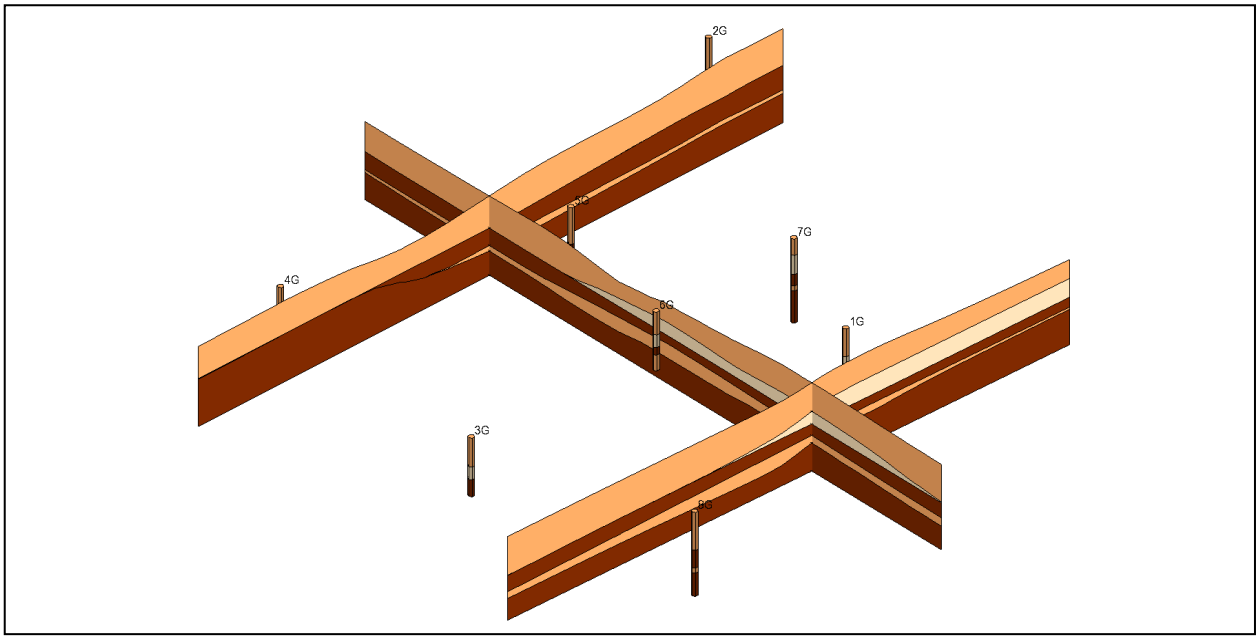
GMS 10.0 Tutorial

Stratigraphy Modeling—Horizons and Solids

Create solids from boreholes using the **Horizons** → **Solids** tool.



Objectives

Learn how to construct a set of solid models using the horizon method in GMS. Become familiar with how horizons are numbered and used to create solids. Use borehole cross sections to help control the solid generation process.

Prerequisite Tutorials

- Feature Objects
- Stratigraphy Modeling—Boreholes and Cross Sections
- Stratigraphy Modeling—TIN Surfaces

Required Components

- Sub-surface Characterization
- Geostatistics
- Map module

Time

- 35-45 minutes

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1 Introduction

The Solid module of GMS is used to construct three-dimensional models of stratigraphy. Once the solids are created, the following can be accomplished: cross sections can be cut anywhere on the model, the volumes of the solids can be computed, and the solid model can be used to define elevation data for numerical models such as MODFLOW.

This tutorial will illustrate how to construct a set of solid models using the horizon method in GMS. The term "horizon" refers to the top of each stratigraphic unit that will be represented in the solid. Horizons are numbered consecutively in the order that the strata are "deposited" (from the bottom up). Horizons are defined at borehole "contacts" (the interface between different materials on a borehole log). Each contact that the user wishes to include in the construction of the solid must have a horizon ID. A contact with a horizon ID of zero—the default value—will be ignored.

If the borehole data are very complex, it may be inadvisable to assign horizon IDs at all. Horizon IDs only make sense if a relationship exists between boreholes, but some stratigraphy is so complex that very little, if any, relationship exists between the boreholes. In such cases, the approach outlined in the T-PROGS tutorial should be considered.

1.1 Outline

The steps for this tutorial are:

1. Import borehole data.
2. Assign horizon IDs automatically and manually.
3. Create a TIN.
4. Create solids from the horizons.

2 Getting Started

To get started, do the following:

1. If necessary, launch GMS.
2. If GMS is already running, select the *File* | **New** command to ensure that the program settings are restored to their default state.

3 Overview

Creating a solid model of soil stratigraphy using the horizons approach in GMS is quite simple. First, it is necessary to read in a set of borehole data. Second, it is necessary to assign horizon IDs to the contacts of the boreholes. Then it will be possible to create a TIN that can be used to interpolate and to define the boundary of the solid. Finally, it will be possible to execute the **Horizons → Solids** command to create a set of solids.

4 Reading Borehole Data

The first step in the construction of the solid models is to import a set of borehole logs. Borehole data can be entered into GMS manually, or the data can be read from a file. In the interest of time, the next step will be reading in a previously prepared file.

To read in the file, do as follows:

1. Select the **Open** button.
2. In the *Open* browser dialog, locate the directory entitled: *Tutorials\Stratigraphy_Modeling\Horizons_and_Solids.*
3. Select the file named "holes.gpr."
4. Click on the **Open** button.

A 3D view of the borehole logs should now appear. Each of the colors represents a different type of soil. They are clean sand, silty sand, and silty-clayey-fine sand.

5 Determining Horizons

The model should look like the one in **Error! Reference source not found.**.

