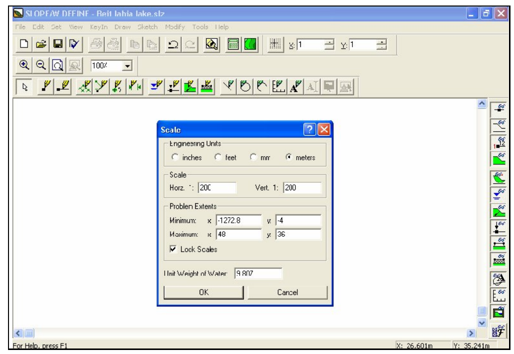
- Gets assistance using the context-sensitive HTML help system?
- Enhance the drawing by sketching lines and adding text labels that automatically update as parameter values change.
- Select the Undo command when you wish to undo your changes.

Slope Model Formation

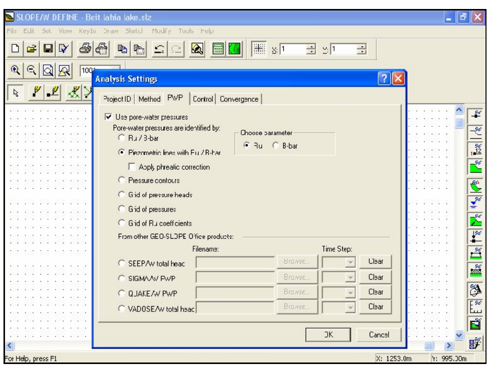
The following figures shows the formulation of the section using geoslope software



