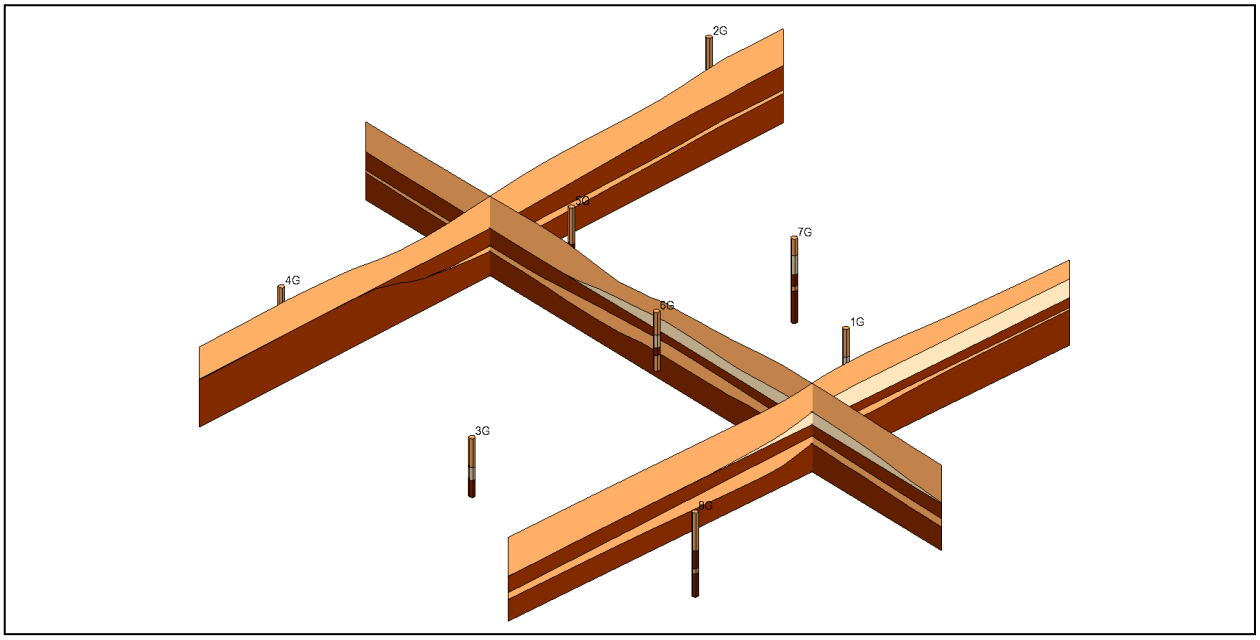
GMS 9.2 Tutorial

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

- None

Required Components

- Sub-surface Characterization
- Geostatistics
- Map

Time

- 30-60 minutes

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1 Contents

2 Introduction

The *Solid* module of GMS is used to construct three-dimensional models of stratigraphy. Once the solids are created: 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.

In this tutorial you will learn 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 (interface between different materials on a borehole log). Each contact that you wish to include in the construction of the solid must have a horizon ID. A contact with a horizon ID of zero will be ignored (which is the default value for each contact).

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

2.1 Outline

This is what you will do:

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

3 Getting Started

Let's get started.

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

4 Overview

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

5 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, we will read in a previously prepared file.

To read in the file:

1. Select the *Open* button  .
2. Locate and open the directory entitled **Tutorials\Stratigraphy_Modeling\Horizons_and_Solids**.
3. Select the file named **holes.gpr**.
4. Click on the *Open* button.

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

6 Determining Horizons

Your model should look like the one in Figure 1.