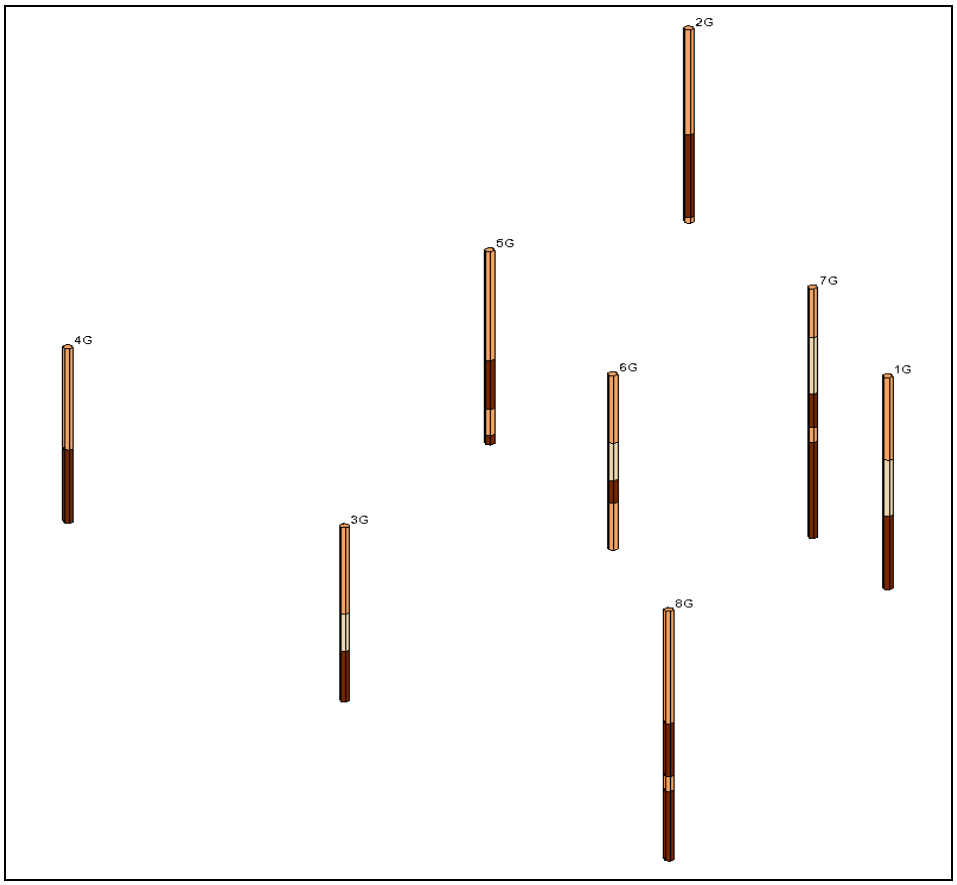

Figure 1 Boreholes

1. Look at this set of boreholes and plan how to assign horizon IDs to them.

Remember that horizons are numbered consecutively in the order that the strata are "deposited" (from the bottom up). Horizon IDs are assigned at borehole contacts (the interface between different materials on a borehole log).

Notice what is common among all the boreholes and what is different. For example, silty-clayey-fine sand is at the top of every borehole. Also, several boreholes have a clean sand layer on top of a silty sand layer. But some boreholes have more than one silty-clayey-fine sand layer, and some also have more than one silty sand layer.

Hole 7G seems to include all the layers that are present on all of the other holes. Therefore, it can be used as a guide to show the order in which the layers were deposited. This tutorial will assign horizon IDs to each contact on hole 7G, starting with 0 at the bottom and ending with 5 at the top. On the other holes, the numbering will have a gap where a layer is missing.

6 Displaying Horizon IDs

Next it is necessary to turn on the display of the horizon IDs.

1. Select the ***Display Options*** button.
2. In the dialog, turn on the *Horizon IDs* option.
3. Select the **OK** button.

Horizon IDs should now be displayed next to each contact. As the results show, all the horizon IDs are currently 0. Zero is a key value that indicates to GMS that it should ignore that horizon when constructing solids.

7 Automatically Assigning Horizon IDs

The next step in the construction of the stratigraphy model is to assign the horizon IDs to the borehole contacts. The easiest way to assign horizon IDs is to let GMS do it automatically.

1. Select the *Boreholes* | **Auto-Assign Horizons** menu command.
2. In the *Auto-assign Horizons* dialog, make sure the *Start from scratch* option is selected and click the **Run** button.

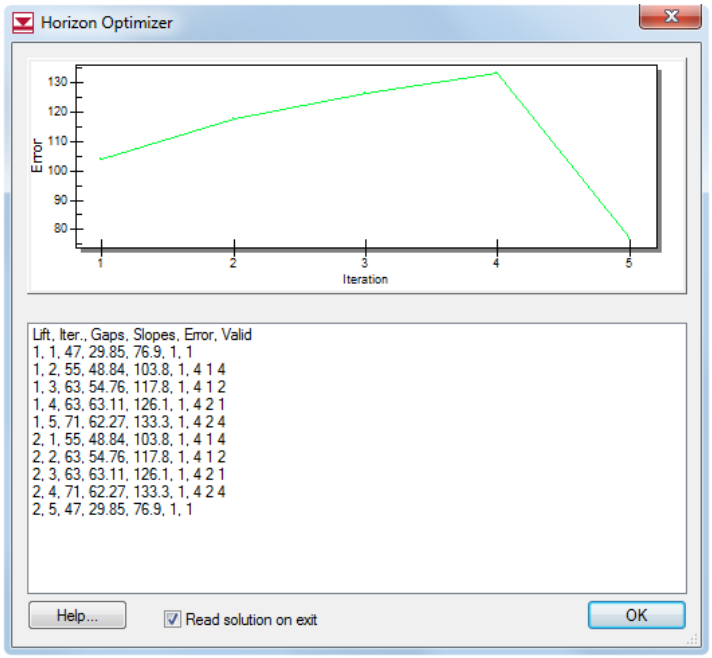

Figure 2 The Horizon Optimizer

The *Horizon Optimizer* dialog now appears as seen in Figure 2. Since only a small number of boreholes exist, the optimizer finishes quickly. With a bigger and more complex set of boreholes, the optimizer can take a significant amount of time.