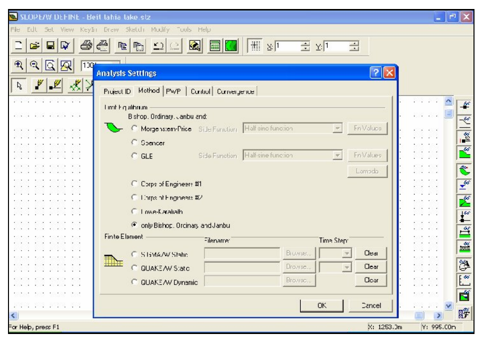
Sketch the problem



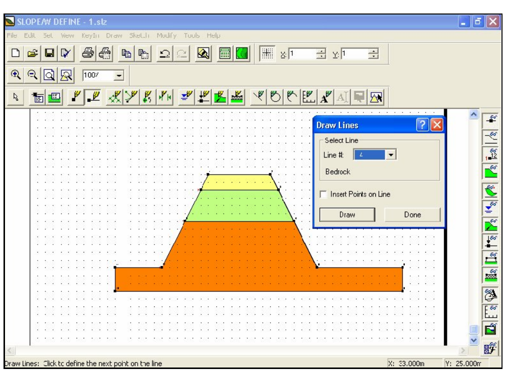
Defining the Problem

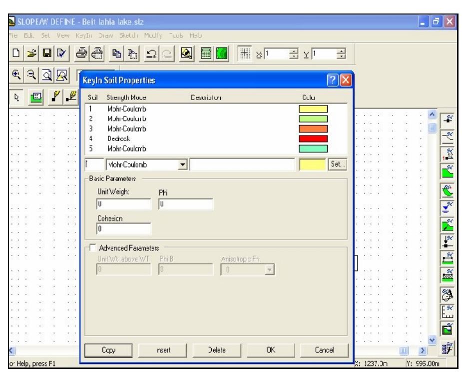


Specify the Analysis Method

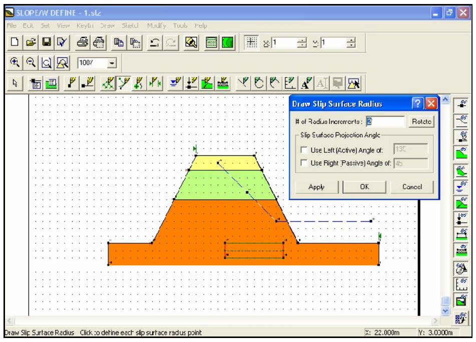


Specify the Analysis Option

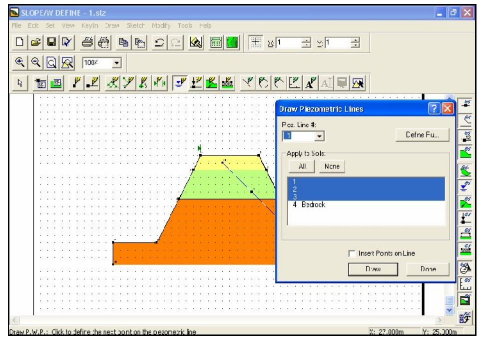




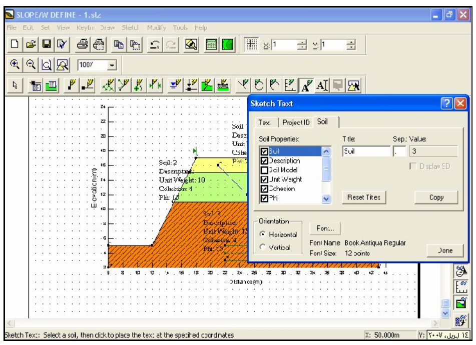
Define the Soil Properties



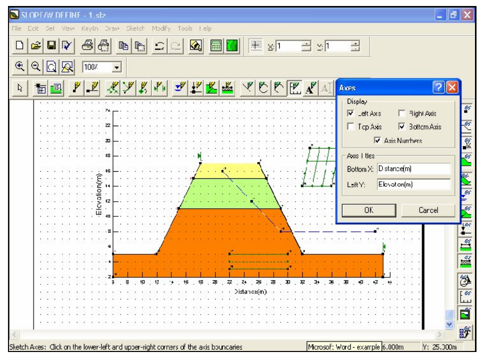
Specify the Piezometric Lines



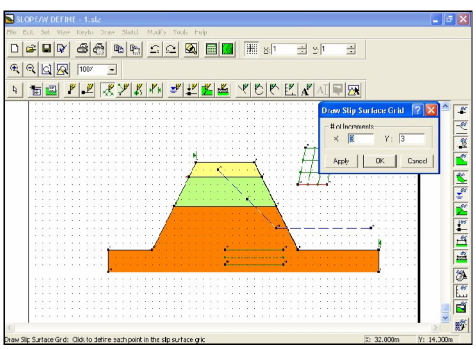
Draw the Slip Surface Radius



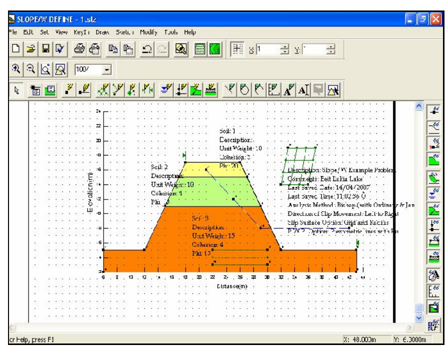
View Preferences



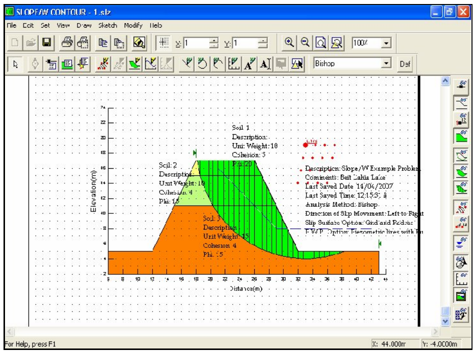
Draw the Slip surface Grid



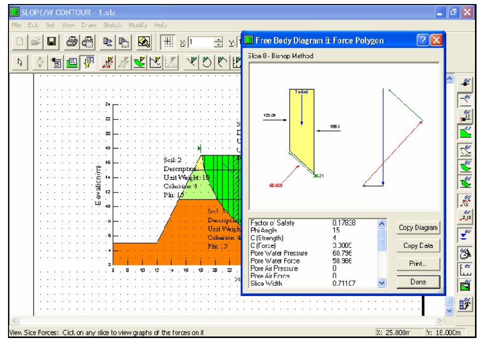
Specify the Center of Slip Surface



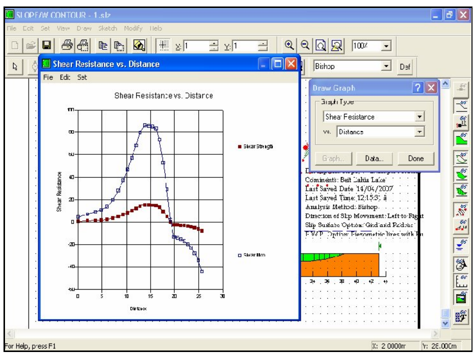
Show all Data on the Drawing



Viewing the Results - The Critical Surface



The Slice Forces



Plot Graph of Results

Solving any problem using slope/w require five components. They are:

- Geometry – description of the stratigraphy and shapes of potential slip surfaces.
- Soil strength – parameters used to describe the soil (material) strength.
- Pore water pressure – means of defining the pore water pressure conditions
- Reinforcement or soil-structure interaction – fabric, nails, anchors, piles, walls and so forth.
- Imposed loading – surcharge or dynamic earthquake loads.

Appendix 4.3 Selected photos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