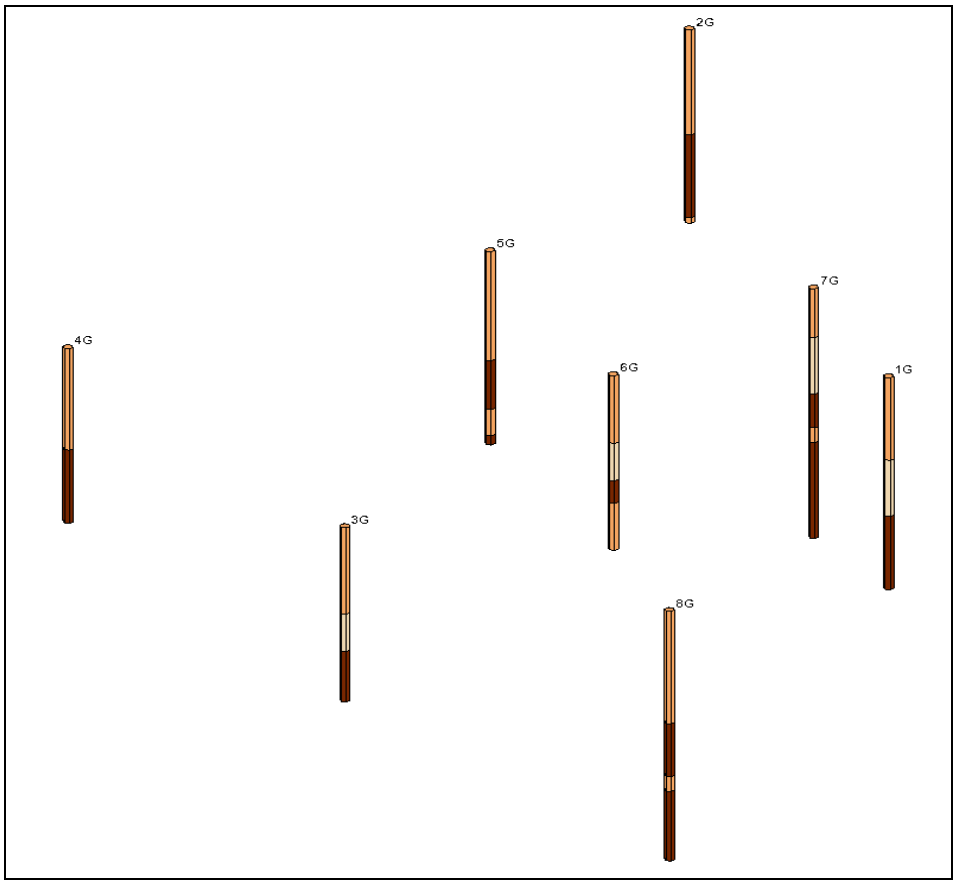

Figure 1. Boreholes.

1. Look at this set of boreholes and plan how you would 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's 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-find 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, we can use it as a guide to show the order in which the layers were deposited. We 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 there will be gaps in the numbering where a layer is missing.

7 Displaying Horizon IDs

We will turn on the display of the horizon IDs.

1. Select the *Display Options* button .
2. Turn on the *Horizon IDs* option.
3. Select the *OK* button.

Horizon IDs should now be displayed next to each contact. As you can see, 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.

8 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. Make sure the *Start from scratch* option is selected and click the *Run* button.

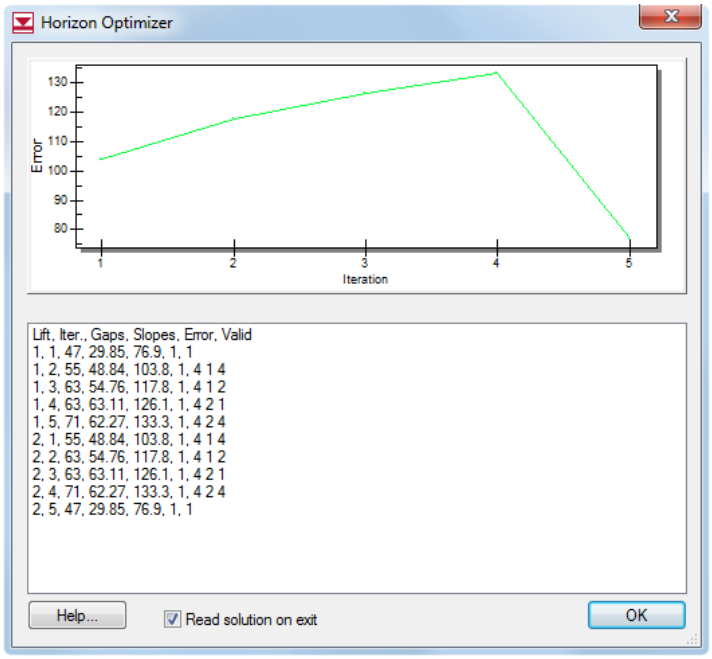

Figure 2. The Horizon Optimizer.