3. When the *Horizon Optimizer* finishes, click **OK**.

The horizon IDs should now be assigned as seen in **Error! Reference source not found.**.

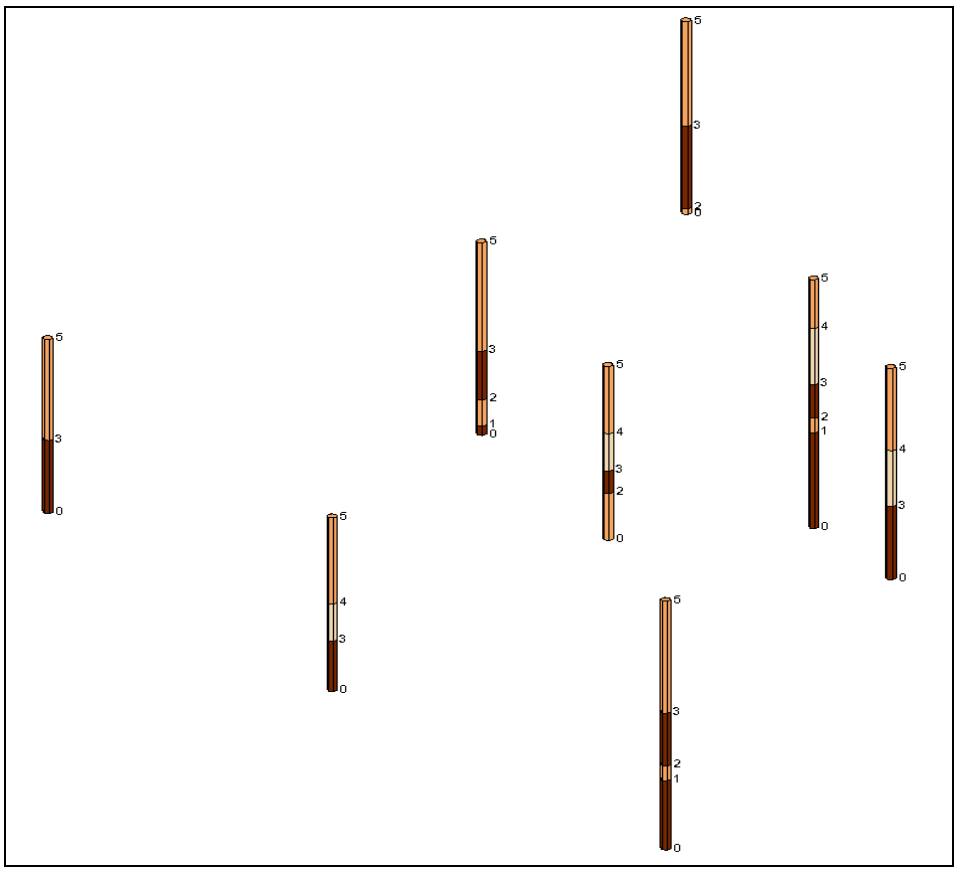

Figure 3 Horizon IDs after automatic assignment

Note: The algorithm for automatically assigning horizon IDs is complex and beyond the scope of this tutorial.

The ability to automatically create cross sections and horizon IDs can save a lot of time and effort—especially if the user is working with a large set of complex boreholes. Nevertheless, automatic creation of cross sections and horizon IDs should only be conceptualized as an initial guess at the real solution. Careful examination of the automatic results is essential, and it is usually necessary to make manual adjustments.

8 Manually Assigning Horizons

Now the tutorial will show how to assign horizon IDs manually. First, it is necessary to set all the horizon IDs back to 0.

1. Select the **Select Contacts** tool.
2. Hit *Ctrl + A* or select the *Edit* | **Select All** command to select all the contacts.
3. Select the **Properties** button.
4. Enter "0" for *Horizon ID*, and click **OK**.
5. Click anywhere in the background space to unselect the borehole contacts.

8.1 Selecting Borehole Contacts

Now it is necessary to select a group of borehole contacts and set the horizon IDs. The first horizon to be defined will be the top of the lower silty-clay layer as indicated by arrows in Figure 4.