The *Horizon Optimizer* dialog now appears. Since we have a small number of boreholes, 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 in Figure 3.

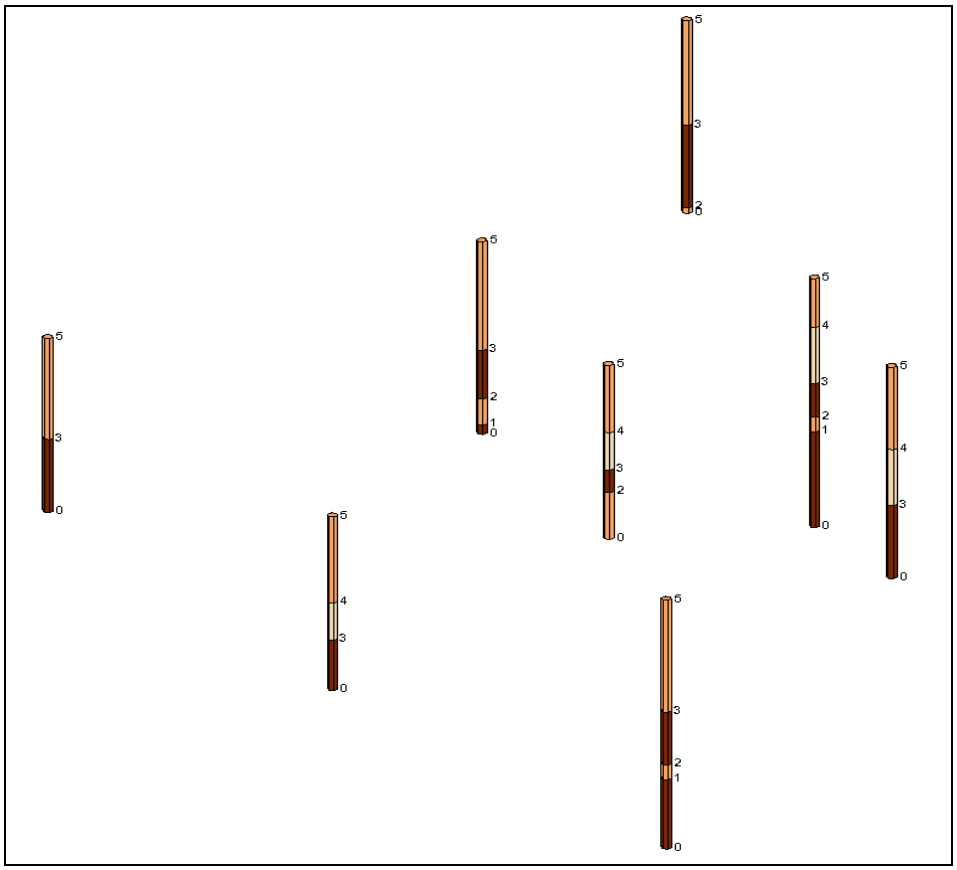

Figure 3. Horizon IDs after automatic assignment.

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 you have a large set of complex boreholes. Nevertheless, automatic creation of cross-sections and horizon IDs should only be thought of 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.

9 Manually Assigning Horizons

Now we'll show how to assign horizon IDs manually. First we will 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 the *Horizon ID* and click *OK*.
5. Click anywhere in the background space to unselect the borehole contacts.

9.1 Selecting Borehole Contacts

We need to select a group of borehole contacts and set the horizon ID. The first horizon we will define will be for the top of the lower silty clay layer.