1. First, select the ***Display Options*** button.
2. In the *Display Options* dialog, turn on the *Hole names* option.

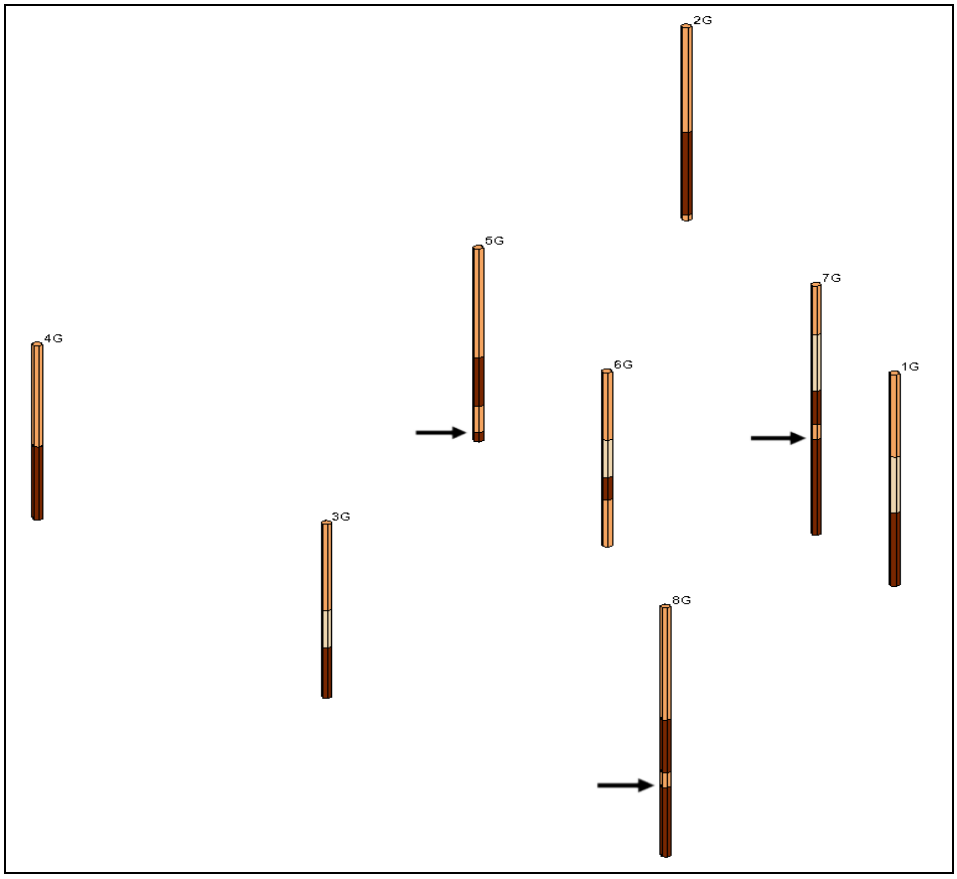

Figure 4 Contacts for Horizon 1

3. Select the **Select Contacts** tool.
4. Select the top of the lower silty sand material on hole 8G as shown in **Error! Reference source not found.** above.
5. While holding down the *Shift* key, select the same contact on holes 5G and 7G.
6. Select the **Properties** button.
7. In the *Contact horizon ID* dialog, assign a horizon ID of "1."
8. Select the **OK** button.

8.2 Assigning Horizon ID 2

Now it is important to assign a horizon ID of 2 to the top of the lower silty-clayey-fine sand layer.

1. Select the **Select Contacts** tool.

2. Select the borehole contacts shown in Figure 5 below.

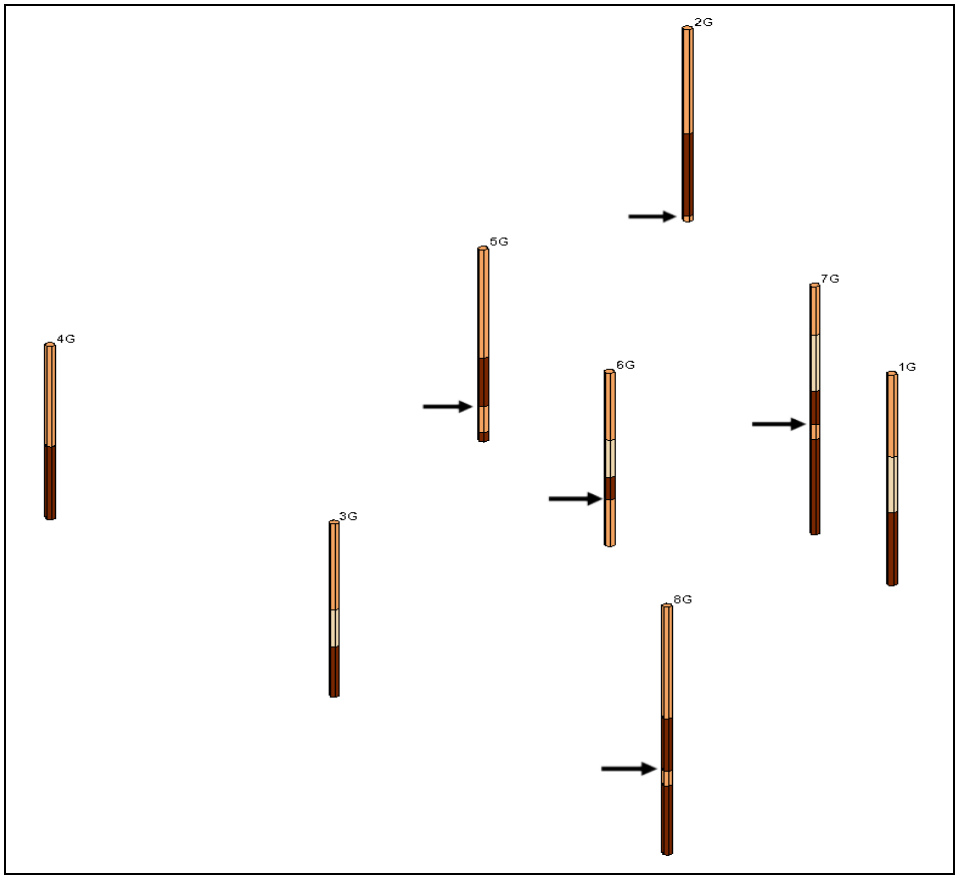

Figure 5 Contacts for Horizon 2

3. Select the **Properties** button.
4. In the *Contact horizon ID* dialog, assign a horizon ID of "2."
5. Select the **OK** button.

8.3 Assigning Horizon ID 3

Horizon ID 3 will be assigned to the top of the upper silty clay layer.