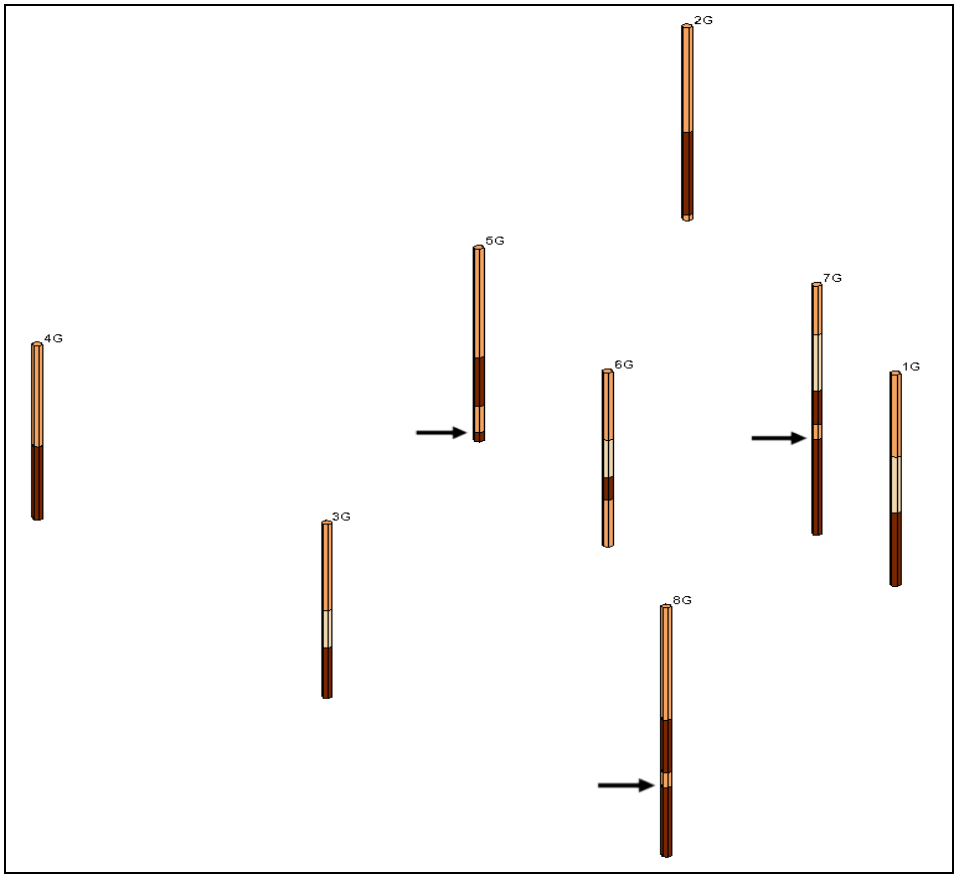

Figure 4. Contacts for Horizon 1.

1. Select the top of the lower silty sand material on hole 8G as shown in Figure 4 above.
2. While holding down the *Shift* key, select the same contact on holes 5G and 7G.
3. Select the *Properties* button .
4. Assign a horizon ID of **1** and select the *OK* button.

9.2 Assigning Horizon ID 2

Now we will assign a horizon ID of 2 to the top of the lower Silty or Clayey Fine Sand layer.

1. Select the borehole contacts shown in the figure below.

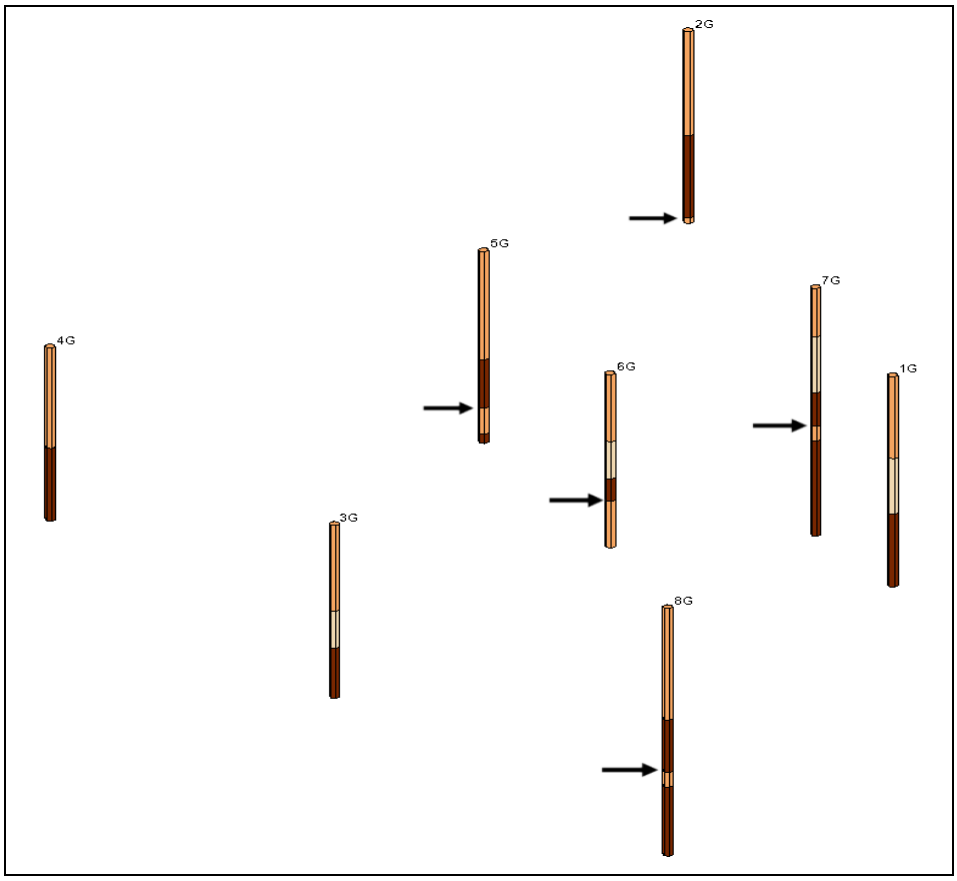

Figure 5. Contacts for Horizon 2.