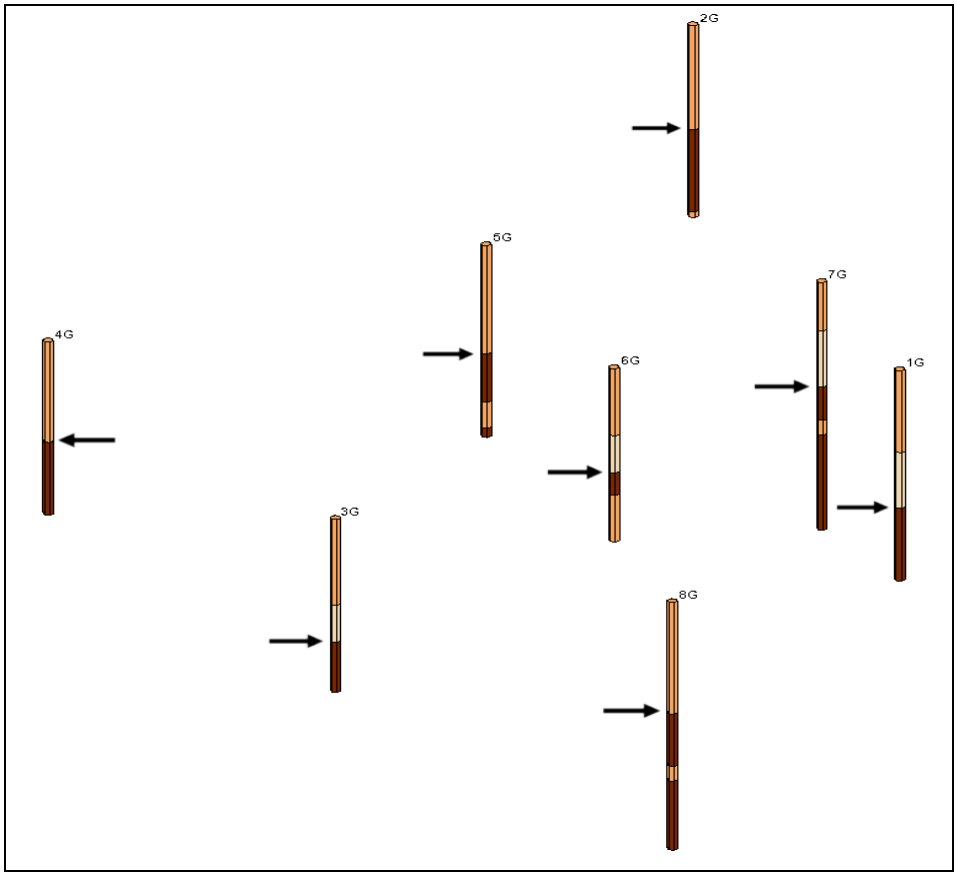

Figure 6 Contacts for Horizon 3

1. Select the **Select Contacts** tool.
2. Select the borehole contacts shown in Figure 6 above.
3. Select the **Properties** button.
4. In the *Contact horizon ID* dialog, assign a horizon ID of "3."
5. Select the **OK** button.

8.4 Assigning Horizon IDs 4 and 5

The top of the clean sand layer will be assigned horizon ID of 4.

1. Select the **Select Contacts** tool.
2. Select all of the contacts at the top of the clean sand material as seen in Figure 7.

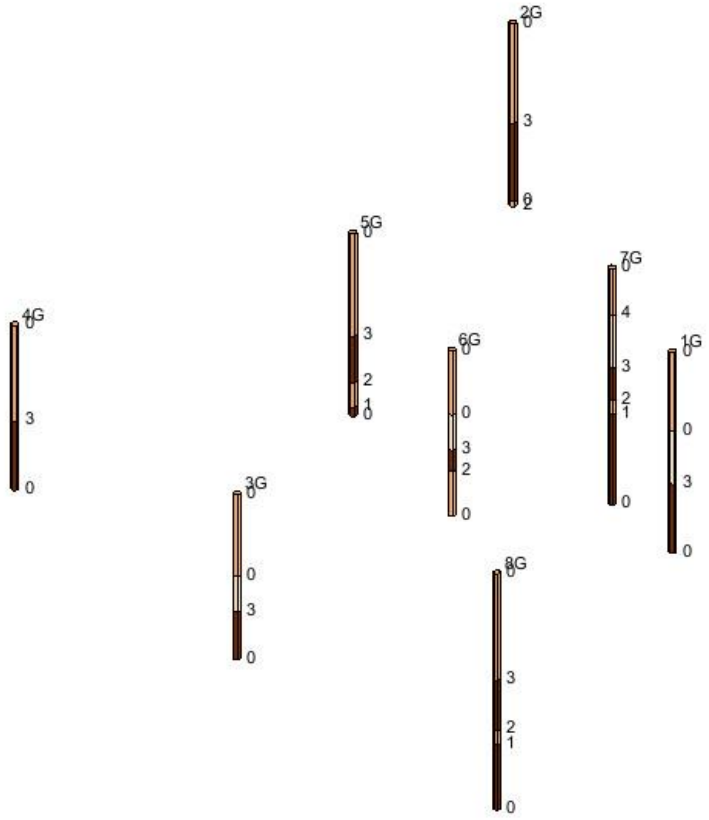

Figure 7 Contacts for Horizon 4

3. Select the **Properties** button.
4. In the *Contact horizon ID* dialog, assign a horizon ID of "4."
5. Select the **OK** button.

The top of the upper silty-clayey-fine sand layer is horizon 5.