2. Select the *Properties* button .

3. Assign a horizon ID of **2** and select the *OK* button.

9.3 Assigning Horizon ID 3

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

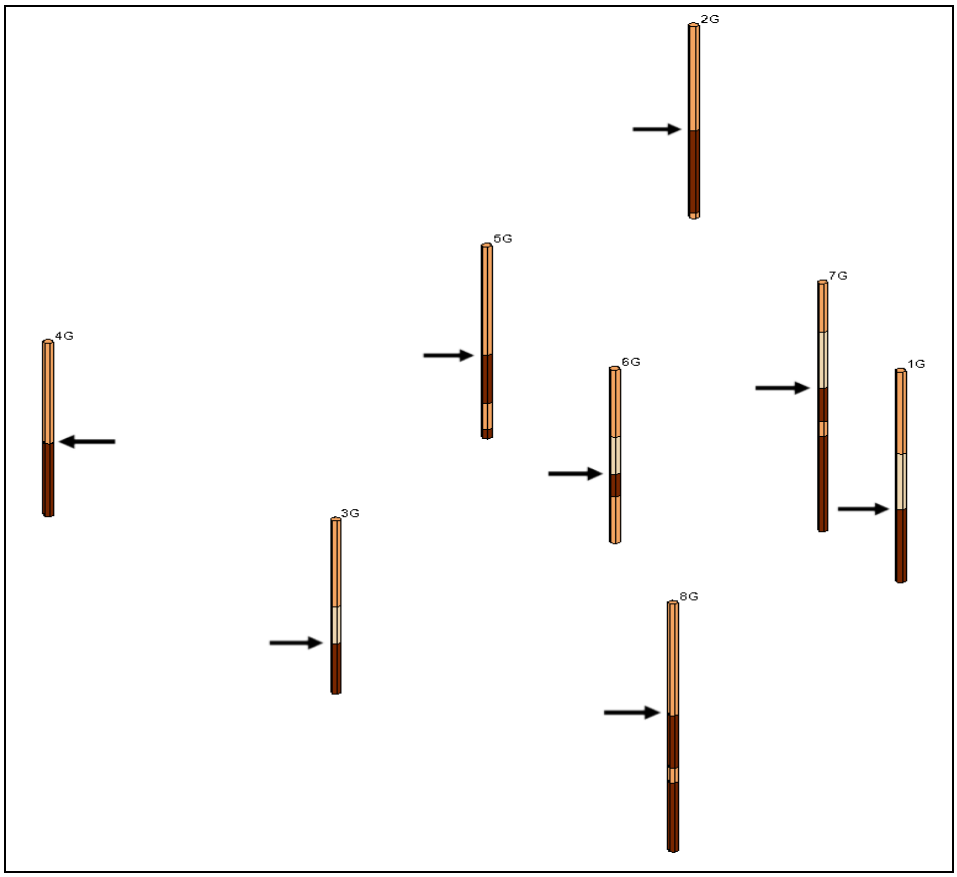

Figure 6. Contacts for Horizon 3.

1. Select the borehole contacts shown in the figure above.
2. Select the *Properties* button .
3. Assign a horizon ID of **3** and select the *OK* button.

9.4 Assigning Horizon IDs 4 and 5

The top of the Clean Sand layer will be assigned horizon ID of 4.

1. Select all of the contacts at the top of the Clean Sand material.
2. Select the *Properties* button .
3. Assign a horizon ID of **4** and select the *OK* button.

The top of the upper Silty or Clayey Fine Sand layer is horizon 5.

4. Select the top contact on each borehole.
5. Select the *Properties* button .

6. Assign a horizon ID of **5** and select the *OK* button.

Your horizon IDs should be assigned like the ones in Figure 7.

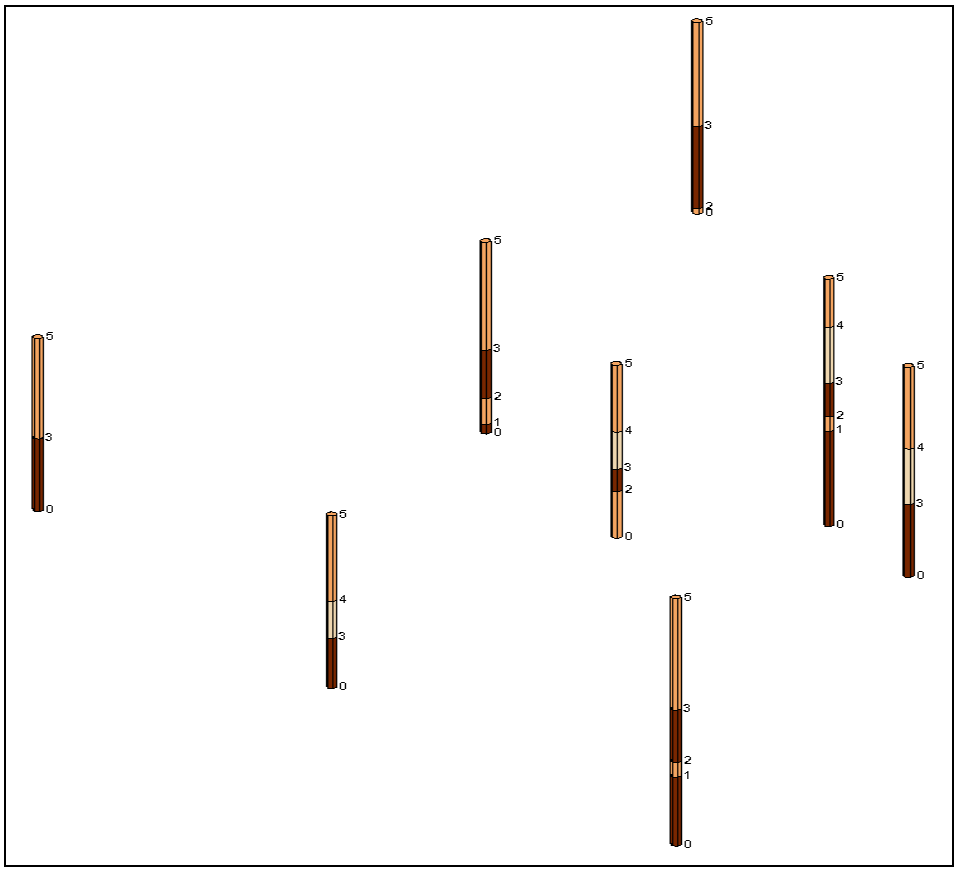

Figure 7. Horizon IDs.

9.5 Turning off Horizon IDs

We'll turn off the display of the horizon IDs so that the display is not cluttered as we construct the TIN in the next step.

1. Select the *Display Options* button .
2. Turn **off** the *Horizon IDs* and select *OK*.

10 Constructing the TIN

You are now ready to construct a TIN using the map module. We will construct a TIN that 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 between each of the surfaces defined by the interpolation.

10.1 Setting up the Coverage

We will 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.

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

10.2 Creating the Boundary Polygon

Now we will create a polygonal boundary surrounding the boreholes.

1. Select the *Plan View* button .

2. Select the *Zoom* tool .

3. While holding the *Shift* key down, click on hole **6G**. This will zoom out so we can create the arc surrounding the boreholes.

4. Click on the *Map Data* folder in the *Project Explorer*.

5. Select the *Create Arc* tool .

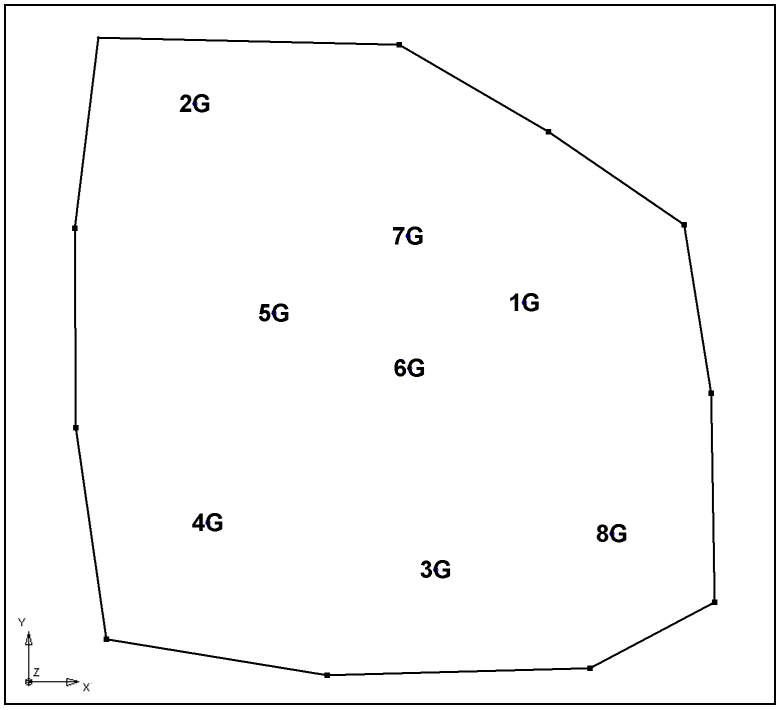

Figure 8. Map polygon surrounding boreholes.

6. Click out a polygon, similar to the one in the figure above. Single click in the upper left portion of the graphics window to begin creating the polygon. Click

out the rest of the points that make up the polygon. 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 arc that you just created and select the *Redistribute Vertices* command from the pop-up menu.

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

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

10.3 Creating a TIN

We will now use the polygon that we have defined to create a TIN.

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

2. Select the *OK* button to accept the default TIN properties.

A TIN should now appear in the GMS graphics window.

11 Creating the Solids

We are now ready to create the solids from the borehole horizons.

1. Select the *Borehole data* folder .

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

This brings up the *Horizons to Solids* Wizard in which we will pick the interpolation scheme used to create the solids. Also, we will specify how the top and bottom elevation of the stratigraphy model will be determined.

3. On the first page of the wizard we will accept the defaults. Click the *Next* button.

4. 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.