1. Select the **Select Contacts** tool.
2. Select the top contact on each borehole as shown in Figure 8.

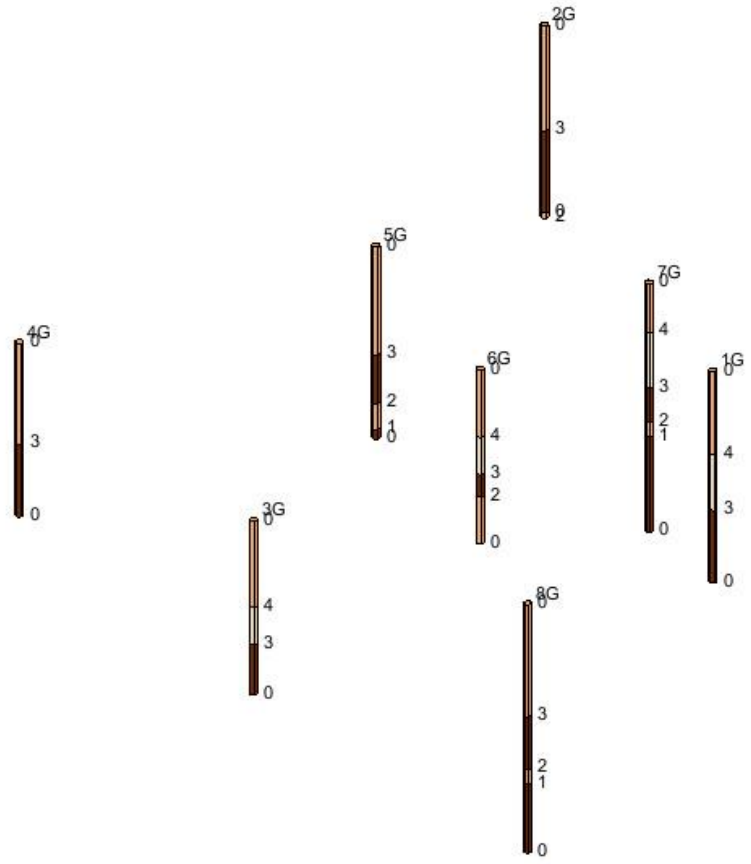

Figure 8 Contacts for Horizon 5

3. Select the **Properties** button.
4. In the *Contact horizon ID* dialog, assign a horizon ID of "5."
5. Select the **OK** button.

The horizon IDs should be assigned like the ones in Figure 9.

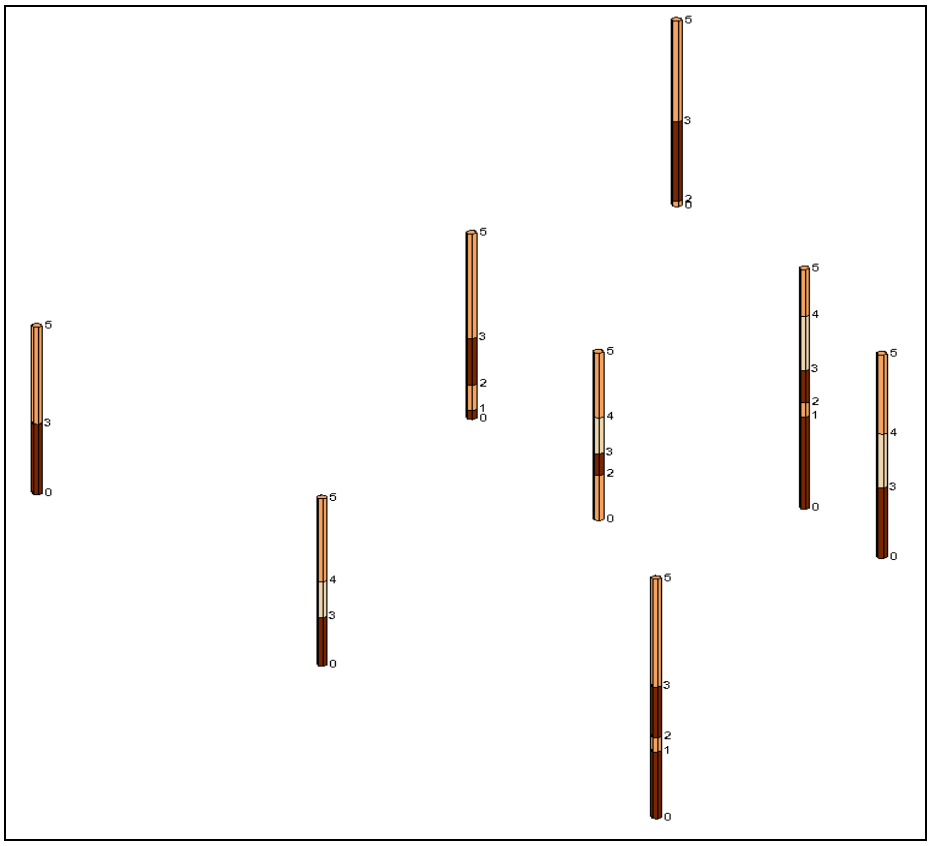

Figure 9 Completed horizon IDs

8.5 Turning off Horizon IDs

Next, it is beneficial to turn off the display of the horizon IDs so that the display is not cluttered before constructing the TIN in the next step.

1. Select the **Display Options** button.
2. In the *Display Options* dialog, turn off the *Horizon IDs* and select **OK**.

9 Constructing the TIN

Now it is possible to construct a TIN using the map module. The TIN to be constructed will define the boundary of the solid. The horizons will also be interpolated to the TIN to define a surface for each horizon. The solid is created by filling in the space between each of the surfaces defined by the interpolation.

9.1 Setting up the Coverage

The next steps illustrate how to define a polygon that will serve as the boundary for the TIN.

1. In the Project Explorer, right-click on the empty space and then, from the pop-up menu, select the *New* | **Coverage** menu command. The *Coverage Setup* dialog will appear

2. Accept the defaults by selecting the **OK** button.

9.2 Creating the Boundary Polygon

Do the following to create a polygonal boundary surrounding the boreholes:

1. Select the **Plan View** button.

2. Click on the "Map Data" folder in the Project Explorer.

3. Select the **Create Arc** tool.

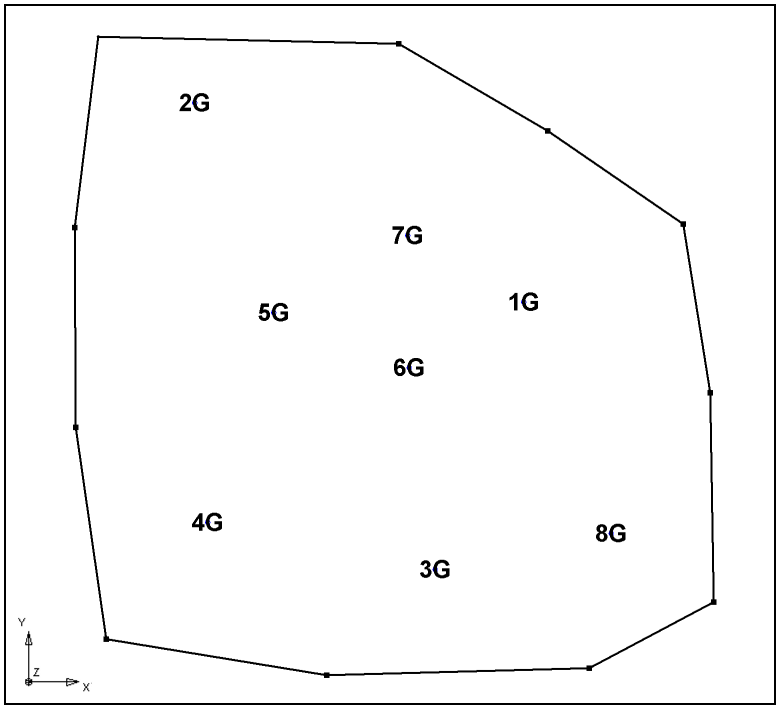

Figure 10 Map polygon surrounding boreholes

4. Single-click in the upper left portion of the graphics window to begin creating the polygon.

5. Single-click to create the rest of the points to make up the polygon.

6. Double-click on the starting point to finish creating the polygon.

7. Select the *Feature Objects* | **Build Polygons** menu command.

8. Switch to the **Select** tool.

9. Right-click on the newly created polygon and select the **Redistribute Vertices** command from the pop-up menu. The *Redistribute Vertices* dialog will appear.

10. In the *Specify* section of the dialog, make sure that the *Specified Spacing* option is selected.

11. Enter a value of "50" for the *Average spacing*, and click **OK**.

9.3 Creating a TIN

This polygon will now be used to create a TIN.

1. Select the *Feature Objects* | **Map → TIN** menu command.

2. When the dialog appears, select the **OK** button to accept the default TIN properties.

A TIN should now appear in the GMS graphics window.

10 Creating the Solids

Now it is possible to create the solids from the borehole horizons.

1. In the Project Explorer, select the "Borehole data"  folder.

2. Select the *Boreholes* | **Horizons → Solids** menu command.

This brings up the *Horizons to Solids* wizard in which it is possible to pick the interpolation scheme used to create the solids. This tutorial will specify how the top and bottom elevation of the stratigraphy model will be determined.

3. On the first page of the wizard, accept the defaults.

4. Click the **Next** button.

5. In the *Top elevation* section of the dialog, select the *Top of boreholes* option. This means that the top of every borehole will be used in interpolating to the top of the solid.

6. In the *Bottom elevation* section of the dialog, select the *Constant elevation* option and enter a value of "-37."

7. Click the **Next** button.

8. In the *Interpolation method* section of the dialog, select the *Inverse distance weighted* option.

9. Select the **Finish** button.

10.1 Viewing the Solids

To view the solids:

1. Select the **Oblique View** button.
2. Select the "Solid data" folder.
3. Select the **Display Options** button.
4. In the *Display Options* dialog, turn on the *Solid faces*.
5. Select the **OK** button.

The result will be a simple solid model consisting of five different layers of materials.

10.2 Cutting Cross Sections

To better view the solids, cut some cross-sections:

1. Select the **Plan View** button.
2. Select the **Create Cross-Section** tool.

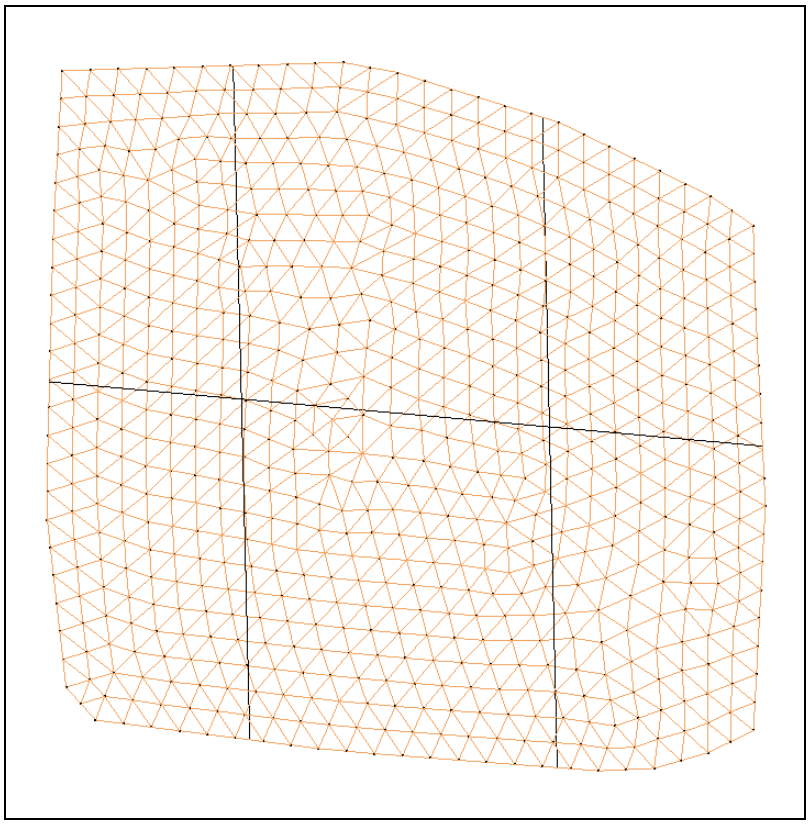

Figure 11 Cross-sections through stratigraphy model

3. Cut three cross-sections through the solid similar to the ones shown above. Single-click to begin making a cross section and double-click to end.

4. In the Project Explorer, expand the "Solid Data" folder if necessary.

5. Find the subfolder under the "Solid Data" folder that contains the solids and uncheck the box next to it to hide the solids. (The solids that were just created by the *Horizons to Solids* Wizard should be in a folder called *solids*).

6. Select the **Display Options** button.

7. In the list on the left of the dialog, select the *Cross Sections* item.

8. Turn on the *Cross section faces*, and select **OK**.

9. Hide the "TIN" by unchecking it in the Project Explorer.

10. Select the **Oblique View** button.

Now it is possible to see how the solids' different surfaces vary (see Figure 12).

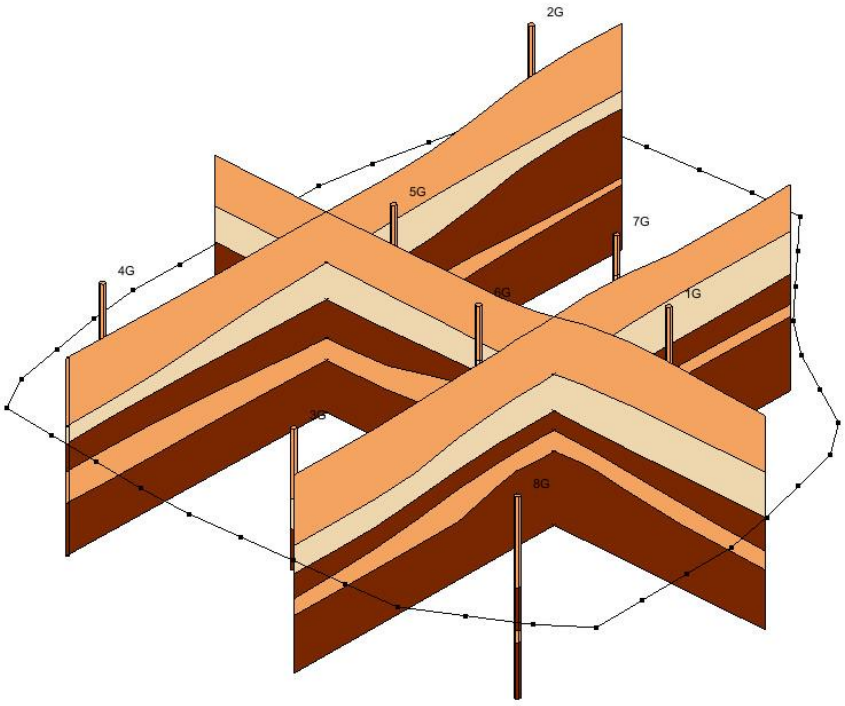

Figure 12 Cross sections in Oblique View

10.3 Using Borehole Cross Section Data

The next step is to use borehole cross sections to help guide the creation of the solids. Borehole cross sections are different from cross sections that are cut through solids. They are described in the tutorial entitled "Stratigraphy Modeling—Boreholes and Cross Sections." If the user had created borehole cross sections and the *Use borehole cross section data* option is on in the *Horizons to Solids* dialog, GMS will use the borehole cross sections to help guide the interpolation as it builds the solids.

If the user were to cut cross sections through the resulting solids, the solid cross sections would more closely resemble the borehole cross sections (although they would not match exactly). To do this, the next step is to read in a previously defined set of cross sections.

To read in the cross sections:

1. Select the **New** button.
2. If GMS asks to save the changes, select *No*.
3. Select the **Open** button.
4. In the *Open* dialog browser, locate and open the directory entitled: *Tutorials\Stratigraphy_Modeling\Horizons_and_Solids.*
5. Select the file named "xsects.gpr," and click **Open**.

It should now be possible to see the cross sections that have been created between the boreholes.

6. Click on the "Borehole Data" folder in the Project Explorer.
7. Select the *Boreholes* | **Horizons → Solids** menu command. The *Horizons to Solids* dialog will appear.
8. Make sure the *Use borehole cross sections* option is on, and click **Finish**.

10.4 Cutting Cross Sections

The next step is to create cross sections through the solids in the same location as the borehole cross sections.

1. Select the **Plan View** button.
2. Select the *Solid Data* folder.
3. Select the **Create Cross Section** tool.
4. Create solid cross sections in the approximate location where the borehole cross sections are. This can be done in any order, but the most probable order

is as follows: First, single-click on hole 1G, then single-click on holes 7G, 2G, 5G, 6G; then finish by double-clicking on hole 8G.

5. Create another cross section by single-clicking on holes 3G and 6G, and then double-clicking on hole 7G.

6. Create the final cross section by single-clicking on hole 4G and double-clicking on hole 5G.

To view the newly created solid cross sections, do the following:

7. In the Project Explorer under the "Borehole Data" folder, uncheck the box next to the "Cross Sections" folder to hide all of the solids.

8. In the Project Explorer under the "Solid Data" folder, uncheck the box next to the "solids" folder to hide all of the solids.

9. Switch to the **Oblique View** tool.

It should now be possible to see the cross sections were created from the solids. The solid cross sections should look very similar to the borehole cross sections.

11 Conclusion

This concludes the tutorial. Here are some key concepts in this tutorial:

- Solids can be created directly from boreholes if horizon numbers are assigned to the borehole contacts.
- If the borehole data is too complex, it is probably better to use the T-PROGS approach rather than create cross sections and assign horizon IDs.
- Horizons are numbered consecutively in the order that the strata are "deposited" (from the bottom up).
- It is possible to can automatically assign horizon IDs to all boreholes, but it will take a long time for a large, complex set of boreholes.
- Solids can be created from horizons.
- Borehole cross sections can be used to further control the **Horizons → Solids** process.