5. In the *Bottom elevation* section of the dialog select the *Constant elevation* option and enter a value of **–37**.

6. Click the *Next* button.

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

8. Select the *Finish* button.

11.1 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. Turn on the *Solid faces*.

5. Select the *OK* button.

You have created a simple solid model consisting of five layers of different materials.

11.2 Cutting Cross Sections

We can better view the solids by cutting some cross-sections:

1. Select the *Plan View* button .

2. Select the *Create Cross-Section* tool .

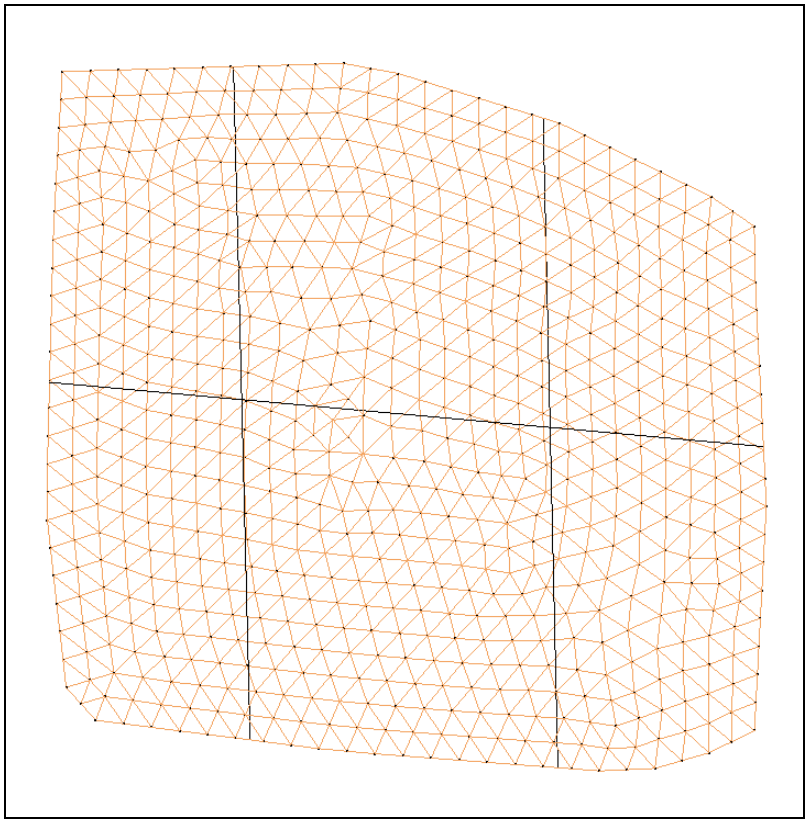

Figure 9. Cross-sections through stratigraphy model.

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 which 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 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 .

You can now see how the different surfaces of the solids vary.

11.3 Using Borehole Cross Section Data

Now we will 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 you have 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 you 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, we will read in a previously defined set of cross sections.

To read in the cross sections:

1. Select the *New* button .
2. If you are asked to save your changes, select *No*.
3. Select the *Open* button .
4. Locate and open the directory entitled **Tutorials\Stratigraphy_Modeling\Horizons_and_Solids**.
5. Select the file named **xsects.gpr** and click *Open*.

You should now 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.
8. Make sure the *Use borehole cross sections* option is **on** and hit *Finish*.

11.4 Cutting Cross Sections

We will now create cross sections through the solids in the same location as the borehole cross sections.

1. Switch to *Plan View* .
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. You can do this in any order. For example, single click on hole **1G**, then single click on holes **7G**, **2G**, **5G**, **6G** and 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**.

We will now view the solid cross sections that we just created.

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

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

9. Switch to *Oblique View*.

You should now see the cross sections we created from the solids. The solid cross sections should look very similar to the borehole cross sections.

12 Conclusion

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

- Solids can be created directly from boreholes if you assign horizon numbers 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).
- You can automatically assign horizon IDs to all boreholes, but it may take a long time on a large, complex set of boreholes.
- You can use borehole cross sections to further control the *Horizons* → *Solids* process.
- Borehole cross sections and solid cross sections are two different things.

